UNIVERSITATEA DE MEDICINĂ ȘI FARMACIE
GRIGORE T. POPA IAȘI

HABILITATION THESIS

Modern approaches of the edentulous and bone loss management through new implanto-prosthetic rehabilitation therapies

Assoc. Prof. DORIANA AGOP-FORNA, DMD, PhD

IASI

2023

Table of contents:

ABBREVIATIONS

AFM- Atomic Force Microscopy

ASA- American Association of Anesthesiology

ATR-FTIR- Attenuated Total Reflection Fourier Transform Infrared

CAD/CAM- Computer-aided design/Computer-aided manufacturing

CBCT- Cone-Beam Computed-Tomography

CI-Confidence Interval

DMFT- Decay-Missing-Filling-Teeth

EDX- Energy dispersive spectroscopy

FPD- Fixed Partial Denture

GI-Gingival Index

IP-FPD- Implant-supported Fixed Partial Denture

IR- Infrared spectra

OR-Odds ratio

OHRQoL-Oral-health-related quality of life

OHIP-Oral Health Impact Profile

ppm-parts per million

RPD- Removable Partial Denture

Rx- Radiographic examen

SEM- Scanning Electron Microscopy

SES- Socio-economic status

SPSS- Statistical Package for Social Sciences

WHO-Word Health Organization

ABSTRACT

This habilitation thesis entitled **"**Modern approaches of the edentulous and bone loss management through new implanto-prosthetic rehabilitation therapies**"** presents the main scientific achievements of 2018-2023 period after I obtained the title of Doctor of Dental Medicine, and it is structured into three sections, according to CNATDCU recommendations: Section I – Scientific achievements in postdoctoral period; Section II – Future plans in the professional, academic and scientific activity; Section III – Bibliography.

Before the first section I made a short presentation of my professional, academic and scientific achievements for my whole teaching career that started in 2015.

The **1st Section** is dedicated to postdoctoral scientific researches; it is structured into 2 research domains and comprises the most relevant articles of my scientific activity indexed in *Web of Science Core Collection* and international databases.

The **first chapter** of this section entitled *"Oral status and quality management of implant therapy for edentulous patients"* presents researches specific to the field of pro-implant surgery and implantology being preceded by a section which details the latest and most relevant information in the literature regarding this theme.

From this perspective, in my *first line of research*, I highlighted the role of oral health status and the quality of life of edentulous patients, with a focus on the oral health and behaviors of adults from the North-East region of Romania, as well as trends in their access to oral healthcare. Additionally, I assessed the oral health and quality of life of edentulous patients treated with removable partial dentures, aiming to highlight the challenges of this temporary therapeutic solution.

In *my second line of research*, I concentrated on evaluating the level of risk presented by certain demographic, loco-regional, and local factors for the medium and long-term success of implant-prosthetic therapy.

In *the third line of research*, I evaluated the possibilities to use digital software applications in the measurements of post-operative evolution and bone gain in alveolar bone areas grafted with various biomaterials as well as in the virtual planning of the implant surgical stage.

In the fourth line of research, I performed clinic radiological studies regarding the post-operative evolution (success/failure rate, biological and mechanical-technical complications) of the edentulous patients treated by implant-supported fixed partial dentures.

In **the second chapter** entitled *"Clinical and experimental studies on biomaterials used in alveolar bone reconstruction in implant-prosthetic therapy*" I followed two lines of research preceded by an update of the latest literature data regarding the benefits and limits of the grafting biomaterials used in guided bone regeneration techniques.

The *first line of research* focused on clinical and radiological studies regarding therapeutic success and alveolar bone gain in severe resorbed areas that requested guided bone regeneration techniques with xenografts.

The *second line of research* approached *in vitro* studies of bone grafting materials and barrier membranes while analyzing physico-chemical and biomechanical properties related to their performance in guided bone regeneration techniques.

The 2nd Section presents the future lines of research both from the scientific and academic viewpoints. In this respect, on one hand I wish to continue the already approached themes specific to approaches in modern implant-prosthetic therapy subject and, on the other hand, I wish to approach new and innovating lines of research that may allow interdisciplinary researches with national and international teams.
In this section, I underlined the strategies and projects relating to my activity with future doctoral candidates while detailing the research themes that may be approached by them, namely clinical and experimental researches regarding: bone regeneration influence in the success of implant surgery, the role of barrier membranes in guided bone regeneration techniques, computerised planning of the preimplant and implant surgical preparation using laser technology.

Another concern consists in the coordination of students and residents on oral disease *screening* topics for the early detection of precancerous and cancerous lesions and bone resorption.

In collaboration with the *Tissue Engineering Center*, I propose the creation of new biodegradable materials for the bone regeneration of patients with severe resorptions, an application that can be carried out together with residents, students and doctoral students.

The 3rd Section includes a list of the main papers that I consulted in order to elaborate the habilitation thesis.

REZUMAT

Această teză de habilitare intitulată *" **Abordări moderne în managementul edentației și pierderii de os prin terapii noi de reabilitare implanto-protetică** "* prezintă principalele realizări științifice din perioada 2018-2023, după obținerea titlului de Doctor în Medicină Dentară, și este structurată în trei secțiuni, conform recomandărilor CNATDCU: Secțiunea I - Realizări științifice în perioada postdoctorală; Secțiunea II - Planuri de viitor în activitatea profesională, academică și științifică; Secțiunea III - Bibliografie.

Înainte de prima secțiune, am realizat o scurtă prezentare a realizărilor mele profesionale, academice și științifice pe întreaga carieră didactică, care a început în 2015.

Prima secțiune este dedicată cercetărilor științifice postdoctorale, este structurată în două domenii de cercetare și cuprinde cele mai relevante articole ale activității mele științifice indexate în Web of Science Core Collection și baze de date internaționale.

Primul capitol al acestei secțiuni, intitulat *"Starea orală și managementul calității terapiei cu implanturi pentru pacienții edentați"*, prezintă cercetările specifice domeniului chirurgiei pro-implantare și terapiei implanto-protetice, fiind precedat de o secțiune care detaliază cele mai recente și relevante informații din literatura de specialitate referitoare la acest subiect.

Din această perspectivă, în prima mea linie de cercetare, am evidențiat rolul stării de sănătate orală și calității vieții pacienților edentați, cu accent pe sănătate orală și comportamentul adulților din regiunea de nord-est a României, precum și tendințele în ceea ce privește accesul lor la serviciile de sănătate orală; de asemenea, am evaluat starea de sănătate orală și calitatea vieții pacienților edentați tratați cu proteze dentare parțiale mobile, pentru a scoate în evidenţă provocările pe care le poate pune această soluție terapeutică temporară.

În a doua linie de cercetare, m-am concentrat asupra gradului de risc pe care îl prezintă pentru succesul pe termen mediu şi lung al terapiei implanto-protetice, unii factori demografici, loco-regionali și locali.

În a treia linie de cercetare, am evaluat posibilitățile de utilizare a aplicațiilor software digitale în măsurătorile evoluției postoperatorii și câștigului osos în zonele osoase alveolare reconstruite cu diferite biomateriale, precum și în planificarea virtuală a etapei chirurgicale implantare.

În a patra linie de cercetare, am realizat studii radiologice clinice referitoare la evoluția postoperatorie (rata de succes/eșec, complicații biologice și mecanice-tehnice) a pacienților edentați tratați cu proteze fixe cu suport implantar.

În al doilea capitol, intitulat *"Studii clinice şi experimentale asupra biomaterialelor utilizate în reconstrucția osului alveolar în terapia implanto-protetică"*, am urmat două linii de cercetare precedate de o actualizare a celor mai recente date din literatura de specialitate referitoare la beneficiile și limitele biomaterialelor de adiţie osoasă utilizate în tehnici de regenerare osoasă ghidată.

Prima linie de cercetare s-a concentrat pe studii clinice și radiologice referitoare la succesul terapeutic și câștigul osos alveolar în zonele cu rezorbţie moderată sau severă care au necesitat reconstrcuţia prin tehnici de regenerare osoasă ghidată cu biomateriale de tip xenografe.

A doua linie de cercetare a abordat studii *in vitro* privind unele materiale de grefare osoasă și membrane barieră, analizând proprietățile fizico-chimice și biomecanice care sunt relevante pentru performanța clinicã în tehnici de regenerare osoasă ghidată.

Secţiunea II prezintă direcţiile viitoare de cercetare, atât din punct de vedere ştiinţific, cât şi academic.
În acest sens doresc, pe de o parte, continuarea tematicii deja abordate, iar pe de altă parte, doresc să abordez direcţii noi, inovatoare, care să permită cercetări interdisciplinare în echipe naţionale şi internaţionale.
În această secțiune am subliniat strategiile și proiectele privind activitatea cu viitorii doctoranzi, detaliind temele de cercetare care pot fi abordate de către aceștia, si anume: cercetări clinice și experimentale privind regenerarea osoasă și conditie importantă pentru obtinerea succesului în implantologie, rolul biomembranelor în tehnicile de regenerare osoasă, planificarea computerizată utilizată în etapele preimplantare și postimplantare cu ajutorul tehnologiei Laser.

O altă preocupare constă în coordonarea studenților și rezidenților pentru aplicarea programelor de *screening* populațional pentru detecția într-o fază incipientă a leziunilor precanceroase, canceroase și a rezorbției osoase.

În colaborare cu Centrul de Inginerie Tisulară propun crearea de noi materiale biodegradabile necesare pentru regenerarea osoasă la pacienții cu rezorbții osoase severe, aplicație care vizează atât studenții, cât și rezidentii și doctoranzii.

Secţiunea III include o listă a principalelor lucrări de referinţă care au fost consultate în vederea elaborării tezei de abilitare.

SECTION I

SCIENTIFIC ACHIEVEMENTS FROM THE POSTDOCTORAL PERIOD

Professional and academic activity

I graduated from the Faculty of Dental Medicine, University of Medicine and Pharmacy "Grigore T Popa" Iași in 2013, diploma series B no. 0006167. In February 2014, I became an assistant in the Oral Surgery discipline. Anesthesia, sedation and medical-surgical emergencies, Faculty of Dental Medicine; from 2014 I continued my teaching activity as a university assistant from 2018 when I became a Lecturer. From 2022, I am Lecturer in the Oral Surgery discipline. Anesthesia, sedation and medical-surgical emergencies, Surgical Department I, Faculty of Dental Medicine, "Grigore T. Popa" University of Medicine and Pharmacy, Iasi.

My teaching activity was carried out in the field of Dento-Alveolar Surgery and Anesthesia in MD where I supported and continue to support practical works and courses with the students of the Faculty of Dental Medicine, fourth year (courses and internships at the Romanian and English language classes in the discipline of " Oral Surgery") and the 6th year (courses and internships in the Romanian and English classes in the discipline of "Rehabilitation with surgical lasers in Dental Medicine). I was and am always concerned about the quality of the clinical internships and their scientific foundation, at the same time making great efforts to continuously improve the content and quality of the teaching materials.

Through the didactic activity, I was involved, as an author, in the development of the course "Use of lasers in dental medicine" in 2017, which was introduced for the first time in the academic program of the faculty. In 2018, we published a "Practical guide in laser applications" used to support internship hours within the discipline of lasers.

The onset of the pandemic determined major changes in the mode of interaction between teaching staff and students, this interaction being mediated by the university's e-learning platform where we posted all the developed didactic materials (course/practical works) in electronic form for the disciplines in the workload of the teacher. The research activity of the students coordinated by me resulted in more than 35 graduation theses of the students in the Romanian and French language series.

Starting from 2020, I am the coordinator of 2 Romanian and English master's programs entitled: "Non-invasive methods of diagnosis and treatment in Dental Medicine (Laser Therapy)", respectively, "Non-invasive methods of diagnosis and treatment in Dental Medicine (Laser Therapy); The results of the activity within these master's have been materialized in the more than 25 dissertations that I have coordinated.

My teaching activity is complemented by the coordination of resident doctors of Dento-Alveolar Surgery, a sustained activity that is continuously carried out in the O.M.F Surgery Outpatient Clinic within the Sf Spiridon Iasi Hospital.

Being a tutor in the project "Professional counseling for medical students and integrated practice program in the field of general and dental medicine" ID POSDRU 160/2.1/S/139881, offered me another opportunity to collaborate with students and teaching staff from within the Faculty of Dental Medicine for the implementation of internships in dental medicine offices with the aim of integrating students into the labor market.

Another educational project in which I participated as an expert trainer was Proiect AUF (iunie-noiembrie 2020): L'assurance de la qualité dans l'enseignement supérieur par la formation de spécialistes dans le domaine de la Réhabilitation Orale Complexe,

This challenge requires a permanent concern to update the curriculum of courses and practical works, by completing the topics offered during the faculty and by creating an educational platform in collaboration with other specialists of the traditional faculties in the country.

In all these years I have kept on improving through different methods and techniques necessary to the didactic and research activity by participating to workshops, post-university courses and courses for the recognition of competences**.**

The most relevant are the following ones:

- 2015: Master: "Management of health services in the medico-pharmaceutical field"-coordinator: University Prof. Dr. Zanoschi Georgeta, M series diploma, no. 0042299
- 2015: Master "Implant-prosthetic restoration of edentination" - coordinator Prof. Univ. Dr. Forna Norina-Consuela (Diploma No. 036520)
- September 18, 2015-September 27, 2016: Master "Laser Therapy in Dentistry" (Aachen, Germany) (No.AC004-22306-12021)
- 2017: BioLase refresher course "The use of lasers in periodontal treatment and implantology" (course organized by ARSMI)
- 2018- Competence in Laser Dentistry, organizer: University of Genoa: International Master in Laser Dentistry, Bucharest, March-November 2018
- Workshop in Laser : "LASER WORKSHOP IN BOPPARD"- 11 Iulie 2014
- Cours - The clinical and therapeutic management of dental erosion – Iasi, 21 Aprilie 2015
- Workshop – Diode laser application in soft tissue – Iasi, 21-23 Martie 2019

My specializations in terms of **professional training** are:

- *Dental Practitioner*- Forna Clinic, since 2013
- *Implantology Certificate*: seria C, nr. 036520/ 2015
- *Junior Specialist* – Oral surgery, from 2016(Confirmed by Order of Minister of Health no. 1623 / 2016)
- *Junior Specialist* – Dental prosthetics, from 2019(Confirmed by Order of Minister of Health no.)
- *Senior Specialist* – Oral surgery, from 2021 (Confirmed by Order of Minister of Health no.80 / 13.01.2022).

Scientific research activity

In 2007 I became a PhD in Dental Medicine-confirmed by Order of the Ministry of Education and Research no.5701/ 27.12.2017, series J no. 0029386, with the title entitled: " Systems of computerised planning of the preimplant and implant surgical preparation (laser vs. Classic", coordinator: Prof. Univ. Dr Eugenia Popescu, UMPh „ Grigore T. Popa" Iaşi.

The PhD Thesis is structured in a theoretical part (the actual stage of knowledge) and a personal part (four chapters with personal research).

The four chapters of the theoretical part include organised literature data regarding the field of the researched issues („Expert systems role in the clinical decisions and treatment planning in dental medicine", „Fundamental principles regarding the functioning of lasers and interaction with biological tissues", „Clinical applications of lasers in pro prosthetic and implant stage", „Clinical applications of lasers in oral surgery techniques").

The first chapter of personal part ("Study regarding the possibilities to use expert systems and finite element analysis in pre-implant and implant stage") is focused on the investigation of the possibilities to use the system experts in the planning of the pre-implant and implant therapy as well as the possibilities to use finite element analysis in the planning of the ideal stress formula to the interface implant-bone tissue in real clinical situations and in relation to the bone parameters, implant parameters and crown/implant ratio.

In the second chapter of personal part ("Study regarding the evolution of clinical parameters in pro prosthetic and pre-implant laser interventions") the investigation of the evolution of the clinical postoperative parameters between patients treated by various laser dental procedures and patients treated by conventional procedures was investigated.

The third chapter of the personal part ("Clinical study regarding biostimulation therapy of soft tissues") was focused on the investigation of the effectiveness of laser biostimulation in the treatment of recurrent ulcerative aphthous lesions.

In the fourth chapter of personal part ("Ex vivo study regarding the optimising possibilities of laser energy interaction with biological tissues") are focused on the investigation of the the interaction between laser energy and various biological tissues to establish the combination of laser parameters that ensures high quality laser ablation.

The original research presented in the first chapter of the personal part aimed to extend the depth-in-knowledge regarding the expert systems used in the pro prosthetic stage, pre-implant stage and implant stage to encourage the minimal invasive approach and higher accuracy of the implant therapy. The original research presented in the second chapter of the personal part proved the superiority of the laser techniques by comparing them with surgical classic techniques used in the pro prosthetic stage. The original research presented in the third chapter of the personal part proved the possibility to use laser biostimulation in the pro prosthetic stage of patients with soft tissues lesions. The original research presented in the fourth chapter of the personal part found the optimal laser parameters for high quality ablation in relation to various biological tissues (bone, muscle, soft tissues, dental tissues).

After 2016, I continued the same research line while analyzing:

- bone regeneration through the use of different types of materials and techniques,
- dental lasers in restorative dentistry and surgery
- implantology
- digital dentistry
- oral health care and quality of life among adults from N-E region of Romania

The results of my research have materialized:

- **56 ISI (Web of Science) indexed articles**
- **20 BDI indexed articles**
- **96 presentations at national and international events**

Starting with the year 2022, I was appointed by competition to the position of Researcher degree II at the "Constantin Angelescu" Institute for Advanced Interdisciplinary Research (ICAI) Bucharest.

Other relevant activities in the field of scientific research are:

My research has been carried out in several directions, some realized in the form of internal grants as follows:

o Member of the UMF internal Grant no. 27500/2018 with the title: "Influence of 3D Printing /Selective Laser Melting processing parameters on surface quality and biological level between metal/ceramic components in dental prosthodontics"

o Member of the UMF Internal Grant no. 30879/2014 with the title "Assessment of root cementum surface corresponding periodontal pockets after instrumentation with: gracey curette, piezoelectric ultrasonic device and periotor reciprocating instruments", carried out in the period 2015-2016, project director: project manager dr Solomon Sorina

o Research Project PN-II-ID-PCE-2007-2: "The impact of smoking on the state of oral health. Implementation of smoking cessation methods in dental medicine" with participation in Working group in 2nd European Workshop on Tobacco Use Prevention and Cessation for Oral Health Professionals: "Content and methods of education revised".

o Project financed by AUF with the title L"assurance de la qualite dans l'enseignement superieur par la formation de specialists dans le domain de la Rehabilitation Orale Complexe, carried out between 22.06.2020 - 20.12.2020, ctr no. 10817/2020, coordination UMF Iasi

The project aimed at conducting courses for French-speaking teachers in the member countries of the CIDCDF association and 6th year students, French language series, Faculty of Dentistry, UMF "Grigore T Popa" Iasi. The theme of the courses addressed the problem of the edentulous patient whose dental treatment includes complex oral rehabilitation, in terms of diagnosis and dental, periodontal, prosthetic and surgical treatment. In addition, the curriculum also provided interdisciplinary courses, presented by specialists in the fields of anatomy, biochemistry, radiology, internal medicine and cardiology, providing a complete picture of common clinical situations in current practice.

Achievements in the scientific publication area:

- Monographs in the national publishing house: 5
- Monographs in the international publishing house: 1
- Book chapters: 15
- Courses for dental students Romanian: 2
- Articles published in extenso in Web of sciene Core Collection-indexed journal with IF-56
- Articles published in International Data Base: 20
- Articles published in extenso in the volumes of international conferences:96
- Oral presentation at national congress as Invited Speaker: 33
- Abstracts at national al international manifestations : 27
- Hirsch Index (Clarivate Analytics):16.
- Hirsch Index (Google Scholar):17
- Citations: 435

Recognition at the national and international level

I am currently member in 4 international scientific societies and 5 national societies:
International societies:

- EPA (din 2010)

a. European Prosthodontic Specialist (EPA) – 2020
b. Trustees EPA 2020

- Fellow Global Dental Implant Academy (GDIA) (2018)
- Consilier BASS (2017)
- Fellow International Congress of Oral Implantologists ICOI(din 2012)

National societies:

- Corresponding member of the Romanian Academy of Scientists
- Director of the Academic Society of Anthropology (2021)
  Member of the Society of Doctors and Naturalists Iasi (2014)ASRRO (2012)
- ADRE (2010)
- UNAS (2007)

Patents/Inventions Diplomas

Patents

1. Aseptic box. Registration number Osim A/00705 of 8.X. 2012
Norina Consuela Forna, Doriana Forna, C.M. Antohi
2. Installation for countercurrent air disinfection A/00705/2012
Norina Consuela, Doriana Forna, C.M. Anthony

Diplomas

1. CHIM-INVEST diploma and medal awarded to the authors Norina Consuela Forna, Doriana Forna, C.M. Antohi for the invention: Procedure for obtaining a dental composite, awarded by the National Invention Salon 2013, Romanian Academy, Institute of Macromolecular Chemistry "Petru Poni"
2. The Diploma of Excellence and the Gold Medal awarded to the authors Norina Consuela Forna, Doriana Forna Agop for the invention: Premises for the intermediate storage of waste resulting from medical activities, awarded by the Romanian Inventor Society, 2017
3. "Award women inventor" prize for the invention: The module for air ozonation, awarded to the authors: Norina Consuela Forna, Antohi Constantin Marin, Doriana Forna Agop, awarded by the International Fair of Practical Inventions and Ideas-Chisinau INVENT-INVEST 2018
4. Diploma of excellence and Silver Medal for the invention: Aseptic dustbin, awarded to the authors Doriana Agop Forna by the International Trade of Inventions and Practical Ideas-Chisinau INVENT-INVEST 2018
5. The prize for microbacteriologically protected activities in dental offices for the invention "Installation for air disinfection against current." The module for air ozonation" - Laureate of the Targul INVENT-INVEST jury award December 2020
6. The prize ”Francisc Rainer” for Practical guide to laser applications, Academy of Medical Sciences, 2020
7. Member of the jury of oral presentations and posters – EPA SEPES Congress, 13-15 September 2018, Madrid, Spain
8. Laureate of the Jury Prize of the International Fair of Practical Inventions and Ideas 2018- Chisinau – Module for air ozonation
9. Diploma Debut book, "Haptic systems and lasers used in modern dentistry" - September 2018

10. Silver medal for the Invention/work Aseptic Bin - Laureate of the jury award of the International Fair of Practical Inventions and Ideas 2018,
11. Woman Inventor Award for Air Ozonation Module, Invent-Invest 2018
12. Diploma of excellence and gold medal for the invention Premises for the intermediate storage of waste resulting from medical activities - International Fair of Inventions and Business Ideas, 2017
13. Certificate of Good Standing International Congress of Oral Implantologists 1.10-2015 – 30.09.2016
14. Diploma Gold Medal – Computerized systems for the planning of preimplantary and implantary surgical preparation, Euroinvent 2015, 16 Mai 2015
15. Silver Medal-12th International Innovation Exhibition Zagreb Croatia-15-18 October 2014
16. CHIM-INVENT diploma and medal for the Procedure for obtaining a dental composite - Chim-Invent National Invention Exhibition 2013, July 3-5, Iasi

Chapter 1.

ORAL STATUS AND QUALITY MANAGEMENT OF IMPLANT THERAPY FOR EDENTULOUS PATIENTS

1.1. ORAL HEALTH STATUS AND LIFE QUALITY OF ROMANIAN EDENTULOUS PATIENTS

State of art

According to the World Health Organization Quality of Life Assessment Group, "quality of life (QoL) is defined as the perspective of persons about their place in life, within the cultural context and value systems where they live, and as a function of their goals, expectations, standards and worries" (WHOQQL, 1995). The loss of teeth can have an impact on regular functional activities, as well as on the meals that can be chosen and enjoyed during mealtimes, according to several published studies (Nakanishi et al, 1999).

Oral health represents a standard for the quality of life of the individual in society. Good oral health allows an individual socio-economic integration as well as personal development to the maximum capacity, thus making him useful to society. The presence of untreated oral diseases produces great pressure on society, affecting the functioning in normal parameters due to the presence of pain, discomfort, deformity, and sometimes death (Schwendicke et al, 2015). These problems can be readily avoided if patients seek dental treatment on time. Early diagnosis of oral disorders, as well as fast clinical treatments, are promoted by good oral health-seeking behavior (Petersen, 2004). Oral health condition is an important component of general health, both in children and adolescents and in adults (FDI, 2015). Although progress has been made in the field of population oral health worldwide, there are still countries and communities where oral health is a public health issue (Reich et al, 2001). Over the last 30 years, in Europe there has been a declining trend in the prevalence of tooth decay in children and adults living in Western Europe, as well as the percentage of people without natural teeth. This is mainly due to the improvement of living conditions, the use of fluoridation methods, especially fluoride toothpaste, and the improvement of oral hygiene skills. Another explanation is that in Western countries there are national programs for the prevention of oral diseases, as opposed to those in Eastern Europe (Marcenes et al., 2013). According to the statistical data provided by WHO (2010), severe periodontis disease was found in 5-20% of middle-aged adults (aged 35-44) in Europe and up to 40% of older people (aged 65-74), while about 30% of Europeans between the ages of 65 and 74 do not have natural teeth. WHO/Global Burden of Disease Study 2017, estimated that diseases of tooth decay affect almost 3.5 million people worldwide, with permanent tooth decay being the most common condition. Worldwide, it estimated that 2.3 million people suffer from permanent tooth decay. In the European Region as a whole, the average number of teeth affected by tooth decay varies greatly between different European countries, and tooth decay is the most common non-communicable disease (Hosseinpoor et al., 2012). In a study by Kassebaum et al. (2014), the authors concluded that untreated carious lesions on permanent teeth remained the most common health condition in the world in 2010, affecting 2.4 billion people.

Total edentulism is still a major problem in this age group, although in some industrialized countries there is a decrease in its prevalence. The main cause of tooth loss remains tooth decay, although some studies show that after the age of 45, parondotitis plays a

major role. Numerous studies show that in some countries oral status has improved by reducing the number of people completely edentulous. This situation is encountered, for example, in the United Kingdom, where the prevalence of edentulism has been observed, from 85% in 1962 to 57% in 1992. In Europe, the percentage of people over the age of 65 completely edentulous varies considerably: from 12% in Switzerland, 13% in Sweden, 25% in Germany, 57% in the United Kingdom, to 70% in Portugal (WHO, 2023). Despite all these positive aspects, found only in certain regions, however in most countries, the treatment needs for this age group are represented by prosthesis.

Periodontitis affects the adult population differently, depending on regional characteristics, risk factors, habits, and unhealthy behaviors. In fact, it is known that this condition has an important social character (Petersen, 2004). Its appearance and spread over time is related to age, sex, occupation, standard of living, education, frequency of regular check-ups at the office, factors that greatly influence the risk predictors of periodontal disease (Reich et al, 2001).

Table I. WHO Objectives for the years 2000, 2010 and 2025

Years	**2000**	**2010**	**2025**
5-6	50% caries free	90% caries free	90% caries free
12	DMFT max 3	DMFT max 2	DMFT max 1
18-20	85% complete dentate	75% caries free 75% without periodontal disease	90% caries free 90% without periodontal disease
75% of the young population to have sufficient knowledge on the etiology and prevention			

Trends of oral diseases in Romania.

In Romania, even though there were socioeconomic disparities across groups, oral health in adults has improved in recent decades. This condition can be explained by inequalities in individual oral status, as well as the impact of social variables such as economic, environmental, and lifestyle factors (Armencia et al., 2019). A low socioeconomic and education level, in association with reduced access to dental services and poor oral hygiene behavior, will result in a higher frequency and severity of dental caries and periodontal disease (Global Burden of Disease Collaborative Network, 2020; Peivand et al., 2021; Kumar et al., 2016; Petersen, 2005; Balan et al., 2013). The studies carried out so far in the adult population in Romania indicate an increased prevalence of oral diseases, the prevalence of dental caries varying between 70-90% (Carausu et al., 2017; Balan et al., 2013) and periodontal disease between 60-70%, values that can be compared with those of neighboring countries (Winkelmann et al., 2022). The socioeconomic and cultural factors associated with the level of knowledge and attitudes accumulated regarding oral health have an impact on oral status. The information regarding tooth decay in Romania is quite poor, and the studied groups are small in number and insufficiently representative for the total population. A study on the oral health of the population in the Member States of the European Union conducted in 2010 of the percentage that in Romania, a percentage of 30% of the population declared that they are all natural. Among those who no longer have all their natural teeth, 14% are partially or totally edentulous. 32% have difficulty chewing due to dental lesions, and approximately 16% have experienced dental or periodontal pain. 16% were embarrassed by the aesthetic appearance of their teeth - the first place in Europe, while 81% believe they can reach a dentist within 30 minutes from home or work if necessary. The results of a study carried out in Iasi in 2019

regarding the level of knowledge and skills regarding oral health, showed that 35% of the participants chose toothpaste with a whitening effect, and almost 25% considered the type of toothpaste teeth rather insignificant (Romanian Health Program for Results, 2019).

A study conducted in Iasi County established a prevalence of tooth decay of 66.7% in adults aged between 35 and 44 years, and a value of 10.33 was recorded for the CAO-D indicator (Murariu, 2008). The highest level of damage was observed in those from rural areas or those with a low socio-economic level. In 2013, in a study conducted in the counties of Moldova, the prevalence of tooth decay was 70.2% in urban areas, respectively 72.7% in rural areas. In the same study, the prevalence of total edentulism in the elderly population in the counties of Moldova in 2013 was 3% for the urban population, respectively 3.5% for the rural area (Forna, 2015). The "European Platform for Better Oral Health" report (2012) showed that Romania is placed on the last ranks on the status of oral health and the budget allocated from public funds for preventive and therapeutic procedures on oral diseases (Patel, 2012). Regarding the situation of the N-E region of Romania, physicians draw attention to the high degree of oral damage due to tooth decay, periodontitis, edentulism, above the average recorded in the Romanian population. It is very probable that the low socio-economic level of the population of some counties in the N-E Romania region contribute to this state of affairs, knowing that the socio-economic income is strongly related to the general and oral health. (Pop, 2010).

The reforms introduced in the last few years have expanded the range of health benefits provided by Romania's National Health Insurance House (NHIH), and levels of public spending on health have increased, but even so, the allocated funds are extremely low, value this being 5% of the value of 5.7% insured for general medical insurance. Therefore, access to dental care is limited due to budget constraints (State of Health in EU, 2021; Murariu et al, 2020). Due to a lack of infrastructure and primary healthcare facilities, access to healthcare is especially limited in rural areas, which is exacerbated by significant gaps in health insurance coverage. Even though many people are exempt from paying health insurance contributions (including children and people with disabilities), the proportion of the population with health insurance is decreasing year after year (State of Health in EU). Another aspect that influences access to medical services supported by the government is the fact that the dental medicine system is 99% private, consisting of private dental practices that can offer dental medical services compensated by the state through Romania's National Health Insurance House (NHIH), the remaining 1% being represented by the faculties of dental medicine or emergency dental offices within university hospitals that offer compensated dental services. The value of the amount granted monthly / doctor differs depending on the fact that the doctor is a specialist or not, or if he works in a rural or urban area. This amount does not exceed the value of 900 €/month/specialist, the amount that can cover the treatment for at most 1-2 patients/month who require complex (prosthetic) treatments, a situation that further restricts access to medical services. The economic crisis induced by the COVID-19 pan-demic as well as the existing war in the region increases the pressure on the population that already has deficiencies in accessing services for the previously stated reasons (OECD, 2014). Another obstacle in the way of access to medical services is represented by the method of payment for the services. Patients with a high socio-economic level prefer to pay for dental medical services from their own funds (out-of-pocket payments) for dental check-ups as well as for curative treatments, in private clinics. Patients with low socio-economic status generally only go to the dentist when needed (for emergencies) (WHO, 2022).

Not all regions of Romania have the same socio-economic level, the regions in the south and west are better rated than the region in the N-E (Moldavia) which for a long time has registered a much lower GDP compared to the other regions of Romania, a fact that corroborates the action of the other factors that influence access to medical services (Török,

2013). All these listed factors influence the sanogenic behaviour of the inhabitants of the regions of the country, so the purpose of our study was to highlight the factors that influence the access of adult residents from the N-E region of Romania to dental medical services. The working hypothesis is that the gender, occupation, and level of the monthly income of the participants significantly influence the access to medical services as well as the sanogenic attitudes.

Even though oral-health-related quality of life (OHRQoL) does not reflect actual oral health status on its own, it provides the patient's perspective of their own oral health as well as the significance and influence it has on their lives. OHRQoL may serve as a public health indicator, indicating both the limits of oral health in communities and the influence of oral health and dental therapies on people's lives (Armencia et al, 2019).

The medical field's primary focus has shifted in recent years from diagnosis and treatment to other aspects of patient care. The patient's quality of life is a primary focus of attention. More techniques are becoming available to assess oral-health-related quality of life (OHRQoL) during routine dental procedures using the fewest possible items. The oral- health-related quality of life assessment instrument was created by experts and academics based on health-related quality of life ideas.

The Oral Health Impact Profile (OHIP), established by Australian academics Slade and Spencer is the most often used method for predicting oral-health-related quality of life in the domestic and international related literature (Forna et al., 2013). One such measure is known as the Oral Health Impact Profile (OHIP-5), which consists of five questions (Forna et al., 2013; WHO, 2022). The assessment of the respondents' subjective feelings provides an estimate of their quality of life. The respondents' subjective feelings about a disease and its therapy have a greater impact on their quality of life than numerous clinical indices. The interviewees' satisfaction with oral healthcare services and the score of the oral-health-related quality of life are regarded as two different indices, which represent the efficacy of services in the older population (Baeten et al., 2018). According to research, dentists' evaluations of dentures are not necessarily associated with patient contentment (Palvarinne et al., 2018; Widstrom and Eaton, 2004). There must be consideration given to the difference between patient perception and dental evaluations. So far, research has been conducted regarding many topics concerning the quality of life associated with oral health. Some researchers have focused on understanding the concept of quality of life associated with oral health (Oancea et al., 2016). Others have made associations between oral health and quality of life, as measured by generic health tools (Murariu et al., 2020; State of Health in the EU, 2021).

In conclusion, in Romania there are no national population studies that include a complete picture of oral health of edentulous patients, being important to design appropriate epidemiological tools, such as questionnaires, clinical and paraclinical examination methods to collect information on socioeconomic, educational and motivational factors that allow correlation with oral health condition.

Publications on this topic:

1.Walid Edlibi Al Hage, Carina Balcoș, Adina Oana Armencia, **Doriana Agop-Forna**, Norina Forna. Oral Health Status and Related Behavior in Adults from N-E Region of Romania. *RMC* 2023; 127(2):308-3171.

2.Walid Edlibi Al Hage, **Doriana Agop Forna**, Norina Consuela Forna. Evolutionary trends in oral health: Review. *Rom.J.Med.Dent*. 2022; 10(2): 59-64

3.Edlibi Al Hage W, Dascălu CG, Balcoș C, **Agop-Forna D**, Forna NC. Trends in Access to Oral Health Care among Adults from the N-E Region of Romania. *Medicina (Kaunas)*. 2022 Dec 29;59(1):74. doi: 10.3390/medicina59010074. FI=2,94

4.Bida FC, **Agop-Forna D**, Bulancea BP, Balcoș C, Forna NC. An Observational Study on Oral Health and Quality of Life for RPD Wearers in the N-E Region of Romania. *Medicina (Kaunas).* 2022 Sep 9;58(9):1247. doi: 10.3390/medicina58091247. FI=2,94

1.1.1. Oral health status and related behavior in adults from N-E region of Romania

The aim of the study was to evaluate the oral health status as well as the behavioral factors that influence this status in the adult population from the N-E region of Romania.

Materials and Methods

After receiving clearance from the Ethics Committee of the University of Medicine and Pharmacy "Grigore T. Popa" Iasi, Romania (no.322/08.06.2023), this retrospective observational study was undertaken among adults from the N-E area of Romania. The information was gathered via questionnaires presented to participants in the "Prophylaxis Caravan" oral health screening annual event.

The following criteria were used to select participants: adults over the age of 18 from Romania's N-E region, who signed informed consent and completed the full questionnaire after receiving explanations about the study under the condition of anonymity. We utilized the calculation procedure with a confidence level of p = 95% to an adult population of 3.7 million people, on a group of 385 adults (Xia et al, 2021). Because adults completed 765 of the total surveys completed at the previous activity, we chose all questionnaires completed by adults between March 2022- April 2023.

In addition to demographic questions (age, gender, residence, occupation), the questionnaire included questions about the type of medical insurance they have, their monthly income, the type of dental office they visit, and questions about oral hygiene habits (number of daily tooth brushings, toothbrush changing, frequency of dental check-ups.

The DMFT index was used to evaluate the oral health status, measured by adding the number of decaying (DT) teeth, the number of missing (MT) teeth, and the number of filled (FT) teeth (D)(Broadbent et al, 2005).

To evaluate the periodontal status, we used the Community Periodontal Index of Treatment Needs (CPITN) as a method of screening that evaluates the presence or absence of periodontal pockets, calculus, and gingival bleeding. Scores from 0 to 4 are given for each tooth examined, and finally, the need for periodontal treatment is established according to the score obtained on each sextant (Leroy et al, 2010).

SPSS Software Version 26.0 (SPSS® Inc., Chicago, IL, USA) was used to produce descriptive statistics and evaluate the data gathered. Frequency, percentages, averages, and standard deviations were used to show descriptive data. The most essential characteristics that can define person’s attitudes about oral health are age, gender, occupation, monthly income, and the frequency of visits to the dentist. To assess the differences between variables, t Student test was utilized. A multivariate regression analysis was performed to assess the predisposition for an affected oral health condition. A p-value of 0.05 or less was judged statistically significant.

Results

Table I shows the analysis results regarding the study group's demographic data. Thus, of the total of 765 participants, 53.7% are female subjects, 81.6% come from the urban zone and 55% are unemployed (student, unemployed, retired). The average age was 47.68±17.42 years (min. 19-max. 82 years) (table I).

Regarding the distribution by socio-economic 31.9% of participants have a high level, 49.7% a medium level, and 18.4% a low level. From a financial point of view, 63.5% of the participants have a monthly income > 501 €, and 64.2% are self-financed, followed by 35.8% of those who have state insurance. 78.8% of the participants were from private clinics (table II).

Table II. Distribution (%) of subjects according to sociodemographic (N= 765).

		No	%
Age	47.68±17.42(min.19, max.82)		
Sex	*Female*	411	53.7
	Male	354	46.3
Residence	*Urban*	624	81.6
	Rural	252	18.4
Occupation	*Employee*	344	45
	Unemployed (student, unemployed, retired)	421	55
Socio-economic level	*High level*	244	31.9
	Medium level	380	49.7
	Low level	141	18.4
Monthly income	*EUR <500*	279	36.5
	EUR >501	486	63.5
Payment for dental services	*State insurance*	274	35.8
	Private insurance and self-funded	491	64.2
Preferred dental clinic	*Private clinic*	603	78.8
	State clinic	162	21.2

The evaluated oral health habits indicate that 64.3% of the subjects brush their teeth more than once a day, and 75.8% change their toothbrush 1-3 times/per year. 35.8% go to the dentist "when needed" and 34.1% "once a year". The reasons to visit a dentist were for 59.3% of check-ups or treatment and for 40.7% for dental emergencies (table III).

Table III. Oral health habits

		No	%
Oral hygiene habits			
Number of brushing/days	1 toothbrushing /day	273	35.7
	>1 toothbrushing /day	492	64.3
Number of toothbrushes/year	1-3 times/year	580	75.8
	>3 times/year	185	24.2
Number of visits to the dentist/ year	Less than 1 year	43	5.6
	Once a year	261	34.1
	Once in 5 years	187	24.4
	When needed	274	35.8
Reasons to visit a dentist	*Check-up or treatment*	454	59.3
	Emergency	311	40.7

The evaluation of the dental status achieved by determining the DMFT index indicates an important carious experience, DMFT having an average value of 11.4, consisting of DT(decayed teeth)= 2.38, MT(missing teeth)=6.20 and the FT(filled teeth)component=2.49. The increased value of the extracted teeth component is observed. In relation to certain socio-demographic variables, dental status is more affected in the case of male subjects (DMFT=12.16), in those with a low socio-economic level (DMFT=15.65), and in those unemployed (DMFT=12.68). The recorded differences were statistically significant for all evaluated variables (p=0.000) (table III). In the case of the periodontal status evaluated through the CPITN index, the evaluation indicates an increased frequency of subjects presenting dental calculus, followed by those with superficial pockets (up to 5mm deep) and those with gingival

bleeding. The distribution of the results in relation to the socio-demographic variables shows that male subjects (25.7%), with a high socioeconomic level (26.6%), employed (31.1%) show increased values for the dental calculus, while female subjects (16.8%), with medium socio-economic level (16.1%), unemployed (21.9%) show increased values for superficial periodontal pockets. The recorded differences were statistically significant (p=0.000) (table IV).

Table IV. Oral health status vs. gender, socioeconomic level and occupation

	Mean value	**Gender**		**Socio-economic level**			**Occupation**	
		Female	**Male**	**High level**	**Medium level**	**Low level**	**Employee**	**Unemployed**
Odontal status								
DT	2.38	2.14	2.65	2.00	2.31	3.21	2.44	2.32
MT	6.20	5.75	6.71	3.95	6.13	10.26	3.57	8.35
FT	2.49	2.22	2.49	2.61	2.47	2.32	3.02	2.06
DMFT	11.04	10.07	12.16	8.56	10.92	15.65	9.03	12.68
p		0.000**		0.000**			0.000**	
Periodontal status - CPITN								
Healthy	51.0%	47.9%	54.5%	54.1%	49.7%	48.9%	55.2%	47.5%
Bleeding	6.8%	8.5%	4.8%	9.0%	6.8%	2.8%	8.7%	5.2%
Calculus	23.5%	21.7%	25.7%	26.6%	23.4%	18.4%	31.1%	17.3%
Shallow pockets	14.0%	16.8%	10.7%	8.2%	16.1%	18.4%	4.4%	21.9%
Deep pockets	4.7%	5.1%	4.2%	2.0%	3.9%	11.3%	0.6%	8.1%
p		0.017*		0.000*			0.023*	

*t student test, **ANOVA test, statistically significant differences when p<0.05

Certain sanogenic habits as well as income can influence the adult's oral status. Thus, those who brush their teeth once a day have higher DMFT values (13.67) compared to those who brush more than once a day, the difference being statistically significant (p=0.000). The same trend is recorded in the case of those who go to the doctor ”when needed” (toothache) (12.42) but also in those who go to the doctor only once a year (11.82). Although monthly incomes >501 euros/month, the value of the DMFT index was higher (11.64) compared to the value recorded in the case of those with incomes <500 euros/month (9.99) (table V).

Table V. Factors related to oral health habits and dental service’s frequency of utilization

	Odontal status				***P***
	DT	MT	FT	DMFT	
Number of brushing/day					
1 toothbrush /day	3.07	7.89	2.79	13.67	0.000
> 1 toothbrush/day	1.99	5.26	2.32	9.58	
Number of visits to the dentist/ year					
less than once a year	3.30	4.28	2.33	9.91	0.000
once a year	2.65	6.46	2.71	11.82	
twice a year	1.71	3.57	2.89	8.17	
when needed	2.42	8.05	2.03	12.42	
Monthly income					
< 500 euro	1.52	6.76	1.72	9.99	0.000
> 501 euro	2.87	5.88	2.93	11.64	

ANOVA test, Statistically significant differences when p<0.05

Table VI. Multivariate regression between gender, occupation, monthly income (independent variables), and dependent dental status and hygiene attitudes.

	B	Std. Error	Sig.	OR	95% Confidence Interval for Exp(B)	
					Lower Bound	Upper Bound
DMFT >10	.869	.215	.000			
[Gender=Male]	-.492	.161	.002	.611	.446	.838
[Ocupation=employed]	-.759	.179	.000	.468	.329	.665
[Socio-economic level=high]	-.994	.238	.000	.370	.232	.590
[Socio-economic level=medium]	-.863	.208	.000	.422	.281	.635
[Monthly income=<500 euro]	-.634	.183	.001	.531	.371	.759

The multivariate logistic regression (table VI) shows us that in the case of the number of toothbrushings, male subjects have a 0.611 greater predisposition to have a DMFT>10 than female subjects (p = 0.002, OR = 0.611), the same positive trend being recorded and in the case of those employed (p = 0.000, OR = 0.468), those with high socio-economic level (p = 0.000, OR = 0.370) and medium (p = 0.000, OR = 0.422) as well as for those with monthly income <500 euros (p=0.001, OR=0.531).

Discussions

Oral health, which has become a serious public health issue in every country, regardless of the degree of development, is an indication of individuals' standard of life and education (FDI, 2015; Petersen et al., 2005; Listl et al., 2015). Socioeconomic and cultural factors impact the oral health of Romanians, who, despite the assistance of the medical insurance system and an increased number of dentists, have poor oral health (Cigu & Cigu, 2022; Chen et al., 1997; Weida et al., 2020; Dudovitz et al., 2018; Takeuchi et al., 2017).

The aim of our study was to evaluate the oral health status and the behavioral factors that influence this status in a group of adult patients from the N-E region of Romania. For this purpose, we analyzed the indicators of the oral status (dental, periodontal) and the behavioral factors that affect attitudes related to oral hygiene, visits to the dentist, reasons for going to the doctor or monthly income, factors that influence access to medical services. The analysis of the collected data showed us that more than half of the subjects brush their teeth more than once a day, change their toothbrush 1-3 times/per year, and less than half of the participants go to the dentist "when needed" or "once a year". The reasons to visit a dentist were for 59.3% of check-ups or treatment and for 40.7% of dental emergencies. This kind of behavior can explain the high carious experience, with a DMFT index having an average value of 11.4. The increased value of the extracted teeth component is observed. The dental status is more affected in the case of male subjects, those with a low socio-economic level, and unemployed. The mean DMF index in this study was higher than in other previous studies (Moradi et al., 2019; Kamberi et al., 2016; Vano et al., 2015; Chan et al., 2021; Ghoddusi Johari et al., 2021). In the case of the periodontal state, as measured by the CPITN index, the results show an increased incidence of participants with dental calculus, followed by those with superficial pockets (up to 5mm deep) and gingival bleeding.

The distribution of the results in relation to socio-demographic variables reveals that male subjects with a high socioeconomic level who are employed have higher values for dental calculus, whereas female subjects with a medium socioeconomic level who are unemployed have higher values for superficial periodontal pockets. These findings vary from those of other research in which female respondents have superior periodontal health due to higher levels of dental care knowledge and attitudes (Marulanda et al., 2014; Rydén et al., 2016). Certain sanogenic habits, as well as income level, can influence the adult's oral status (Ahmed et al., 2023; Zimmermann et al., 2015; Sambunjak et al., 2011).

In our study, those who brush their teeth once a day have higher DMFT values (13.67) compared to those who brush more than once a day. The same trend is recorded in the case of those who go to the doctor "when needed" (toothache) (12.42) but also in those who go to the doctor only once a year (11.82). The results are similar to those of the studies carried out so far (Mishra et al., 2019; Kakatkar et al., 2011). The income level is linked to oral diseases and a poor quality of life in terms of oral health (Singh et al., 2019; Bhandari et al., 2015).

In our study, although monthly incomes >501 euros/month, the value of the DMFT index was higher (11.64) compared to the value recorded in the case of those with incomes <500 euros/month (9.99). The studies carried out so far support the fact that socioeconomic factors might impact dental service use. In Romania, dental treatments are generally supplied in private dentist offices, and patients pay for treatment out of their own pockets, and access to these services is influenced by many factors.

Inequalities in access to medical services are found in all countries of the world, and the pattern is similar in all European countries. Improving access to medical services can be done through better education regarding oral health as well as financial support for dental treatments, with the stimulation of preventive attitudes related to oral health. Currently, the costs for oral health care amount to significant values because patients in Romania present themselves to the doctor at an advanced stage of the disease, which entails high treatment costs (Edlibi et al, 2023; Aldabe et al, 2011).

Conclusions

The results of our study show us that the oral health of adults in the N-E region of Romania is influenced by an important carious experience, dental edentulism having an increased value. Sanogenic behavior as well as monthly income are elements that influence the quality of oral health of the population.

1.1.2. Trends in access to oral health care among adults from the N-E region of Romania

The aim of study was to highlight the factors that influence the access of adult residents from the N-E region of Romania to dental medical services.

Materials and Methods

This retrospective observational study was conducted among the adult population from the N-E region of Romania, after obtaining the approval of the Ethics Commission of the University of Medicine and Pharmacy" Grigore T. Popa" Iasi, Romania (no. 231/13.10.2022). The working hypothesis is that the gender, occupation, and level of the monthly income of the participants significantly influence the access to medical services as well as the sanogenic attitudes. The data on the factors that influence access to specialized medical services were collected through the questionnaires distributed to the participants in an oral health screening action called "Prophylaxis Caravan", an action that takes place annually in the N-E region of Romania for the last 10 years with the aim of screening oral diseases among the population of the N-E region of Romania. The data were selected from the questionnaires collected in the year 2022.

The participant's selection criteria were the following: adults over 18 years of age, with permanent residence in the N-E region of Romania, who signed the informed consent and completed the full questionnaire, after receiving explanations on what the study consisted of, under conditions of anonymity. To an adult population of 3.712.396 peoples (INS, 2020), we

applied the calculation formula for a confidence level of p = 95%, z = 1.96, with a margin of error of 5% and the sample size was 385 adults (Xia et al, 2021). Of the total questionnaires completed at the last action, 696 were completed by adults, which is why we selected all the questionnaires completed by adults in 2022.

The questionnaire contained, in addition to questions related to demographic characteristics (age, sex, residence, occupation), questions related to the type of medical insurance they benefit from, monthly income, the type of dental office they frequent, the reasons for choosing a certain type of office as well as questions about oral hygiene habits (number of daily tooth brushings, toothbrush rotation, frequency of dental check-ups). The financial status determined by the occupation of the individual as well as the monthly income influences the access to medical services.

The data collected were analyzed using SPSS Software Version 20.0 (SPSS® Inc., Chicago, IL, USA) was used to generate descriptive statistics and analyze the data. Descriptive statistics were presented as frequency, percentages, means, and standard deviations. Age, gender, occupation, monthly income, and the number of visits to the dentist were considered the most important variables that can describe the attitude of adults regarding access to dental services. Pearson's chi-square test was used to find an association between categorical variables. A p-value less than 0.05 was considered statistically significant.

Results

Table I shows the analysis results regarding the study group's demographic data. Thus, of the total of 696 participants, 55.6% are female subjects, 83.3% come from the urban environment and 42.1% are retired. The average age was 49.66±18.21 years (min. 19-max. 85 years) (Table I). From a financial point of view, 43.5% of the participants have a monthly income between 501-1000€, and 67.9% are self-financed, followed by 25% of those who have state insurance. More than 70% of them prefer to access private dental services and only 20% to the state ones.

The evaluation of the general health status shows us that 42.7% of the participants have systemic diseases. The self-assessment of the state of health indicated that 52.4% perceive their general state of health as "very good" and 27% as "good". Regarding the self-assessment of the need for dental treatment, 60.5% of the participants consider that they do not need dental treatment (Table I). The evaluated sanogenic habits indicate that 58.1% of the subjects brush their teeth twice a day, and 59.9% change their toothbrush 1-3 times/per year. Regarding the number of visits to the dentist, 33.7% go to the dentist "when needed" and 33.5% "once a year" (Table VII). Access to dental services varies depending on various factors. Thus, male subjects declare that they go to the dentist once a year (33.5%) and women when needed (33.7%). The participants from the rural area tend to go to the doctor when they need it, while the participants from the urban area address in a proportion of 34.9% to the doctor's office at least once a year. Employed subjects access dental services at least twice a year, while unemployed or retired subjects go to the dentist when needed. The recorded differences were statistically significant (p=0.000)(Table VIII). Among the subjects with monthly income > 500€ declare that they see a doctor at least once a year and those with < 500€ only when needed (medical emergencies). For preventive checks the participants presented themselves once (58.9%) or twice/year (38.9%). From those who presented the emergency room, 62.3% of the subjects pre-sented only when they needed it, and for treatments, only 34.7%. The differences were statistically significant for the ”occupation” variables, the ”reasons for presenting to the dentist”, and the ”payment method” for medical services (Table VIII). The payment of medical services is made mainly from own sources, especially when the subjects call on the services of private offices. Those who benefited from government-settled services came to the dental office more "as needed" (41.9%)(Table VIII). Table IX shows the relationship between the variables gender

and monthly income and the factors influencing access to dental services. Female subjects perform between 2 and 3 brushings/day (60.4%, respectively 68%) and change their brushes annually more frequently (72.5%) (p=0.001, p=0.000). Also, they have more annual treatment sessions than male subjects, the reasons varying between preventive control and treatment of dental problems for which they paid more from their own sources. Significant differ-ences were recorded in the case of ”reasons to visit the dentist” (p=0.018), ”payment for dental services” (p=0.009) and ”preferred dental clinic” (p=0.010) (Table IX). The reasons for women not appearing regularly at the office are ”costs” (24.3%) and ”fear of dental procedures” (9.8%), while men's reasons were ”high costs” (26.4%) and ”lack of time” (5.9%).

Table VII. Distribution (%) of subjects according to sociodemographic, general, and oral health-related variables (N= 696).

		No	%
Age	49.66±18.21(min.19, max.85)		
Sex	Female	376	55.6
	Male	320	44.4
Residence	Urban	579	83.3
	Rural	117	16.7
Occupation	Student	46	6.7
	Employee	271	38.9
	Unemployed	86	12.3
	Retired	293	42.1
Monthly income	<500 €	197	28.2
	501-1000 €	303	43.5
	>1000 €	196	28.2
Payment for dental services	Never been to a dentist	14	2.0
	State insurance	174	25.0
	Private insurance	35	5.0
	Self-funded	473	67.9
Preferred dental clinic	I don't frequent any clinic	14	2.0
	Private clinic	544	78.2
	Government clinic	138	19.8
Systemic health problems	Yes	297	42.7
	No	399	57.3
Self-rated oral health	Very good/good	365	52.4
	Fair	188	27.0
	Poor/very poor	143	20.6
Self-rated dental treatment need	Yes	275	39.5
	No	421	60.5
Oral hygiene habits			
Number of brushing/day	1 toothbrush /day	170	24.4
	2 toothbrushes/day	404	58.1
	3 toothbrushes/day	70	10.1
	from time to time	52	7.5
Number of toothbrushes/year	1-3 time/year	417	59.9
	4- 6 time/year	184	26.4
	When needed	95	13.7
Number of visits to the dentist/ year	Less than once a year	33	4.8
	Once a year	233	33.5
	Twice a year	181	26.0
	When needed	235	33.7
	I didn't go to the dentist	14	2.0

Table VIII. Factors related to dental service’s frequency of utilization

Variable	Number of visits to the dentist	*p*

		Less than once a year	Once a year	Twice a year	When needed	I didn't go to the dentist	
Sex	*Female*	4.3%	33.3%	26.4%	35.5%	0.4%	0.051
	Male	5.5%	33.6%	25.5%	31.4%	4.1%	
Residence	*Urban*	4.4%	33.2%	25.7%	34.9%	1.9%	0.648
	Rural	7.2%	34.9%	27.7%	27.7%	2.4%	
Occupation	*Student*	0.0%	36.4%	36.4%	27.3%	0.0%	0.000*
	Employee	4.7%	34.2%	31.6%	24.9%	4.7%	
	Unemployed	8.2%	18.0%	32.8%	41.0%	0.0%	
	Retired	4.8%	36.8%	17.2%	40.7%	5.0%	
Monthly income	*< 500 €*	4.3%	34.3%	20.0%	40.0%	1.4%	0.418
	501-1000 €	4.2%	33.8%	26.9%	33.3%	1.9%	
	> 1000 €	6.4%	32.1%	30.7%	27.9%	2.9%	
Reasons to visit a dentist	*Check-up*	1.2%	58.9%	39.9%	0.0%	0.0%	0.000*
	Emergency	7.0%	13.6%	16.6%	62.3%	0.5%	
	Treatment	5.6%	34.7%	25.0%	34.7%	0.0%	
	I didn't go to the dentist	0.0%	0.0%	0.0%	0.0%	100%	
Payment for dental services	*Never been to a dentist*	0.0%	0.0%	0.0%	0.0%	100%	0.000*
	State insurance	4.0%	37.9%	16.1%	41.9%	0.0%	
	Private insurance	4.0%	40.0%	12.0%	44.0%	0.0%	
	Self-funded	5.3%	32.3%	31.5%	30.9%	0.0%	

*Statistically significant differences when p<0.05(Anova Test)

Table IX. Relationship between the variables gender and monthly income with the factors that can influence access to dental services.

		Gender		Monthly income			Occupation			
		Female	Male	< 500 €	501-1000 €	> 1000 €	Student	Employed	Unemployed	Retired
Number of toothbrushes/day	1 toothbrush /day	43.8%	56.2%	21.4%	24.1%	27.9%	3.0%	21.2%	36.1%	27.3%
	2 toothbrushes/day	60.4%	39.6%	59.3%	57.9%	57.1%	78.8%	61.7%	44.3%	55.5%
	3 toothbrushes /day	68.0%	32.0%	10.0%	10.2%	10.0%	15.2%	12.4%	8.2%	7.7%
	From time to time	40.5%	59.5%	9.3%	7.9%	5.0%	3.0%	4.7%	11.5%	9.6%
	p	0.001*		0.799			0.003*			
Number of toothbrushes changed/ year	1-3 times/year	49.8%	50.2%	57.1%	60.2%	62.1%	39.4%	63.2%	50.8%	62.7%
	4- 6 times/year	72.5%	27.5%	27.9%	25.5%	26.4%	54.5%	28.5%	23.0%	21.1%
	When needed	48.5%	51.5%	15.0%	14.4%	11.4%	6.1%	8.3%	26.2%	16.3%
	p	0.000*		0.870			0.000*			
Reasons to visit a dentist	Check-up	54.6%	45.4%	28.6%	34.7%	34.3%	51.5%	38.3%	27.9%	26.3%
	Emergency	59.8%	40.2%	47.9%	38.4%	35.0%	33.3%	31.1%	47.5%	47.4%
	Treatment	54.0%	46.0%	21.4%	25.5%	27.9%	15.2%	25.9%	24.6%	25.8%
	I didn't go to the dentist	10.0%	90.0%	2.1%	1.4%	2.9%		4.7%		.5%
	p	0.018*		0.383			0.001*			
Payment for dental services	Never been to a dentist	10.0%	90.0%	1.4%	1.9%	2.9%		4.7%		.5%
	State insurance	62.1%	37.9%	88.6%	0.0%	0.0%	45.5%	2.1%	3.3%	49.3%
	Private insurance	64.0%	36.0%	0.0%	4.2%	11.4%		8.3%	8.2%	1.9%
	Self-funded	54.0%	46.0%	10.0%	94.0%	85.7%	54.5%	85.0%	88.5%	48.3%
	p	0.009*		0.000*			0.000*			
Preferred dental clinic	I don't frequent any clinic	10.0%	90.0%	1.4%	1.9%	2.9%		4.7%		.5%
	Private clinic	57.5%	42.5%	77.9%	78.7%	77.9%	66.7%	77.2%	70.5%	83.3%
	Government clinic	53.1%	46.9%	20.7%	19.4%	19.3%	33.3%	18.1%	29.5%	16.3%
	p	0.010*		0.930			0.002*			
Self-rated oral health	Very good/good	55.1%	49.1%	50.7%	53.7%	52.1%	84.8%	58.0%	52.5%	42.1%
	Fair	29.0%	24.5%	22.9%	25.5%	33.6%	12.1%	29.5%	32.8%	25.4%
	Poor/very poor	15.9%	26.4%	26.4%	20.8%	14.3%	3.0%	12.4%	14.8%	32.5%
	p	0.170		0.075			0.000*			
Self-rated dental treatment need	Yes	37.0%	42.7%	38.6%	41.7%	37.1%	21.2%	39.9%	41.0%	41.6%
	No	63.0%	57.3%	61.4%	58.3%	62.9%	78.8%	60.1%	59.0%	58.4%
	p	0.192		0.670			0.166			

*Statistically significant differences when p<0.05(Anova Test)

Female subjects perceive their own oral health status as "very good" (55.1%) and "good" (29%) in a higher proportion than male subjects who, on the other hand, see the necessity of treatment as being higher than female subjects.

Relating the healthy habits to the monthly income, the results indicate that at the declarative level, more than half of the subjects brush their teeth 2 times a day and change 1-3 toothbrushes a year. Those with incomes below 500 €/ per month have a percentage higher than subjects who brush from time to time, and the toothbrushes are changed as needed. Those with incomes below 500 € go to the doctor "when needed" (40%), such as medical emergencies (47.9%), expenses being covered state medical insurance (88%), and those with more than 1000 € have 1-2 annual sessions (32%), more for emergencies (35%) and finance their services from their own pockets (94%, respectively 85.7%). The differences are significant (p=0.000) between groups when we talk about the financing of medical services.

The analysis of the data according to the occupation of the participants shows us that students perform two brushings/day in a higher proportion compared to the other categories. Those employed change their toothbrush at most 3 times/ year and go to the dentist most of the time for check-ups. The treatments and check-ups are done in private clinics (77.2%) and are paid from their own pocket (85%). Retirees have good hygiene habits (toothbrush 2 times/day, up to 3 toothbrushes changed/year) but they go to the dentist more for medical emergencies and the medical payment is made from state insurance and from their own pocket in almost equal proportions (49.3%, respectively 48.3%).

Discussions

Oral health, a major public health problem now for any country regardless of the level of development due to increased costs for treatments, represents an indicator of the level of living and education of individuals (FDI World Dental Federation, 2015; Petersen et al., 2005). Socio-economic as well as cultural determinants influence the oral health of Romanians who, although they benefit from the support of the medical insurance system and the increased number of dentists, have poor oral health (Cigu & Cigu, 2022; Dudovitz et al., 2018; Ruff & Niederman, 2018; Takeuchi et al., 2017).

In Romania, oral health services are provided by private and state clinical centers in urban and rural areas that are financially supported by the state or from personal sources (private insurance or out-of-pocket payments). A big impediment in accessing the services supported by state insurance is the type of medical treatment settled in Romania for adults, within the limit of 60% of the costs; this is restricted only to odontal, periodontal, endodontic treatments, minimal prosthetic treatments (1 removable acrylic prosthesis/ 10 years or metal-acrylic crowns) or dental extractions (Cigu & Cigu, 2022; Righolt et al., 2018).The hypothesis that gender, occupation, and level of the monthly income of the participants can influence access to medical services, as well as their sanogenic attitudes, is supported by the results obtained in our study.Studies confirm that low individual income is associated with oral cancer, increased dental caries prevalence, any caries experience, tooth loss, traumatic dental injuries, periodontal disease, and poor oral health-related quality of life (Singh et al., 2019; Bhandari et al., 2015). In our study, the incomes of the participants were modest, with less than half of them having incomes between 501-1000 € /month, a fact that significantly influences access to medical services, be they general medicine or dentistry, adding to this aspect the fact that 99% of the dental services system is private. The results of our study indicate that over 60% of those who came to the private dental office paid for their treatments from their own pocket. Many of the subjects with moderate monthly incomes greater visited the dentist at least once a year, and those with low income only when they had medical emergencies. This result confirms previous findings showing that socioeconomic conditions can influence dental services usage (Klein et al., 2014; Muirhead et al., 2009; Filmer, 2003). Inequalities in access to medical services are

found in all countries of the world, the pattern is similar in all European countries. Eliminating financial barriers to accessing healthcare may have a positive effect on oral healthcare utilization (Mackenbach, 2006; Mackenbach et al., 2008; Eikemo et al., 2008; Aldabe et al., 2011). by supporting costs related to dental treatments and implementing prevention programs because, according to 2015 data, the global cost of treating dental conditions for one year was $442 billion, including both direct treatment costs and indirect costs caused by school and work absenteeism (Righolt et al., 2018). Regarding the relationship between oral hygiene attitudes to monthly incomes, the studies conducted in this field confirm the link between socioeconomic status, oral health in an individual, and various factors which directly or indirectly affect oral health (Mishra et al., 2019). Our results show that subjects with low incomes have deficient sanogenic behavior, many of them brush their teeth from time to time, and toothbrushes are changed "when needed". In the case of participants with a high income, it can be observed that the number of annual sessions is higher compared to that of subjects with lower incomes, but the reason for presenting to the doctor is still a medical emergency. What is important to emphasize is that everyone perceives their own oral health as good without the need for dental treatment, a perception that can influence access to dental medical services. This behavior can be explained by the relatively modest level of oral education and low income among adults in Romania, which results in poor oral health among them compared to other countries.The method of paying for medical services is another element that influences the frequency of accessing medical services.

In our study, most participants pay out-of-pocket expenses, followed by those who benefit from state medical insurance; this situation is due to the non-performing health insurance system in Romania. Thus, those with low incomes pay their medical expenses through state medical insurance, while those with moderate and high incomes finance their services from their own pockets. So, income level can be a significant predictor of the non-utilization of dental services among adults. The results of our study agree with those of the studies in the literature (Kakatkar et al., 2011; Obeidat et al., 2014; Winkelmann et al., 2022).

In the countries where the insurance system is set up, patients will receive treatments compensated by state or private insurance, in state or private clinics. More than 70% of the participants go to private offices, motivated by the fact that there are no longer many state dental clinics, but also by the idea that they will benefit from quality medical services. The studies carried out so far emphasize the preference for private offices because of the availability of different types of treatment, quality of dental care, easy and early availability of appointments, no waiting time, and the possibility to continue treatment. This finding is like the study reported by Obeidat et al. (2014). The low number of subjects who benefited from state-settled medical services is mainly due to the small budget provided by the Romanian state for dental services (approx. 900 €/month/specialist doctor). Many private dental offices provide medical services that are not supported by the government because the budget is low and the bureaucracy is high (Pizarro et al., 2009; Duncan et al, 2014). Other factors such as employment, gender, and residence can influence access to medical services. Employed subjects go to the dentist at least twice a year, while unemployed or retired subjects go when needed due to low income and probably due to lack of education. While the male subjects presented themselves once a year, the women go to a dentist "when needed". The participants from the rural environment go to the doctor when they urgently need treatment and those from the urban environment at least once a year due to the higher income that the latter have and because in the urban environment the number of offices is higher. In most cases, the behaviors of rural people can often delay access to health services because they believe that their oral health is good and the need for treatment is reduced just because they do not have dental pain. The results obtained are like those of other studies in the literature (Wall et al, 2007; Ogunbodede et al, 2004; Ajaiy et al, 2012). Preventive check-ups as well as emergencies are

the main reasons for presenting to the dentist. Less than 40% of the participants show up for treatments. The reasons for not visiting the office regularly are the costs and the fear of dental procedures, especially for women, while for men it was the high costs and lack of time. The results of our study agree with those of the study conducted by Ajayi and Arigbede (2012), who identified the cost of dental treatment as a major barrier to oral healthcare utilization, but they observed a more significant association between access to care and the fear of dental treatment.

The limitations of our study are given by the fact that the descriptive study was carried out on a self-reported questionnaire, a situation that is accompanied by a large dose of subjectivity that can influence the analysis of the causal link between the variables. Carrying out a longitudinal study on a larger number of participants can help to accurately establish all the factors that reduce access to dental medical services in Romania.

Conclusions

The results of our study show us access to the dental medicine services of Romanians in the N-E region is influenced by variables such as gender, occupation, and level of monthly income. Access to dental services is frequently done in case of a dental emergency, more by the female subjects and those from the rural environment. Payment for dental services, most of them done in dental private offices, are made from state insurance for those with low monthly income and their own pocket in the case of higher monthly income. Inequalities in accessing medical services in Romania can only be solved by increasing the funds allocated for dental services as well as by establishing preventive programs to improve the level of education on the oral health of the adult population.

1.1.3. An Observational Study on Oral Health and Quality of Life for RPD Wearers in the N-E Region of Romania

The aim of this study was to assess the relationship between the essential func- tional qualities of RPDs and participants' oral-health-related wellbeing among an edentulous population from the N-E region of Romania using the OHIP-5-questionnaire, taking into consideration whether the algorithm for RPDs developed by the Faculty of Den- tistry was followed. We began with the hypothesis that there are statistically significant differences in the quality of life between the three groups.

Materials and Methods

Study Design

This observational study was conducted using a sample of 546 patients who received removable partial dentures (RPDs) in the Department of Prosthodontics, at the Faculty of Dentistry in Iasi, Romania, between January 2004 and January 2019. Undergraduate students and interns worked together under the direction of teaching personnel to provide medical care to the patients. This research study was authorized by the "Grigore T.Popa" Iasi University's Ethical Committee.

To provide an RPD that is both functional and comfortable, rigorous assessment, design, and care are required. Steps involved in RPD-related therapy include assessment of the abutment teeth, positioning and preparation of the abutments, adjustment of the RPD metal framework, connecting the edentulous areas to the metal framework, interaction with the laboratory, health education for home care and maintenance, and regular preventive recall. Patients who are partially dentate may have lost teeth because of improper oral hy- giene; therefore, it is essential for them to practice good home maintenance hygiene, caries

intervention strategies, and appropriate use of their removable prostheses to minimize the risk of developing future complications.

It is essential to the operation's effectiveness to perform careful individualized planning and manufacture of the RPD for each patient. The RPD design that may best satisfy the demands of an individual patient should be determined by factors such as the architecture of hard and soft tissues, occlusal relationships, tooth location, and the patient's goals for aesthetics and comfort.

Participant Selection

In the beginning, 546 subjects (304 men and 242 women) were selected after following a set of sorting procedures: we recorded data sheets containing all information regarding the treatment and the protocol used and specific laboratory data sheets containing all features of the RPDs as well as the design and distribution of elements for support and stability. RPDs with metal frameworks were fabricated following therapeutic treatment recommendations, with acrylic dentures as an interim treatment followed 1 year later by metal-framework RPDs with clasps or special elements, including hinge, ball and socket, interlocks, bar attachment, and the university prosthetic algorithm for RPDs.

When selecting patients in the second phase, each participant was contacted and asked to proceed by completing an OHIP-5 questionnaire; they were also asked for their written consent. After excluding those who did not respond and those who were treated only with partial acrylic base dentures, 338 (61.90%) valid participants were included in the final analysis. They were then divided into three categories:

1. The first group included 106 patients (following the RPD treatment algorithm) who agreed to the treatment plan and received acrylic dentures first and then an RPD with metal framework and special elements. This group was considered the control group, due to the RPD's strong stability and retention and patients' compliance with the clinic's protocol.
2. The second group included 181 patients (following the RPD treatment algorithm) who agreed to the treatment plan and received acrylic dentures first and then an RPD with metal framework and clasps.
3. The third group included 51 patients (disregarding the algorithm and lacking interim acrylic dentures) who refused interim acrylic dentures and received an RPD with metal framework and special elements.

OHIP5 Instrument

The shortest OHIP has 5 items. The OHIP-5 was devised to obtain information equivalent to 90% of the OHIP-49 summary score (with fewer questions than the OHIP-49) and does not categorize items into a set of seven domains. Five items are included in the OHIP-5: one for each of the four aspects of oral-health-related quality of life (OHRQoL)— oral function, orofacial pain, orofacial appearance, and psychosocial impact—and an additional item for oral function. The OHIP-5 has four dimension scores and one summary score [17–19]. The OHIP-5 questions were as follows:

1. Have you had difficulty chewing any foods because of problems with your teeth, mouth, dentures, or jaw?
2. Have you had painful aching in your mouth?
3. Have you felt uncomfortable about the appearance of your teeth, mouth, dentures, or jaws?
4. Have you felt that there has been less flavor in your food because of problems with your teeth, mouth, dentures, or jaws?
5. Have you had difficulty doing your usual jobs because of problems with your teeth, mouth, dentures, or jaws?

Answers were recorded on a 5-level Likert scale, with the authors indicating a coding from 0 to 4 (4—very often, 3—quite often, 2—occasionally, 1—almost never, and 0—never).

The total score varies depending on the number of questions. The higher the score, the greater the impact of oral health issues on quality of life.

To answer each OHIP question, participants were questioned about the frequency with which they had encountered the problem in the preceding month.

Statistical Package for Social Sciences (SPSS, version 20) was used for data entry and analysis. We used nonparametric statistical tests to determine whether there were statistically significant differences between groups for each question. The Kruskal–Wallis test is the nonparametric equivalent of the Anova test. It shows whether there are statistically significant differences between the three groups for the participants' answers to the five questions. However, to see which groups had statistically significant differences, we ap- plied the Mann–Whitney test, the nonparametric equivalent of the t test for independent samples. We considered the null hypothesis to be that there were no statistically significant differences between the three groups; the research hypothesis was that there were statistically significant differences between the three groups. The statistical significance was set at $p < 0.05$.

Results

The final study group consisted of 338 participants, with an average age of 64.09 ± 7.38 (min. 49, max. 82). In total, 196 (58%) participants were females and 70% of participants were from urban areas. Of all participants, 49.4% were employed, 36.4% were retired, and 14.2% were unemployed. Regarding the distribution of the participants according to the type of edentation, the statistical analysis showed that 173 (51.2%) of the subjects had Kennedy class II edentation, followed by those with Kennedy class I (42.9%) and class III (5.9%) (Table X).

Table X. Demographic features of study group

		No	%
Age	64.09 ± 7.38 (min. 49, max. 82)		
Sex	Female	196	58.0
	Male	142	42.0
Residence	Urban	241	71.3
	Rural	97	28.7
Occupation	Employee	167	49.4
	Unemployed	48	14.2
	Retired	123	36.4
Type of edentation	Class I Kennedy	145	42.9
	Class II Kennedy	173	51.2
	Class III Kennedy	20	5.9

Statistical analysis of questionnaire answers showed that subjects from groups 2 and 3 had a higher quality of life than subjects from group 1 (control) as evidenced by the increased frequency of their answers "never" (26.4% and 29.4%, respectively) and "almost never" (46.2% and 29.4%, respectively) recorded both in terms of difficulties chewing any foods and the aesthetic aspect of the smile. The answer variants "almost never" and "occasionally" were more frequently selected for questions pertaining to the presence of oral cavity pain and the loss of taste in food. The answer variant "never" was more frequently selected for questions pertaining to the presence of difficulty in performing routine tasks, with the highest frequency recorded for group 1 (control), followed by group 3 (70%), and group 2 (53%) (Table XI).

The test results, shown in the Table XII, were expressed by a chi-square value with two degrees of freedom and were statistically significant ($p = 0.0001 < 0.05$) for questions 1, 2, 3, and 5. In these cases, the null hypothesis can be rejected, as there were statistically

significant differences between the three groups. We used the Mann–Whitney test to determine whether there were significant differences between the various groups.

Table XI. Comparison of satisfaction between three groups of RPD patients

OHIP 5-ITEM		LOT 1	LOT 2	LOT 1	LOT 3	LOT 2	LOT3
Have you had difficulty chewing any foods because of problems with your teeth, mouth, dentures or jaw?	Mean rank	90.54	175.31	77.80	81.49	129.85	69.14
	Mann–Whitney U	326.5		2576		2200	
	p	0.000		0.615		0.000	
Have you had painful aching in your mouth?	Mean rank	109.37	164.28	116.32	117.15	68.44	100.95
	Mann–Whitney U	5922.5		4582.5		1583.5	
	p	0.000		0.934		0.000	
Have you felt uncomfortable about the appearance of your teeth, mouth, dentures or jaws?	Mean rank	115.48	160.7	124.07	89.64	79.22	78.55
	Mann–Whitney U	6570		3245.5		2680	
	p	0.000		0.001		0.925	
Have you felt that there has been less flavor in your food because of problems with your teeth, mouth, dentures or jaws?	Mean rank	146.12	142.76	117.86	111.67	81.01	74.82
	Mann–Whitney U	9368.5		4369		2490	
	p	0.732		0.548		0.409	
Have you had difficulty doing your usual jobs because of problems with your teeth, mouth, dentures or jaws?	Mean rank	112.39	162.51	122.57	94.94	75.95	85.34
	Mann–Whitney U	6242		3516		2379.5	
	p	0.000		0.004		0.069	

Mann–Whitney test, $p < 0.05$.

Table XII. Patients' satisfaction with RPD usage

OHIP 5-ITEM	Lot	N	Variables					Mean Rank	Chi -Square	df	*p*
			Never	Almost Never	Occasionally	Quite Often	Very Often				
Have you had difficulty chewing any foods because of problems with your teeth, mouth, dentures or jaw?	LOT1	106	4.4%	13.8%	39.2%	26.0%	16.6%	114.84	86.542	2	0.000
	LOT2	181	26.4%	46.2%	16.0%	8.5%	2.8%	214.15			
	LOT3	51	29.4%	29.4%	27.5%	9.8%	3.9%	124.63			
Have you had painful aching in your mouth?	LOT1	106	17.0%	55.7%	18.9%	6.6%	1.9%	124.31	37.180	2	0.000
	LOT2	181	3.9%	35.9%	37.6%	13.3%	9.4%	189.60			
	LOT3	51	2.0%	33.3%	47.1%	11.8%	5.9%	192.10			
Have you felt uncomfortable about the appearance of your teeth, mouth, dentures or jaws?	LOT1	106	48.1%	34.9%	10.4%	4.7%	1.9%	141.20	26.716	2	0.000
	LOT2	181	21.5%	42.0%	26.5%	6.1%	3.9%	193.77			
	LOT3	51	52.9%	25.5%	15.7%	5.9%	0.0%	142.19			
Have you felt that there has been less flavor in your food because of problems with your teeth, mouth, dentures or jaws?	LOT1	106	7.5%	24.5%	33.0%	25.5%	9.4%	173.63	0.664	2	0.718
	LOT2	181	10.5%	25.4%	32.0%	22.7%	9.4%	169.63			
	LOT3	51	9.8%	33.3%	23.5%	23.5%	9.8%	160.49			
Have you had difficulty doing your usual jobs because of problems with your teeth, mouth, dentures or jaws?	LOT1	106	85.8%	11.3%	1.9%	0.9%	0.0%	134.49	37.326	2	0.000
	LOT2	181	53.0%	24.9%	5.5%	9.9%	6.6%	194.09			
	LOT3	51	70.6%	15.7%	7.8%	5.9%	0.0%	154.28			

For question 1, scores for groups "1" and "2" differed significantly, with $p = 0.0001 < 0.05$; scores for groups "2" and "3" differed significantly, with $p = 0.0001 < 0.05$; however, scores for groups "1" and "3" did not differ significantly, with $p = 0.615 > 0.05$.

For question 2, scores for groups "1" and "2" differed significantly, with $p = 0.0001 < 0.05$; scores for groups "2" and "3" differed significantly, with $p = 0.0001 < 0.05$; however, scores for groups "1" and "3" did not differ significantly, with $p = 0.934 > 0.05$.

For question 3, scores for groups "1" and "2" differed significantly, with $p = 0.0001 < 0.05$; scores for groups "1" and "3" differed significantly, with $p = 0.001 < 0.05$; however, scores for groups "2" and "3" did not differ significantly, with $p = 0.925 > 0.05$.

For question 4, scores for groups "1" and "2" did not differ significantly, with $p = 0.732 > 0.05$; scores for groups "1" and "3" did not differ significantly, with $p = 0.548 > 0.05$; and scores for groups "2" and "3" did not differ significantly, with $p = 0.409 > 0.05$.

For question 5, scores for groups “1” and “2” differed significantly, with $p = 0.001 < 0.05$; scores for groups “1” and “3” differed significantly, with $p = 0.004 < 0.05$; however, scores for groups “2” and “3” did not differ significantly, with $p = 0.069 > 0.05$

Discussions

There is a substantial need to develop the materials and technology involved with RPDs because of the secondary expenses associated with the oral and systemic health implications of their usage. It is considered a reasonable and practicable therapeutic technique to use an RPD if it can replace lost structures while causing little damage to remaining hard and soft tissues [19]. A denture framework must be designed to ensure that the denture is strong and durable enough not to distort a patient’s repaired occlusion. An RPD’s success depends on a thorough understanding of RPD design and associated information, as well as effective communication with laboratory staff.

There is a substantial need to develop the materials and technology involved with RPDs because of the secondary expenses associated with the oral and systemic health implications of their usage. It is considered a reasonable and practicable therapeutic technique to use an RPD if it can replace lost structures while causing little damage to remaining hard and soft tissues (Fejérdy et al., 2008). A denture framework must be designed to ensure that the denture is strong and durable enough not to distort a patient's repaired occlusion. An RPD's success depends on a thorough understanding of RPD design and associated information, as well as effective communication with laboratory staff.

Various studies have shown that people who have lost teeth and need prosthodontic therapy have poor dental prosthetic status (Peeran et al., 2016; Shigli et al., 2009). It is not uncommon for this group of patients to complain about aspects that are not actually incorrect (Moldoveanu et al., 2010; Damyanov et al., 2012). Satisfying the needs of the patient should be the goal of any prosthodontic therapy (Verma & Sharma, 2019). The variables that characterize patients' perceptions are different from those used by clinicians to evaluate clinical results. After the insertion of a prosthesis, patient satisfaction is determined by the patient's level of physical health, psychological adjustment, social functioning, and the cost-effectiveness of the therapy. A patient's subjective opinion of the requirement for prosthodontic appliances can be compared to an examiner's assessment of that need using the WHO diagnostic criteria or the Geriatric Oral Health Assessment Index (Colussi et al., 2009; Locker & Slade, 1994). Even though RPDs are often used to replace missing teeth, several issues with their use have been recorded in various populations (Cosme et al., 2006; Akeel, 2010; Khan & Khan, 2015; Shams et al., 2015).

In contrast to the findings of the current study, in several other studies, acrylic resin RPDs are significantly more prevalent than cast metal framework RPDs. The treatment approach that is ultimately chosen appears to be influenced by several factors, including the skills and knowledge of dental laboratory technicians and the intraoral circumstances (Lynch & Allen, 2007; Radhi et al., 2007). Life expectancy is steadily rising in most countries throughout the world, including those that are still developing. It is anticipated that by 2030, approximately one billion individuals will be 65 years old or older, making up 13% of the population. The findings of the current study are helpful in assessing the patients' quality of life when using RPDs, and such findings should be presented to patients. In addition, these findings offer valuable information that may be utilized for instructional and educational reasons (Lynch & Allen, 2007; Radhi et al., 2007).

To the best of authors' knowledge, no clinical study has assessed the quality of life related to prosthetic treatment for populations in certain regions of Romania (Schwarz and Barsby, 1980). Sex, educational background, dental attendance patterns, teeth brushing frequency, scarring experiences from childhood dentistry, the expense of dental care, and the care

organization utilized were all connected with prosthodontic status differences, but not using a questionnaire regarding oral health (Schwarz and Barsby, 1980; Akifusa et al., 2005). McEntee et al. showed that approximately two-thirds of the older population suffers from poor dental health; yet, only one-third of those people reported having an issue with it. Approximately half of the individuals (54%) had difficulty with their dentures, and 83% did not have dentures, according to the researchers (MacEntee and Mojon, 1992).

OHIP-measured denture status was revealed to be a substantial predictor of poor OHRQoL (Ekanayake and Perera, 2004; Locker, 1988). Frank et al. examined how satisfied patients were after an RPD was inserted. The most common sources of discontent regarding the new dentures were fit, ease of eating and chewing, hygiene of the mouth, speech, and sanitation (Redford et al., 1996). In addition, according to the findings of Redford et al., the most common issues involving adaptation to denture use among new denture wearers were food becoming caught in the dentures, difficulty cleaning the dentures, discomfort or pain, poor retention, and how the dentures looked (Redford et al., 1996).

If RPD problems were related to denture factors or patient variables, the research could not determine this. The discontent of many patients cannot be explained simply by the poor quality of dentures. For this reason, Romania has already implemented new programs and courses at the Faculty of Dental Medicine (Gerontostomatology) for dentists as well as oral hygienists. Dental personnel should be educated and re-educated regarding the physical, psychological, and social requirements of the elderly population, to provide better service. This study had certain limitations, including a small sample size and the fact that research participants cannot be assumed to represent the entire RPD-wearing population.

To strengthen the external validity of the epidemiological research regarding RPD acceptability and professional–patient appraisal of long-term functioning, more individuals from varied contexts should be included. Additional longitudinal research is necessary; ideally, it should include participants from a variety of regions and a larger sample size so that results will more accurately represent the people who live in this region of Romania.

Conclusions

Information regarding patients' problems with RPDs and contributing variables will assist doctors in making educated decisions in the treatment of partly edentulous patients requiring RPDs, as well as in reducing possible resource waste. Although this study was confined to a specific group, it can provide insight into RPD patients' happiness when treated in an academic environment. If a student-treated patient sample does not apply to other government institutions or a commercial dental practice because of differences in patient populations, quality control, and treatment planning criteria, this should be highlighted. A combination of research and clinical exams is needed to determine the impact of many factors on patient satisfaction with dentures, such as the status of abutment teeth, denture-bearing regions, oral mucosal health, saliva quality, and oral hygiene habits. This research, despite its limitations, provides a general view of RPD wearers' satisfaction in the N-E region of Romania.

1.2. MANAGEMENT OF RISK FACTORS IN IMPLANT-PROSTHETIC THERAPY

State of art

Dental implants represent pure titanium fixtures that are placed in the maxillary or mandibular bone in order to replace the roots of missing teeth. This consists of the direct union of an inert material to the bone tissue and is achieved through a careful surgical installation, as well as a prolonged healing period and an adequate distribution of forces when the implant comes into operation. (Pérez et al., 2018). This rehabilitative alternative allows the natural tooth to be replaced by an artificial one with better functionality. Despite being a scheduled surgery, it is not exempt from failures and complications occur in any of the phases of implant treatment. (Pérez et al., 2018). At the present time, implant techniques offer numerous possibilities of treatment, whose good results can be predicted with great certainty based on their functionality, comfort, beauty, quality, and duration; however, the failure of the procedure can occur during the surgical phase or once the prosthetic rehabilitation has been carried out, due to systemic and psychosocial factors of the patient such as iatrogenic factors, deforming habits or dental implant design, among others. However, currently, some believe that implant failure after the osseointegration process is mainly due to bacterial infection and not to "rejection" when implants of proven quality are placed, although it is also attributed to specific characteristics of the patients and to the skill of surgeons. In this context, dental implant failures constitute an outstanding health problem in many parts of the world due to their frequency and the aesthetic, facial, and psychological alterations they cause in those who do not function favorably (Corona, et al, 2015; Pérez et al, 2018).

Data regarding the risk factors for implant success are scarce, despite the increasing body of evidence-based knowledge regarding the prevalence of biological and mechanical/technical complications.

Experienced dental practitioners must plan the implant-prosthetic treatment based on proper long-term expectations of implant success and must consider possible future biological and mechanical/technical complications when preparing patients for receiving their informed consent (French et al, 2021)..

The long-term dental implant prognosis is determined by, among other factors, the assessment of the risk factors in the planning stage and by stabilizing or removing preexisting oral diseases prior to the start of implant surgery. In this context, the outcome of implant-prosthetic treatment is influenced by various factors as follows: implant-related factors (previous implant failure, implant surface status, degree of exposure to the oral environment); mechanical factors (premature loading, occlusal trauma); patient-related factors (level of oral hygiene, periodontal tissues condition, peri-implant bone condition, distance to adjacent teeth, periodontal status of adjacent teeth; soft tissue condition); systemic factors (smoking, age-related pathology, nutritional deficiencies, diabetes, steroid therapy, chemotherapy or radiotherapy); surgical technique factors (Dutta et al., 2020; Clark and Levin, 2016; Tarawali, 2015; Misch et al., 2008; Salvi and Brägger, 2009; Sailer et al., 2022; Negm, 2016; Chatzopoulos and Wolf, 2017; Karthik et al., 2013).

To reduce the risk of implant failures due to biological or mechanical/technical complications, risk factors must be eliminated or ameliorated. Patients' compliance with a strict follow-up protocol, including consistent home care and maintenance sessions in a private dental office, plays an important role in the early diagnosis of the inflammatory peri-implant processes as well as early detection of factors influencing the onset of the mechanical or technical complications (Clark and Levin, 2016; Tarawali, 2015).

It is known that there are many factors that can contribute to the success or failure of implants, from the condition of the patient to the surgical and prosthetic protocols performed by the operator. (Pérez et al., 2018). Among the exogenous factors are those related to the experience and skill of the operator and to the characteristics of the implants. Among the local endogenous factors, the characteristics of the bone are of great importance (since poor-quality bone will have a higher probability of rejecting an implant), as well as whether the site has received radiation treatment in the head and neck area, since it modifies the vascularity of the bone, making it unsuitable for any intervention. The amount of bone in the place where the implant will be placed should also be considered, as a lack of bone will lead to placing an implant in the wrong position, compromising the final restoration and subjecting the implant to inadequate forces, or this will lead to choosing a smaller size implant, which may affect its stability and survival. (Pérez et al., 2018)

Implant loss is the most serious complication in dental implants. They can occur within 6 months of their placement (early loss) or later (late loss). The growth of healthy bone around the implant — a process known as osseointegration — is the standard measure of implant success.

The following factors can interfere with the process and lead to implant failures (Corona et al, 2015; Pérez et al., 2018).

- Health conditions. Uncontrolled diabetes is a major cause of dental implant failures within the first year of implant placement.
- Age. People over 60 are prone to implant failures due to existing diseases, decreasing jaw bone density, and slow healing rates. Talk to your dentist/implantologist to know if an implant suits your age.
- Smoking. Smoking reduces the blood supply to the oral tissues and slows down healing. Smoking for a long time can also increase the risk of periodontitis and gum infections, increasing the chance of implant failure. Implant failure rates are high among smokers — 11% compared to 5% for non-smokers.
- Oral hygiene status. Poor oral hygiene results in plaque buildup. Gum infections and periodontitis raise the risk of implant failure. Peri-implantitis, an inflammatory condition surrounding the implants, is often linked to poor oral hygiene. It's important to clean the interdental areas regularly to maintain the implants for a long time.
- Jaw bone quality and density. Jaw bone density reduces as we age. A minimum of 1 mm strong bone on all sides is needed to support a standard implant. Diseases like osteoporosis and habits like bruxism can eat away at the jaw bone and increase the risk of implants failing.
- Radiation. Cancers are often treated with irradiation therapy. Radiation can block the blood supply to the jaw bones and cause damage to their structures. Research reveals that the success rate for implants placed in bone undergoing radiation is only 70%, compared to a 90–95% success rate for normal bones (Guzman, 2013).

With so many factors linked to the success of implants, it's natural that all implants don't last forever. Studies highlight a failure rate of up to 5–10%, either early or in the late stages. Keeping the factors and failure rates in mind, it's important to plan an implant placement carefully. An experienced implantologist is the right person to guide you on this (Guzman, 2013).

The placement of an implant foresees the activation of a biological response that leads to the repair of damaged tissues and the integration of the implant. Then, the same sequence of biological events that occurs in traumatic injuries to bone tissue occurs, whatever their origin, that is, bone formation involves a cascade of cellular events. (Tibeică et al., 2023).

Osseointegration of an implant in the bone is defined as the close apposition of newly formed bone in congruence with the implant, including surface irregularities; even,

microscopically, interposed connective or fibrous tissue is not observed and, furthermore, the direct structural and functional connection is established, with the capacity to support normal physiological loads, without excessive deformation and without initiating rejection mechanisms. Light microscopy and transmission electron microscopy analyses have shown an excellent fit between the implant and the bone. (Tibeică et al., 2023)

The proportion of direct bone-material contact of the implant varies according to implant material and design, host condition, surgical technique, loading conditions, and time. A good description for this interface would be to describe it as a discontinuous interface, a term that reflects the trend towards understanding osseointegration as a process and not as a result. (Tibeică et al., 2023)

Proper implant prosthetic treatment planning is essential for long-term success. Obtaining information from a careful medical history is crucial as the first step in treatment planning. For Bascones, the information obtained through the interview and the clinical history, together with the evaluation of the risk factors, are key to assessing the probability that the implant has to osseointegrate. (Tibeică et al., 2023)

Generally, the ideal conditions that allow the achievement of an implant-supported rehabilitation are those that promote the function, phonetics, and aesthetics of the patient. (Tibeică et al., 2023)

Various authors have proposed criteria to determine the success of osseointegrated implants: Schnittman and Schulman, Cranin et al., McKinney et al., Albrektsson et al., and Smith and Zarb. The criteria proposed by Albrektsson are widely used nowadays. According to this author, the success criteria of an implant are the following:

- The implant is immobile when clinically evaluated.
- There is no evidence of peri-implant radiolucency evaluated on a distortion-free radiograph.
- The average vertical bone loss is less than 0.2 mm per year after the first year of service.
- There is no pain, discomfort, or infection attributable to the implant.
- The design of the implant allows the placement of a crown or prosthesis with a satisfactory appearance for both the patient and the dentist.

By applying these criteria, a success rate of 85% at 5 years of observation and 80% at 10 years of observation is expected to classify the implant within the minimum levels of success. However, these criteria describe an ideal quality implant for a clinical study or report but do not address individual implants that may have a stable condition in the mouth after a brief period of bone loss (Tibeică et al., 2023)

It should be taken into account that the criteria that are commonly cited in clinical reports refer to the survival percentage, this means if the implant is physically in the mouth or if it has been removed. Critics argue that implants that must be removed for either pain or disease may also be retained and misclassified as successful (Tibeică et al., 2023).

There are other terms that have been suggested for implant success over time, such as early successful implant for an implant that has 1 to 3 years of service, intermediate successful implant for 3 to 7 years, and successful implant at a long-term for the implant that is older than 7 years (Tibeică et al., 2023).

Systemic diseases can affect oral tissues by interfering with healing or increasing the risk of other diseases. In addition, these diseases must be treated with medication or other therapies that could affect the tissues near the implants and the osseointegration process. In the reviewed literature, systemic conditions are established that may not make the use of dental implants recommendable or, at least, question the success of this treatment. However, with the available evidence, it is not sufficient to contraindicate implant placement in these patients. According to the American Association of Anesthesiology (ASA), patients who are going to receive dental

implants must be in one of the first two physical status categories corresponding to ASA I: healthy patient, or ASA II: patient with mild systemic disease. Patients with compromised conditions or any patient who is in another of the categories should arrive at ASA II to be treated (Pérez et al., 2018)

The risk of infection in immunosuppressed patients is one of the main considerations when placing implants in these patients. Antiretroviral therapy postpones the appearance of AIDS in patients infected with the HIV virus and also reduces the manifestations and appearance of opportunistic infections (Pérez et al., 2018).

Many case reports have demonstrated successful implant rehabilitations in immunocompromised but stable patients. The recommendation is to extend the follow-up time of these patients after the integration of the implants. Strietzel (2006) exposes a series of cases with one hundred percent survival of implants placed in patients with HIV, it is not specified whether antibiotic therapy is used, but the use of 0.2% chlorhexidine daily. Baron et al., published the rehabilitation of a patient with 12 implants and the follow-up with clindamycin antibiotic medication. According to the above, this condition is not contraindicated for the placement of implants as long as they are medicated and stable patients. In addition, as mentioned, the recommendation is to extend monitoring times after implant placement (Pérez et al., 2018).

Among the systemic factors that put the implant at risk are smoking, which compromises healing, some medications such as bisphosphonates that inhibit bone regeneration and give rise to osteonecrosis and are indicated mainly in patients with osteoporosis, the older age of the patients, and the presence of systemic diseases such as diabetes, or heart and immune diseases, among others. (Pérez et al., 2018).

The behavior of the patients is decisive in the appearance of peri-implant pathologies. It is possible that unconscious manifestations such as bruxism, stress, or undiagnosed malocclusion problems favor treatment deterioration. But above all, it is the careless attitude towards dental health that leads to new failures. People forget that the placement of implants is the result of the deterioration of natural parts. After an implantology treatment, if they continue to incur a lack of oral hygiene or engage in harmful habits such as smoking and poor nutrition, it is very likely that they will suffer from implant diseases.

If risk factors are not managed properly, complications of dental implant failures include early phase complications and late phase complications (Guzman et al, 2015; Tamez et al, 2017):

Early phase complications are as follows:

- Lack of implant stability. An unstable implant becomes mobile. Two key causes behind implant instability are trauma, insufficient healing time, and placing an artificial tooth over it immediately after the implant is placed (immediate loading).
- Infections at the site. At times, the implant can get infected, and in severe cases, it can attack the supporting jaw bone. The bone structures degenerate gradually, and the implant loses its supporting base.
- Implant-associated allergy. Titanium, often used in dental implants, can cause an allergic reaction. If you already have an allergy to titanium, don't forget to mention it to your dentist.

Late phase complications are as follows:

- Implant rejection. Dental implants can act as a foreign material, and the body can reject them. Though such cases are rare, they can happen.
- Nerve damage. An implant, if placed too close to a nerve, can cause temporary or permanent damage to it. If you are numb around the lips, gums, or tongue, chances are a nerve has been damaged.

- Intrusion into the sinus. Slight displacement during surgery can lead to intrusion into the maxillary sinus cavity, complicating the process.

Regarding the success/failure rates for different types of implants or those from different manufacturers, there is little data available. It appears overall, however, that implant height (i.e., body length), implant type (cylindrical or tapered), and one-stage or two-stage placement have no statistically significant effect on success or failure, although many studies directed at these effects were not well controlled. Nevertheless, the literature indicates that modern implants with tapered bodies and roughened surfaces exhibit higher success rates than the early smooth surface implant bodies (Guzman et al, 2015; Tamez et al, 2017).

In the treatment of patients with posterior short edentulous span, prosthodontists must balance the influence of multiple factors of prosthetic, periodontal, and endodontic origin as well as the socioeconomic factor and patient's demands (Zitzmann et al., 2010). The clinical decision between the tooth- versus implant-supported fixed partial dentures (FPD) is based on anatomic, esthetic, and economic factors, as well as the demands of the patient (Sailer et al., 2022). The implant-prosthetic treatment of edentulous patients has become a therapeutic approach with reliable functional and aesthetic results. Dental implants also decrease psychological trauma compared with conventional treatment options (Chatzopoulos & Wolf, 2017). However, despite the increased demands for implant-prosthetic rehabilitation, a large category of posterior edentate people cannot benefit from implant-supported fixed partial dentures therapeutic approach due to socioeconomic reasons or a combination of local, loco-regional, and systemic factors (Tan et al., 2004). For candidates for implant-prosthetic therapy, the dental practitioner must make therapeutic decisions based on clinical and paraclinical investigations. An important tool in the decision-making can be data collected from retrospective and prospective studies regarding the survival rates, prosthetic success rates, as well as the potential factors that could influence the long-term outcome of the tooth- or implant-supported FPD. Biological complications (dental caries, endodontic pathology, periodontal disease) and technical complications (loss of retention) can reduce the longevity of tooth-supported FPD. At a 10-year follow-up, FPD supported by 2-4 natural teeth abutments have a risk of 2.1% for abutment fracture, 2.6% for dental caries, and 0.7% for periodontitis; the risk of loss due to technical complications was 6.4% (retention loss) and 3.2% (material fracture) (Heydecke et al., 2012). Biological complications (peri-implantitis) and technical complications (loss of retention, screw loosening, abutment fractures, ceramic veneering chipping) can also reduce the prosthetic success of implant-supported FPD (Wittneben et al., 2014; Lee et al., 2016; Pjetursson & Heimisdottir, 2018).

Systematic reviews and prospective research lead to the following conclusions regarding the risk factors that can influence the success/failure of the surgical and prosthetic stage in implant-prosthetic therapy (Corona et al, 2015; Guzman et al, 2015; Tamez et al, 2017; Pérez et al., 2018):

- Exogenous and endogenous factors are established, related to the surgeon's experience, as well as the presence of bone reabsorption or the need for bone grafts.
- An implant health quality scale and relate the categories of this scale with the prognosis of existing conditions in our patients.
- Radiation, smoking, cardiovascular disease and HIV do not represent contraindications for implant placement, but cases should be analyzed and the risks of the procedure explained to the patient.

Publications on this topic:

1.Forna Norina, Chetruș Viorica, **Agop-Forna Doriana**, Curcă Răzvan, Chirilă Adriana Măriuca, Toader Bianca, Ahmed Ashma, Boiangiu Andy Ariel, Lazaruc Dana. Study regarding the status of the prosthetic field of the patients candidates to dental implants. *Rom.J.Med.Dent*. 2019; 8(4): 43-50.
2.Bardis, D.; **Agop-Forna, D**.; Pelekanos, S.; Chele, N.; Dascălu, C.; Török, R.; Török, B.; Cristea, I.; Bardi, P.M.; Forna, N. Assessment of Various Risk Factors for Biological and Mechanical/Technical Complications in Fixed Implant Prosthetic Therapy: A Retrospective Study. *Diagnostics* 2023, 13, 2341. https://doi.org/10.3390/diagnostics13142341 FI=3,99
3.Cristea, I.; **Agop-Forna, D**.; Martu, M.-A.; Dascălu, C.; Topoliceanu, C.; Török, R.; Török, B.; Bardis, D.; Bardi, P.M.; Forna, N. Oral and Periodontal Risk Factors of Prosthetic Success for 3-Unit Natural Tooth-Supported Bridges versus Implant-Supported Fixed Dental Prostheses. *Diagnostics* 2023, 13, 852. https://doi.org/10.3390/diagnostics13050852 FI=3,99
4.Fetco Andrei, Zanoaga (Afloarei) Elena-Crina, Tibeica Andreea, Cretu Cosmin, Curca Razvan, **Agop-Forna Doriana**, Norina Forna. Influential factors of the success and/or failure of dental implants. *Rom.J.Med.Dent*. 2023; 12(1)

1.2.1. Study regarding the status of the prosthetic field of the patients candidates to dental implants

Introduction

Regarding the high percents of population with partial edentation, a complete functional and esthetic rehabilitation requires the improvement of clinical and biological indices, during pro- implant and pro-psosthetic stage, to reduce the functional imbalances in complex oral rehabilitation cases (Forna et al., 2008; Leung & Pow, 2009). The analysis of the mucous and bone support is requested in the preoperatory stage along with assessment of biomechanical aspects, esthetic demands of patient, as well as the combination of the biological, mechanical, esthetic and physiological factors (Pellizzer et al., 2012).The planning of the proprosthetic and proimplant stages will follow the transfer of the forces from implant to periimplant bone tissues establishing the protective and negative factors in relation to loading protocol, implants materials and design, volume and density of the periimplant bone, and the features of the implant-bone interface (Dundar et al., 2016). The patients with low volume and quality bone represent a major risk factor for the long-term success of the implant- prosthetic restorations (Herrmann et al., 2005).

Aim of study

The aim of study was to evaluate the prosthetic field status for edentulous patients candidates to dental implants as well as the required guided tissues regeneration procedures.

Materials and method

The study group included 297 untreated edentulous patients aged between 30-70 years (99- males, 198 - females), with partial edentation, programmed for implant-prosthetic treatment in Clinical Dental Learning Base of Dental Medicine Faculty, U.M.F. „Grigore T. Popa" Iași and two private dental practices. Informed consent was obtained for all patients. Anamnesis data, clinical examen, paraclinical examens were recorded in clinical papers and Microsoft Excel database. The bone maxillary and mandibular support was assessed by using clinical and radiographic examen, and the prosthetic fields were divided in positive and negative prosthetic fields. The distribution of Misch classes and osteodensity (Ruben-Duval

indices) for maxillary and mandibular prosthetic fields were recorded to determine the required procedures of tissue regeneration techniques for the optimization of clinical and biological indices of the prosthetic field. For patients requiring bone addition or augmentation, the implants insertion was programmed after 3-4 months. For all patients it was planned delayed implantation after an interval of 4-6 months.

Results

In figure 1.a. is presented the status of the bone support for patients with extended partial edentation to maxillary bone. Regarding the number of maxillary hemiarcades with extended partial edentation, in 38% cases the bone support is classified as A/B (do not require alveolar augmention +/-sinus lift), 15% is classified B-w, 53% is classified C. In 68% of maxillary hemiarcades with extended partial edentation is requested alveolar augmentation associated with sinus lift).

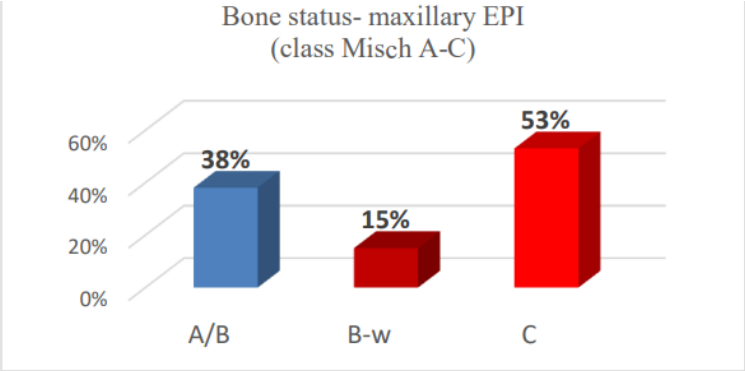


Fig. 1.a. Bone quality for patients with maxillary EPI

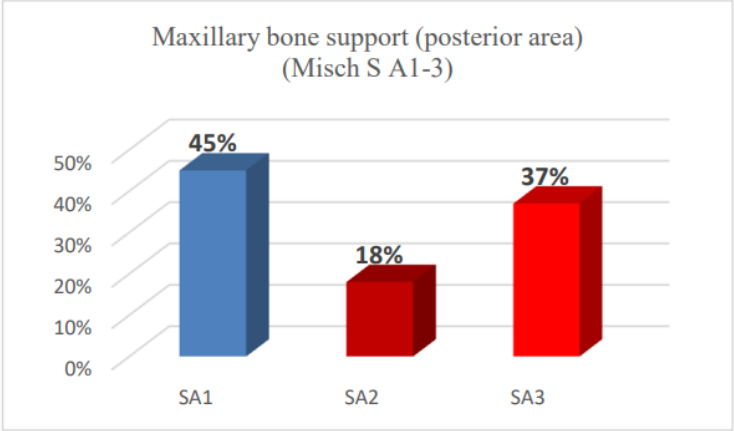


Fig. 1.b. Posterior maxillary alveolar bone quality (posterior area).

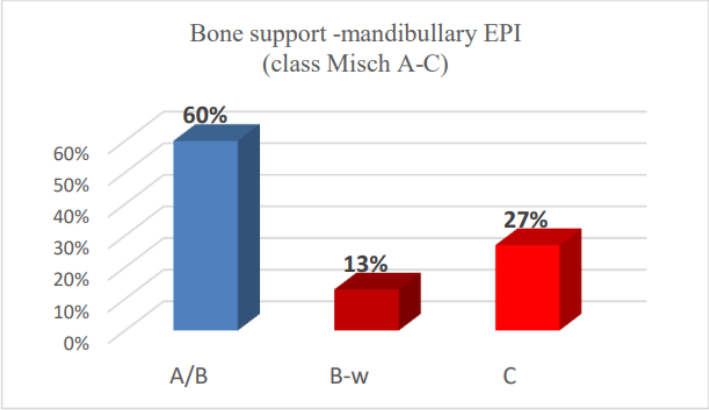


Figure 1.c. Bone support for patients with mandibular edentation

In figure 1.b.-c is presented the status of the bone support for patients with posterior extended partial edentation to maxillary and mandibular bone. Regarding the number of maxillary hemiarcades with extended partial edentation, in 45% cases the bone support is classified as SA1 (do not require alveolar augmention +/-sinus lift), 18% is classified SAA, 37% is classified SA3. In 55% of posterior areas of maxillary hemiarcades with extended partial edentation is requested alveolar augmentation.

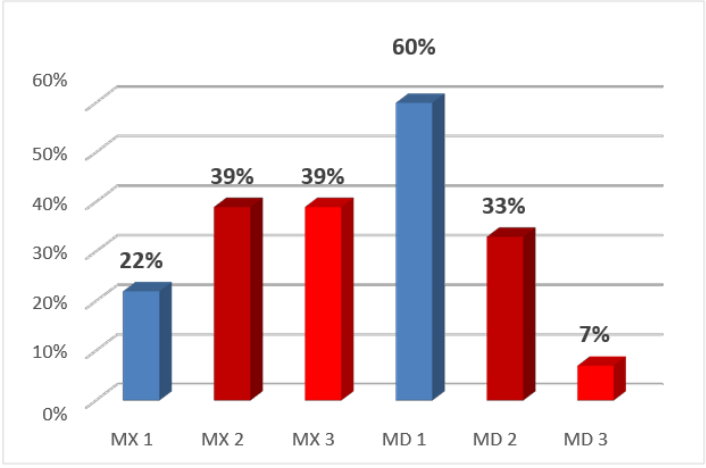


Fig. 1.d. Rubens-Duval osteodensity indices for patients with edentation

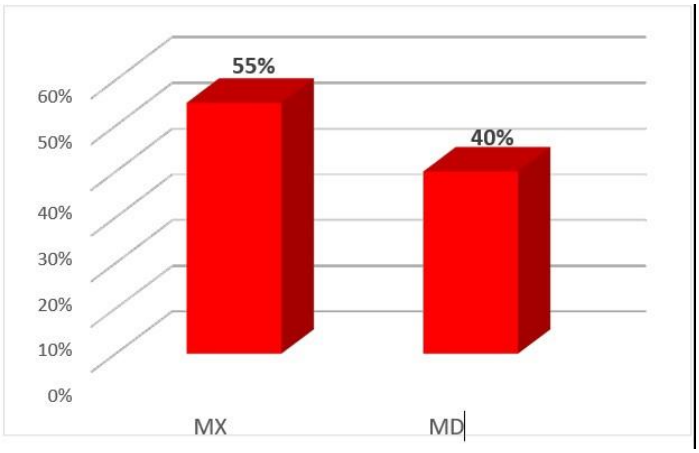


Fig. 2. Proportion of patients requiring guided tissue regeneration techniques (maxillary vs mandibular edentation)

In figure 1.d. are presented Rubens- Duval indices indicating the osteodensity for patients with extended partial edentation. Regarding the number of maxillary and mandibular hemiarcades with extended partial edentation, in 22% cases the bone support is classified as osteodensity indices 1 for maxillary areas, in 60% cases the bone support is classified as osteodensity indices 1 for mandibular areas, the osteodensity indices 2 are detected in 39% of maxillary hemiarcades, and 33% of mandibular hemiarcades, and osteodensity indices 3 are detected in 39% of maxillary hemiarcades, and 7% of mandibular hemiarcades with extended partial edentation. In fig.2. are presented data regarding the proportion of edentulous patients candidates to dental implants requiring guided bone regeneration techniques for the posterior area. 55% of the patients with maxillary extended partial edentation and 40% of patients of the patients with mandibular extended partial edentation require alveolar bone regeneration techniques.

Discussions

The aim of our study was the assessment of the prosthetic field according to Misch criteria and Rubens- Duval osteodensity indices. Considering this aim, the criteria for a

satisfactory prosthetic field are as follows: alveolar ridge height over 10 mm, alveolar ridge width over 6mm, mucous thickness maximum 2-3 mm, the absence of deformations of the alveolar bone both in horisontal and vertical plan to the level of the implant sites (Topalo & Dobrovolschi, 2008; Sârbu et al., 2013)

In our study, we found that for maxillary bone support, only 38% patients are classified with class Misch A/B (optimal and satisfactory bone support), considering both frontal and posterior areas. Regarding the posterior maxillary area, in 45% cases the bone support is classified as SA1 (do not require alveolar augmentation +/-sinus lift).

Regarding the number of mandibular hemiarcades with extended partial edentation, in 60% cases the bone support is classified as A/B (do not require alveolar augmentation +/-sinus lift). Regarding Rubens-Duval indices indicating the osteodensity of the bone support of the edentulous patients, only in 22% cases the maxillary bone support is classified with osteodensity indices 1 , while osteodensity is more satisfactory in mandibular bone support where Rubens- Duval indice 1 is found in 60% cases.

Those clinical situations characterised by negative biological and clinical indices for the edentulous patients candidates to dental implants require guided tissues regeneration interventions (Sârbu et al., 2013). In this context, in our study group it was determined that proportion of prosthetic fields requiring guided tissues interventions was 55% for maxillary edentations and 40% for mandibular edentations.

Papakoca (2011), in a similar study, found that 61% of patients candidates to dental implants require maxillary alveolar augmentation with sinus lifting, and 39% of patients required mandibular alveolar augmentation, with 75% of the mandibular graft procedures requested in the posterior areas. Regarding the need for guided bone regeneration techniques, 46% of the sinus lifting procedures were associated to guided bone regeneration techniques, and 31,5% of the mandibular augmentation procedures were associated to guided bone regeneration techniques.

Sârbu et al. (2016) found that patients candidates to dental implants have moderate or severe defects of bone support in 66% cases. The patients that allow implantation without alveolar augmentation present favourable bone parameters as follows: mean alveolar ridge width 5.8(±0,36)mm (A, B+), mean alveolar ridge height 14.74(±0,54)mm. The author succeded to perform immediate implantation without additional surgical interventions in 49,5% cases. In 51,5% cases the bone support required alveolar augmentation or osteosplitting procedure. The alveolar augmentation was used for patients with bone parameters as follows: width of alveolar ridge 4,83±(0,49)mm (B+), height of alveolar ridge 12.2(±0,5)mm.

The alveolar bone volume and quality influence the implant-prosthetic therapeutic plan regarding the moment of implantation, the loading protocol, as well as the design of the future prosthetic restoration.

The investigation of the prosthetic field elements and areas that need rehabilitation impose the use of diagnostic and treatment algorithms for the optimisation of the prosthetic solutions, avoidance of potential errors and the increase of the accuracy of the implant and surgical procedures (Babbush et al., 2011).

Conclusions

- Patients candidates to dental implant present the severe changes of the mucosal and bone support in 55% cases.

- In maxilary extended edentation, in 38% cases the bone support is classified A/B, in 15% cases the bone support is classified B- w, and 53% cases are classified class C.

- 55% of the maxillary hemiarcades with extended partial edentation require guided bone regeneration techniques.

- In mandibullary extended edentation, in 60% cases the bone support is classified A/B, in 13% cases the bone support is classified B-w, and 27% cases are classified class C.

- 40% of the mandibulary hemiarcades with extended partial edentation require alveolar augmentation by guided bone regeneration techniques.

1.2.2. Assessment of Various Risk Factors for Biological and Mechanical/Technical Complications in Fixed Implant Prosthetic Therapy: A Retrospective Study

The aim of this research was to determine the influence of several factors on the biological and technical complications in the fixed implant-prosthetic therapy of the posterior edentulism.

Materials and method

The research was performed according to the ethical values of the Declaration of Helsinki and received approval from the ethics committee of U.M.F. "Grigore T.Popa" Iasi (Romania) (No.19355). All patients were informed about the research objectives and provided written informed consent.

Study Design. Inclusion and Exclusion Criteria.

This was a retrospective study including 67 patients (mean age: 63.88 ± 11.709 yr; gender: 20 males, 47 females) with posterior partial edentulism that were treated in a private practice from 2006 to 2018. The implant-prosthetic therapy was performed with Nobel Biocare HQ (Switzerland) implants (178 implants; length 10-13 mm; width 3.5-4.5 mm) and metal-ceramic implant-supported fixed partial dentures (IP-FPDs). The mean follow-up time was 7.89 ± 4.626 yr. The subjects were selected from patients invited to recall.

The inclusion criteria were as follows: age ≥ 18 years; 3-5 units IP-FPDs with centric pontic; follow-up 3-15 years. Exclusion criteria were decompensated metabolic diseases and non-compliant patients to periodontal maintenance visits.

The design of the study followed the PICO components (Table XIII). The features of the study group at recall are presented in Table II, globally, as well as by comparison according to the implants' survival.

Table XIII. Study design (PICO). Components.

Component	Description
Population (P)	Patients with posterior edentulism
Intervention (I)	Fixed implant prosthetic therapy—3–5 units metal–ceramic IP-FPDs
Comparison (C)	Implants with biological complications (peri-implantitis) Implants associated with mechanical/technical complications
Outcome (O)	Risk factors for biological complications (OR) Risk factors for technical complications (OR)

Table XIV. Study groups features (at recall) – univariate analysis regarding the implants' survival

		Implants' survival		
	Total (n = 178)	Yes (n = 172) (100,0%)	No (n = 6) (100,0%)	p
Age group				,190
40-60 yr	49 (27,5%)	49 (28,5%)	0 (0,0%)	
>60 yr	129 (72,5%)	123 (71,5%)	6 (100,0%)	
Gender				,179

M	55 (30,9%)	55 (32,0%)	0 (0,0%)	
F	123 (69,1%)	117 (68,0%)	6 (100,0%)	
Smoking status				,193
Non-smoker	130 (73,0%)	124 (72,1%)	6 (100,0%)	
Smoker	48 (27,0%)	48 (27,9%)	0 (0,0%)	
Periodontal history				,340
Yes	45 (25,3%)	45 (26,2%)	0 (0,0%)	
No	133 (74,7%)	127 (73,8%)	6 (100,0%)	
Oral hygiene (mPI)				1,000
0-1	157 (88.2%)	151 (87,8%)	6 (100,0%)	
2-3	21 (11.8%)	21 (12,2%)	0 (0,0%)	
Bruxism				,592
Yes	31 (17,4%)	31 (18,0%)	0 (0,0%)	
No	147 (82,6%)	141 (82,0%)	6 (100,0%)	
Implants number /FPD				,036*
2	100 (56,2%)	94 (54,7%)	6 (100,0%)	
3	78 (43,8%)	78 (45,3%)	0 (0,0%)	
Implant site grafting				,029*
Yes	88 (49,4%)	88 (51,2%)	0 (0,0%)	
No	90 (50,6%)	84 (48,8%)	6 (100,0%)	
Follow-up (yr)				,026*
3-5 ani	82 (46,1%)	76 (44,2%)	6 (100,0%)	
6-10 ani	48 (27,0%)	48 (27,9%)	0 (0,0%)	
>10 ani	48 (27,0%)	48 (27,9%)	0 (0,0%)	
Edentulism location				,029*
Mx	91 (51,1%)	85 (49,4%)	6 (100,0%)	
Md	87 (48,9%)	87 (50,6%)	0 (0,0%)	
Implant location				,553
C / IL	15 (8,4%)	15 (8,7%)	0 (0,0%)	
PM	58 (32,6%)	55 (32,0%)	3 (50,0%)	
M	105 (59,0%)	102 (59,3%)	3 (50,0%)	
Opposing surfaces				,015*
Natural teeth	58 (32,6%)	58 (33,7%)	0 (0,0%)	
Removable dentures (acrylic teeth) with implants support	18 (10,1%)	18 (10,5%)	0 (0,0%)	
FPD (metal ceramic) with natural teeth support	66 (37,1%)	60 (34,9%)	6 (100,0%)	
FPD (metal ceramic) with implants support	36 (20,2%)	36 (20,9%)	0 (0,0%)	

Implant Stage and Prosthetic Procedures

Before the implant stage, patients with periodontal pathology were treated by non-surgical or surgical procedures by a periodontologist. A single surgeon (P.M.B.), with > 15 years of experience, performed the alveolar bone grafting procedures and the implant surgical technique. The alveolar bone rehabilitation was required for 49.4% of the implant sites. For patients with severe resorbed alveolar bone, the implant site reconstruction was performed by horizontal and vertical augmentation techniques with xenografts and resorbable collagen membranes (Wessing et al., 2018; Elnayef et al., 2018). Implants were placed following the standard implant protocol by delayed implant placement protocol (Beschnidt et al., 2018; Canellas et al., 2019). Chlorhexidine 0.12% rinse was recommended pre- and post-operatively. Patients that underwent alveolar bone addition procedures received a preoperative loading dose of antibiotics and postsurgical doses for 3-5 days in relation to infectious risk (Surapaneni et al., 2016). Implants were conventionally loaded (delayed loading) at 3 months with definitive metal-ceramic fixed dentures (Chen et al., 2019; Mitsias et al., 2018).

Definitions

Implant survival definition: implant and abutment still present in the mouth at follow-up examination (Dutta et al., 2020).

Implant failure definition: implants that require removal or have already been lost (Dutta et al., 2020).

ICOI introduced failed implants in Group IV Pisa Implant Health Scale that includes both implants unable to be restored and implants associated with any of these conditions: (1) palpation, percussion or function are associated with pain, (2) horizontal and/or vertical mobility, (3) severe and progressive bone loss, (4) uncontrolled exudate, or (5) more than 50% bone loss around the implant (Dutta et al., 2020).

Success definition: presence of the implant, abutment, and prosthetic suprastructure in situ without biological complications (Sailer et al., 2022) or without mechanical or technical complications during the follow-up time (Salvi & Brägger, 2009).

Implants with biological complications were considered implants with peri-implantitis (associated with progressive marginal loss) (Karthik et al., 2013; Heitz-Mayfield & Salvi, 2018), while peri-mucositis is a reversible condition under proper treatment (Heitz-Mayfield & Salvi, 2018).

Criteria for peri-implantitis diagnosis were as follows:

- Peri-inflammation signs at the clinical level (erythema, swelling, bleeding on probing, and/or suppuration) (Heitz-Mayfield & Salvi, 2018).
- In the absence of a previous radiograph, radiologic bone loss of at least 3 mm (from the implant shoulder) combined with probing depth of ≥6 mm associated with BOP (Renvert et al., 2018; Berglundh et al., 2018; Heitz-Mayfield & Salvi, 2018; Hanif et al., 2017).

The mechanical complications are the loss of screw hole access material, screw loosening, abutment loosening, screw fracture, or implant fracture (Karthik et al., 2013; Heitz-Mayfield & Salvi, 2018).

The technical complications of the implant-supported fixed partial dentures are fracture/chipping of veneering ceramic and fracture of the framework of fixed partial denture (Karthik et al., 2013; Heitz-Mayfield & Salvi, 2018).

Clinical Examination:

- Complete clinical examinations were performed by one independent and calibrated examiner (DB) from October 2021 to May 2022. The following categories were assessed:
- Medical history;
- Familial history;
- Smoking history (smokers > 10 cigarettes/day; non-smokers);
- Mechanical/technical complications: absent, major complications such as implant fracture, medium and minor complications (fracture of abutment, veneer or framework, veneering chipping, loosening of abutment or screw, loss of retention);
- Peri-implant soft tissues condition: probing pocket depth (PPD) using a manual periodontal probe (Click-Probe®, Kerr, Bioggio, Switzerland) at six sites per implant, bleeding on probing (BOP), mobility;
- Modified Gingival Index (mGI) (Mitsias et al., 2018);
- Modified plaque index (mPII) at all implants (Mitsias et al., 2018);
- Width of keratinized tissue (mm) (mandible: 6 sites/implant; maxillary: 3 sites/implant) - measured from the mucogingival junction and the most coronal point of the keratinized mucosa in the center of the IP-FPD (Mitsias et al., 2018).

Radiologic Analysis

The CBCT exam (Sirona Orthophos XG) was used to calculate the peri-implant marginal bone loss (MBL). CBCT scanning conditions were: 85 kV, 6 mA, 14.4 s irradiation time, 25–1025 μSv irradiation dose, 1 mm slice thickness. The measurements were done by an independent radiologist who was not involved in the study. At the mesial and distal implant

sides, Sidexis XG/ DVT (Densply/Sirona) software was used to measure the distance between the connection implant-abutment and the level of MBL. The highest value was taken as the extent of bone loss.

Data collection

All patients were examined during the yearly regular visit for implant and surrounding hard and soft tissues status. Data were collected and introduced into an SPSS database by one investigator (DB). The following data were collected: gender and age group (40-60 yr. vs. >60 yr.), oral hygiene (mPI index), as well as data regarding biological complications and mechanical/technical complications.

Statistical analyses

The statistical analyses were performed in SPSS 29.0. The qualitative variables were characterized through frequencies distributions. The quantitative variables were characterized through descriptive statistics (averages and standard deviations). The assessed variables were as follows: demographic factors (age group: 40-60 yr. vs. > 60 yr.; gender), smoking (1-10 cigarettes/day vs. no smoking), periodontal history (present vs. absent), oral hygiene (mPI 0-1 vs. 2-3), bruxism (present vs. absent), implants number (2 vs. 3), bone grafting (present vs. absent), follow-up (3-5 yrs. vs. 6-10 yrs. vs. >10 yrs.), edentulism location (Mx vs. Md vs. Mx + Md), opposing arch (natural teeth vs. removable dentures with implant support vs. metal-ceramic fixed dentures with implant-support vs. natural metal-ceramic fixed dentures with implant-support). The risk factors for the biological and mechanical/technical complications were assessed through Chi-squared test and OR (Odds Ratio), as well as through binary logistic regression. The survival time was evaluated through Kaplan-Meyer analysis and Log-Rank (Mantel-Cox) test. The degree of statistical significance was set at $p < 0.05$.

Results

Implant data at recall. Implant survival and success rates

The implant data at recall (PPD; mean MBL; BOP; mGI; mPI; width of keratinized mucosa) are shown in Table XV.

Table XV. Implant data at recal

***n* = 178 (100%)**	
PPD	≤3 mm: 160 (89.33%); 3.5–5 mm: 12 (6.74%); >5 mm: 7 (3.93%)
MBL (mean)	1.3625 mm (mesial); 1.0875 mm (distal)
BOP_+ (at least 1 positive site/implant)	117 (64.74%)
mGI (max./implant)	0:68 (38.20%); 1: 85 (47.75%); 2: 18 (10.11%); 3: 7 (3.94%)
mPI (max./implant)	0: 88 (49.45%); 1: 75 (42.13%); 2: 8 (4.49%); 3: 7 (3.93%)
Width of keratinized mucosa	Absent: 18 (10.10%); <2 mm: 84 (47.20%); ≥2 mm: 76 (42.70%)

PPD = periodontal pocket depth; GI = modified gingival index; PI = modified plaque index; BOP = bleeding on probing.

Implant survival rate was 96.6% (172 implants from the total of 178). Implant success rate (absence of biological/technical complications) was 66,3% (118 implants from the total of 178). The complications reported at the level of the 178 implants were as follows: peri-implantitis (24 cases – 13.5%); mechanical/technical complications (51 cases – 28.7%).

Table XVI exposes the univariate analysis on peri-implantitis in relation to variables such as smoking, periodontal history, poor oral hygiene, bruxism, follow up > 10 years, FPD (metal-ceramic) with natural teeth support on the opposing surfaces.

Table XVI. Peri-implantitis occurrence- univariate analysis results

		Peri-implantitis		p
		yes (n = 24)	no (n = 154)	
Age group	40-60 ys	6 (25,0%)	43 (27,9%)	,766
	> 60 ys	18 (75,0%)	111 (72,1%)	
Gender	M	6 (25,0%)	49 (31,8%)	,501
	F	18 (75,0%)	105(68,2%)	
Smoking status	Yes	15 (62,5%)	33 (21,4%)	,000**
	No	9 (37,5%)	121 (78,6%)	
Periodontal history	Yes	21 (87,5%)	24 (15,6%)	,000**
	No	3 (12,5%)	130 (84,4%)	
Oral hygiene (mPI)	0-1	15 (62,5%)	142 (92,2%)	,000**
	2-3	9 (37,5%)	12 (7,8%)	
Bruxism	Yes	6 (25,0%)	25 (16,2%)	,383
	No	18 (75,0%)	129 (83,8%)	
Implants number /FPD	2	15 (62,5%)	85 (55,2%)	,502
	3	9 (37,5%)	69 (44,8%)	
Implant site grafting	Yes	21 (87,5%)	67 (43,5%)	,000**
	No	3 (12,5%)	87 (56,5%)	
Follow-up (yrs.)	3-5	3 (12,5%)	79 (51,3%)	,001*
	6-10	12 (50,0%)	36 (23,4%)	
	>10	9 (37,5%)	39 (25,3%)	
Edentulism location	MX	18 (75,0%)	73 (47,4%)	,012*
	MD	6 (25,0%)	81 (52,6%)	
Implant location	C / IL	3 (12,5%)	12 (7,8%)	,071
	PM	12 (50,0%)	46 (29,9%)	
	M	9 (37,5%)	96 (62,3%)	
Opposing surfaces	Natural teeth	0 (0,0%)	58 (37,7%)	,000**
	Removable dentures (acrylic) with implant support	0 (0,0%)	18 (11,7%)	
	FPD with natural teeth support (ceramic)	24 (100,0%)	42 (27,3%)	
	IP-FPD (ceramic)	0 (0,0%)	36 (23,4%)	

The binary logistic regression model of the significant risk factors is statistically significant (p < ,001 – Omnibus Test of Model Coefficients) and explains 69,1% from the variance of the peri-implantitis (Nagelkerke R^2), with a sensibility of 87,5% and a specificity of 100,0%; the identified statistically significant predictors were: periodontal history and implant site grafting (Table XVII).

Table XVII. Risk factors for peri-implantitis

	Estimated average	SEM	95% CI (average) Lower limit	Upper limit
Implant survival / success	16,528	,189	16,157	16,899
Implants without complications	12,471	,429	11,631	13,312
Implants without biological complications	15,420	,387	14,662	16,178
Absence of mechanical/technical complications	13,159	,439	12,298	14,019

The risk factors for mechanical/technical complications, as depicted in Table XVIII, are age group > 60 yrs., smoking, periodontal history, poor oral hygiene, bruxism, 2 implants support, implant site grafting, follow-up at 3-5 years but also at over 10 yrs., mandibular location, and opposing surfaces on FPD (metal-ceramic) with teeth support.

Table XVIII. Mechanical/technical complications occurrence- univariate analysis results

Parameters:	Univariate analysis				Multivariate analysis			
	Pearson Chi-squared	p	Risk of technical complications		Binary logistic regression			
			OR / RR	95% CI OR / RR*	B coef.	OR	95% CI OR	p
Age group > 60 yrs.	8,903	,003**	3,839	1,518 ÷ 9,709	,172			,879
Periodontal history	58,817	,000**	17,569	7,687 ÷ 40,158	3,065	21,429	1,941 ÷ 236,601	,012*
Oral hygiene (mPI 2-3)	9,454	,002**	4,034	1,581 ÷ 10,297	,704			,665
Bruxism	43,671	,000**	15,238	5,954 ÷ 38,999	3,231	25,293	2,560 ÷ 249,907	,006**
Number of implants (FPD with 2 implants support)	19,890	,000**	5,552	2,494 ÷ 12,357	2,679	14,567	1,260 ÷ 168,402	,032*
Implant site without grafting	19,195	,000**	4,843	2,316 ÷ 10,130	1,663			,090
Mandibular edentulism	7,168	,007**	2,478	1,264 ÷ 4,860	1,921	6,831	1,069 ÷ 43,640	,042*
Opposing arch	64,025	,000**	-	-	1,047	2,850	1,103 ÷ 7,363	,031*
Constant					-8,435	,000		,000

The binary logistic regression model of the significant risk factors is statistically significant ($p < ,001$ – Omnibus Test of Model Coefficients) and explains 69,1% from the variance of technical complications (Nagelkerke R^2), with a sensibility of 82,4% and a specificity of 97,6%; the identified statistically significant predictors were: periodontal history, bruxism, FPD with 2 implants support, mandibular edentulism and opposing surfaces on FPD (metal- ceramic) with natural teeth support (Table XIX).

Table XIX. Risk factors for mechanical/technical complications

Parameters:	Univariate analysis				Multivariate analysis			
	Pearson Chi-squared	p	Risk of periimplantitis		Binary logistic regression			
			OR / RR	95% CI OR / RR*	B coef.	OR	95% CI OR	p
Smoker	17,785	,000**	6,111	2,456 ÷ 15,207	,846	-	-	,376
Periodontal history	56,850	,000**	37,917	10,482 ÷ 137,152	5,065	158,442	22,663 ÷ 1107,699	,000**
Oral hygiene (mPI 2-3)	17,611	,000**	7,100	2,573 ÷ 19,590	,496	-	-	,745
Implant site grafting	16,077	,000**	9,090	2,602 ÷ 31,756	3,280	26,585	2,863 ÷ 246,853	,004**
Follow-up (yrs.)	13,384	,001*	-	-	-,506	-	-	,561
Maxillary location	6,329	,012*	3,329	1,254 ÷ 8,839	1,063	-	-	,217
Opposing arch	47,074	,000**	-	-	,217	-	-	,627
Constant					-7,229	,001		,000

The average survival time of the dental implants is presented in Table XX (follow-up 3-17 years). The implants' average survival time was of 16.528 years, while the survival time without biological or technical complications was of 12,471 years.

Table XX. Kaplan-Meyer survival analysis results

		Mechanical/technical complications		p
		yes (n = 51)	no (n = 127)	
Age group	40-60 yrs.	6 (11,8%)	43 (33,9%)	,003**
	> 60 yrs.	45 (88,2%)	84 (66,1%)	
Gender	M	21 (41,2%)	34 (26,8%)	,060
	F	30 (58,8%)	93 (73,2%)	
Smoking status	Yes	6 (11,8%)	42 (33,1%)	,004**
	No	45 (88,2%)	85 (66,9%)	
Periodontal history	Yes	33 (64,7%)	12 (9,4%)	,000**
	No	18 (35,3%)	115 (90,6%)	
Oral hygiene (mPI)	0-1	39 (76,5%)	118 (92,9%)	,002**
	2-3	12 (23,5%)	9 (7,1%)	
Bruxism	Yes	24 (47,1%)	7 (5,5%)	,000**
	No	27 (52,9%)	120 (94,5%)	
Implants number /FPD	2	42 (82,4%)	58 (45,7%)	,000**
	3	9 (17,6%)	69 (54,3%)	
Implant site grafting	Yes	12 (23,5%)	76 (59,8%)	,000**
	No	39 (76,5%)	51 (40,2%)	
Follow-up (yrs.)	3-5	18 (35,3%)	64 (50,4%)	,150
	6-10	15 (29,4%)	33 (26,0%)	
	>10	18 (35,3%)	30 (23,6%)	
Edentulism location	MX	18 (35,3%)	73 (57,5%)	,007**
	MD	33 (64,7%)	54 (42,5%)	
Implant location	C / IL	3 (5,9%)	12 (9,4%)	,701
	PM	18 (35,3%)	40 (31,5%)	
	M	30 (58,8%)	75 (59,1%)	
Opposing surfaces	Natural teeth	3 (5,9%)	55 (43,3%)	,000**
	IP-FPD (acrylic)	9 (17,6%)	9 (7,1%)	
	Natural teeth- FPD (ceramic)	39 (76,5%)	27 (21,3%)	
	IP-FPD (ceramic)	0 (0,0%)	36 (28,3%)	

Discussions

In our study, the definitions of the implant survival and success were based on the statement of International Congress of Oral Implantologists (ICOI) Consensus Conference for Implant Success (2007) (Misch et al, 2008). In the fixed implant-prosthetic therapy, the major role of the dental implants is to act as abutments for fixed restorations, similar to a natural tooth. In this context, ICOI stated that any success criteria must include implants ability to support functional dentures (Misch et al, 2008). However, implant success is difficult to describe in the same way as the success criteria required for a tooth (Misch et al, 2008). We considered implant success only those implants that were not associated to major biological complications (peri-implantitis) or any technical and mechanical complication during the follow-up time (Salvi&Bragger, 2009). This category of implants correspond to the Group I of the Pisa Implant Health Scale with very good to excellent prognosis (the absence of any biological or technical complications as well as the lack of association to mechanical complications of their prosthetic suprastructure). Despite the stability and the absence of symptoms (pain, tenderness) (Group II of the Pisa Implant Health Scale), the presence of the peri-implantitis has a potential for early clinical problems (Misch et al, 2008). Moreover, implants exhibiting a slight to moderate peri-implantitis and compromised health status (Group III of the Pisa Implant Health Scale) are implants that can be associated with technical or mechanical complications of its prosthetic suprastructure.

The goal of our study was to highlight several risk factors for complications (biological, mechanical/technical) associated with implant poor prognosis or failure. Our research included only patients who were compliant to the annual maintenance sessions. The implant-prosthetic

therapy outcomes require an assessment made through patient-based parameters, as the patient becomes central in the overall analysis. In this context, the treatment success is not based only on the clinical and technical aspects but also on the compliance of patients with oral hygiene rules and maintenance sessions (Del Fabbro et al., 2019). The literature has a great variability of data regarding both the prevalence of implant success and biological and mechanical/technical complications due to different criteria systems and evaluation protocols and techniques. Studies with a minimum of 5-year follow-up report variable results on the prevalence of peri-implantitis. The prevalence of peri-implantitis at the implant level was 7.3% (Dalago et al., 2017), 9.1% (Mir-Mari et al., 2012), 9.8% (Aguirre-Zorzano et al., 2015), 9.83% (Lee et al., 2017), 9.6% (Atieh et al., 2013), 16% (Daubert et al., 2015), 23% (Marrone et al., 2013), 24.9% (Derks et al., 2016), and 72% (Schuldt et al., 2014). At the patient level, the prevalence of peri-implantitis was 13.3% (Konstantinidis et al., 2015), 15.1% (Dalago et al., 2017), 16.3% (Mir-Mari et al., 2012), 18% (patients compliant to maintenance periodontal sessions) (Konstantinidis et al., 2015), 18.8% (Atieh et al., 2013), 19.83% (Lee et al., 2017), 26% (Daubert et al., 2015), 37% (Marrone et al., 2013), and 45% (Derks et al., 2016). Derks and Tomasi (2015) reported the incidence of peri-implantitis of 1-47% (weighted mean prevalence of 22%). Epidemiological studies addressing biological complications are mainly aiming at the assessment of incidence and prevalence but are less focused on determining the peri-implantitis stages due to the absence of consistent case definitions, cohorts with a significant number of subjects, and longer monitoring periods (Derks et al, 2015). There are a relevant number of long-term studies aiming to determine the prevalence of peri-implantitis as well as potential risk indicators or significant predictors (patient age, age of implants, periodontal status, level of oral hygiene) (French et al., 2021; Del Fabbro et al., 2019; Dalago et al., 2017; Mir-Mari et al., 2012; Aguirre-Zorzano et al., 2015; Lee et al., 2017; Atieh et al., 2013; Daubert et al., 2015; Marrone et al., 2013; Derks et al., 2016; Schuldt et al., 2014; Konstantinidis et al., 2015; Costa et al., 2012; Derks and Tomasi, 2015; Wada et al., 2021; Roccuzzo et al., 2014; Roos-Jansaker et al., 2006; Mitrea et al., 2022; Ferreira et al., 2015; Albrektsson et al., 2012). We found that patients' lack of compliance with proper oral hygiene, as well as bruxism, were factors significantly associated with the onset of peri-implantitis. Poor oral hygiene was strongly correlated with the onset of peri-implantitis, while the history of periodontitis was highlighted as a risk indicator for peri-implantitis (Aguirre-Zorzano et al., 2015; Roccuzzo et al., 2014; Derks et al., 2016). The history of periodontitis and the quality of oral hygiene were also proposed as risk factors by other studies (Derks et al., 2016; Konstantinidis et al., 2015; Roos-Jansaker et al., 2006). Significant predictors of peri-implantitis were found in the maxillary implant location (2.98 times higher probability of peri-implantitis when compared to the mandibular area) and the age group < 60 years (Schuldt et al., 2014). The frequency of peri-implantitis increases significantly if the mean follow-up is more than 8 years (Daubert et al., 2015). A positive correlation was detected between peri-implantitis and the parameters age, periodontal history, and the number of missing teeth (Marrone et al., 2013). Increased plaque index increases the probability of peri-implantitis by 1.36 times, while the use of alveolar augmentation techniques of the implant site reduces the risk of peri-implantitis (OR=0.87); the loss of a tooth due to periodontal disease increases the risk of peri-implantitis (OR=1.063) as well as the maxillary location of the implants being associated with an increased probability of peri-implantitis (OR=1.052) (Marrone et al., 2013). The authors of the study concluded that the low level of oral hygiene and active periodontal disease represent the most significant risk factors for the occurrence of peri-implantitis (Marrone et al., 2013). In our study, age group, gender, and implant location were not found as significant predictors of peri-implantitis; this result is confirmed by research that failed to correlate these factors with implant failure (Mitrea et al., 2022). We found that smokers have a 6.11 times higher risk of peri-implantitis when compared to non-smokers. One study reported

that smoking was significantly correlated with peri-implantitis prevalence (Mitrea et al., 2022). Increased prevalence of peri-implantitis was higher in smokers (36.3%) while the maintenance periodontal therapy has a significant role in reducing the risk of peri-implantitis (Atieh et al., 2013). The prevalence of moderate/severe peri-implantitis was higher in patients with fixed implant-prosthetic restorations with follow-up > 9 years (Derks et al., 2016). However, peri-implant pathology is not the only factor that induces marginal bone loss. Other reasons include physiological remodeling after implant insertion, occlusal overload, practitioner experience in surgical and prosthetic stages, the level of oral hygiene, and systemic status (Ferreira et al., 2015; Albrektsson et al., 2012).

In our current study, we found a higher risk of mechanical/technical complications for patients in the age group > 60 years, smokers, and patients with a history of periodontal disease or bruxism. In multivariate analysis, the most significant predictors for mechanical/technical complications were smoking and bruxism. Bredberg et al. (2023) found a significant association between the combination of bruxism and smoking and peri-implant increased marginal bone loss for patients with a minimum 36 months follow-up. Patients who are both bruxers and smokers had significantly greater marginal bone loss when compared to patients who are either bruxers or smokers, or neither (Bredberg et al., 2023). We found that patients with bruxism have a 15.23 times higher risk of mechanical/technical complications when compared to non-bruxers. Chrcanovic et al. (2017) also reported a significantly higher risk of implant failure associated with mechanical/technical complications (OR 2.71) (Chrcanovic et al., 2017). Despite the significant correlation of bruxism with mechanical/technical complications, other risk factors must be considered and analyzed in further studies. Our results regarding the prevalence of mechanical/technical complications are in the range of those reported by literature data (Sailer et al., 2018; Heydecke et al., 2012; Kreissl et al., 2007). We found that age group > 60 yrs., smoking, periodontal history, bone grafting, and bruxism are associated with an increase in the mechanical/technical complications rate. The most frequent mechanical/technical complications reported for implant-supported fixed partial dentures (FPDs) located in posterior areas are as follows: loss of screw access hole material (23.6%), followed by ceramic veneer fracture/chipping (11.8%), and screw loosening (8.4%) (Bardis et al., 2022). Bäumer et al. (2020) found a 19.4% rate of implant technical complications, with abutment/screw loosening being the most common complication (5.3%) (Bäumer et al., 2020). Literature data associated higher rates of mechanical/technical complications with excessive implant loading, bruxism, the length of the implant-prosthetic reconstruction, and a history of repeated complications (Mathieu et al., 2014).

Some limitations of the current study must be considered: retrospective design, patients selected from standard pool of private dental practice, and a homogeneous study group consisting of patients recruited from a single private dental practice.

Conclusions

In univariate models, patients with low-quality oral hygiene and bruxism have an increased risk of peri-implantitis. In multivariate models, significant predictors of peri-implantitis were not identified. Age group > 60 years, smoking, periodontal history, bone grafting, and bruxism are risk factors for the increase of the implant mechanical/technical complications rate. In the multivariate model, bruxism is a significant predictor of mechanical/technical complications.

1.2.3. Oral and Periodontal Risk Factors of Prosthetic Success for 3-Unit Natural Tooth-Supported Bridges versus Implant-Supported Fixed Dental Prostheses

The goals of this study are as follows:

(1) to compare the survival and prosthetic success of metal-ceramic 3-unit teeth- versus implant-supported fixed dental prostheses;

(2) to assess the influence of several factors on the prosthetic success of teeth- or implant-supported FPD.

Materials and method

Study design. Inclusion and exclusion criteria.

The retrospective cohort study was conducted at Clinical Base of Dental Medicine Faculty, University of Medicine and Pharmacy "Grigore T.Popa" Iasi (Romania), and Bardi Clinic (Athens, Greece), between December 2019 and May 2022. The study included 68 posterior edentulous patients (mean age: 61,00 ± 1,325 yr; gender: 20 males, 48 females) treated by one surgeon (P.M.B.) between 2005-2017.

Patients have received 3-unit tooth-supported FPD (Group A- 40 patients) or implant-supported FPD (Group B- 28 patients). The features of the study group (patients, tooth-and implant-supported FPD) were reviewed by one investigator (IC) (Tables XXI and XXII). The study adhered to the ethical values of the Declaration of Helsinki and received approval of ethics committee of U.M.F. "Grigore T.Popa" Iasi (Romania) (Nr.19356). All patients involved in the study received information about the objectives of the research and provided written informed consent.

Inclusion criteria were age > 18 years; 3-unit tooth- or implant-supported FPD with centric pontic; follow-up > 5 years.

Exclusion criteria were decompensated metabolic diseases; non-compliant patients to periodontal maintenance sessions; cantilever design or resin bonded bridges.

Table XXI. Features of study groups per patients (tooth-supported FPD vs. implant-supported FPD)

	Group A (3-unit tooth-supported FPD)	**Group B (3-unit implant-supported FPD)**	**Total**	**Pearson Chi-squared**	**p**
Ns (%)	40 (58,9%)	28 (41,1%)	68(100%)		
Age, m ± SD	57,20 ± 1,597	66,42 ± 1,863	61,00 ± 1,325	-	0,000**
Age group, Ns(%)				11,561	0,001**
40-60 yr	22 (55%)	4 (14,3%)	26(38,2%)		
>60 yr	18 (45%)	24 (85,7%)	42(61,8%)		
Gender, Ns(%)				1,461	0,227
M	14 (35%)	6 (21,4%)	20(29,4%)		
F	26 (65%)	22 (78,6%)	48(70,6%)		
Smoking status, Ns(%)				0,622	0,430
Non-smoker	28 (70%)	22 (78,6%)	50(73,5%)		
Smoker (1-10/day)	12 (30%)	6 (21,4%)	18(26,5%)		
Periodontal disease history, Ns(%)				0,586	0,444
Yes	18 (45%)	10 (35,7%)	28(41,1%)		
No	22 (55%)	18 (64,3%)	40(58,9%)		
Oral hygiene (OHI-S/mPI), Ns(%)				3,631	0,057
0-1	26 (65%)	24 (85,7%)	50(73,5%)		
2-3	14 (35%)	4 (14,3%)	18(26,5%)		

Table XXII. Features of study groups per FPD (tooth-supported FPD vs. implant-supported FPD)

	Group A (tooth-supported FPD)	Group B (implant-supported FPD)	Total	Pearson Chi-squared	p
3-units FPD, Ns(%)	52 (61,9%)	32 (38,1%)	84(100%)		
Follow-up, m ± SD	10,27 ± 0,496	8,656 ± 0,718	9,655 ± 0,417	-	0,060
Follow-up, Ns(%)				7,269	0,007**
5-10 yr	20 (38,5%)	22 (68,75%)	42(50%)		
>10 yr	32 (61,5%)	10 (31,25%)	42(50%)		
Location (MD/MX), Ns(%)				0,182	0,670
MD	38 (73%)	22 (68,75%)	60(71,4%)		
MX	14 (27%)	10 (31,25%)	24(28,6%)		

Table XXIII. Study design (PICO). Components.

Component	Description
Population (P)	Patients with short edentulous span treated either by teeth-supported FPD or implant-supported FPD
Intervention (I)	1. Group A: Tooth-supported FPD. 2. Group B: Implant-supported FPD
Comparison (C)	Inter-groups comparison Group A (Tooth-supported FPD) vs. Group B (Implant-supported FPD)
Outcome (O)	Prosthetic success Risk factors (OR)

Definitions

FPD survival was defined as FPD remaining in situ with or without complications while still functioning (Sailer et al, 2018).

FPD prosthetic success was defined as surviving FPD without biological and technical complications (Sailer et al, 2018).

Biological complications included (Hanif et al, 2011):

- tooth-supported FPD: dental caries, loss of tooth vitality, mobility, pillar tooth loss;
- implant-supported FPD: peri-implantitis or implant loss.

Mechanical/technical complications included (Hanif et al, 2011):

- tooth-supported FPD: tooth fracture, loss of retention, framework fracture, minor or major veneer chipping, occlusal wear, poor marginal adaptation;
- implant-supported FPD: implant fracture, framework fracture, loosening of restoration, loss of screw access hole, veneering fracture/chipping, occlusal wear, poor marginal adaptation.

Collection data

All patients were examined during the yearly regular visit (clinical exam, Rx, CBCT) for FPD status, abutments, surrounding hard and soft tissues as well as patient satisfaction.

The patients' data were collected and entered directly into a database in an SPSS file (SPSS software, version 27, SPSS Inc., Chicago, USA) by one investigator (IC).

The following data was collected:

- demographic parameters: age group (40-60 yr. vs. > 60 yr.), gender;
- oral hygiene (OHI-S index- patients treated with tooth-supported FPD; mPI index- patients treated with implant-supported FPD);
- biological complications of the pillar teeth (tooth-supported FPD) and dental implants (peri-implantitis) (implant-supported FPD);
- mechanical/technical complications of tooth- or implant-supported FPD.

Statistical analysis

Descriptive statistics including frequencies, means and standard deviations were calculated for demographic characteristics and follow-up. Risk factors of the prosthetic success were assessed by chi-square test and OR (Odds Ratio). All tests of significance were evaluated at the 0.05 error level with SPSS v.27.0 (IBM, Armonk, NY, USA).

Variables that showed statistically significant differences in univariate analysis of prosthetic success were introduced into the multivariable logistic regression analysis.

Results

The survival rate of tooth-supported FPD was 100% while survival rate of implant-supported FPD was 87,5% (Table XXIV). The prosthetic success was 69,25% for tooth-supported FPD and 68,75% for implants-supported FPD (Table XXV). The statistical analysis found significant statistical differences between the group of teeth-supported FPD and implant-supported FPD, regarding the rates of survival (p=0,19**) (Table XXIV). The statistical analysis found the absence of significant statistical differences between the group of teeth-supported FPD and implant-supported FPD, regarding the prosthetic success (p= 0,963) (Table XXV).

Table XXIV. Rate of survival (tooth supported FPD vs. implant supported FPD)

Survival, Ns(%)	Group A (tooth-supported FPD)	Group B (implant-supported FPD)	Total	Pearson Chi-pătrat	p
YES	52 (100%)	28 (87,5%)	80 (95,24%)	**6,825**	,019**
NO	0 (0%)	4 (12,5%)	4 (4,76%)		

Table XXV. Rate of prosthetic success (tooth-supported FPD vs. implant-supported FPD)

Prosthetic success, Ns(%)	Group A (tooth-supported FPD)	Group B (implant-supported FPD)	Total	Pearson Chi-pătrat	p
YES	36 (69,25%)	22 (68,75%)	58 (69,05%)	**,002**	**,963**
NO	16 (30,75%)	10 (31,25%)	26 (30,95%)		

Univariate analysis found the absence of statistically significant association between gender, FPD location (maxillary vs. mandible; quadrants), smoking, oral hygiene. However, the prosthetic success of tooth-supported FPD rate was higher for males (81,8%) vs. females (60%), mandible (71,4%) vs. maxillary (68,4%), non-smokers (71,4%) vs. smokers (68,4%), and patients with excellent and good oral hygiene (77,8%) vs. patients with poor oral hygiene (50%).

Chi square test yielded significant statistical differences regarding the prosthetic success of tooth-supported FPD in patients with age >60 yr. (83,3%) comparing to patients in age group 40-60 yr. (57,1%) (p= 0,041*) as well as in patients with no periodontal history (86,7%) comparing to patients with history of periodontal disease (45,5%) (p=0,001**) (Table XXVI).

Univariate analysis found the absence of statistically significant association between age groups, gender, FPD location (maxillary vs. mandible; quadrants), smoking, oral hygiene) and prosthetic success of implant-supported FPD. However, the prosthetic success of implant-supported FPD rate was higher for males (75%) vs. females (66,7%), mandible (80%) vs. maxillary (63,6%), non-smokers (71,4%) vs. smokers (50%), and patients with excellent and good oral hygiene (76,9%) vs. patients with poor oral hygiene (33,3%).

Chi square test yielded significant statistical differences regarding prosthetic success of tooth-supported FPD in patients with no periodontal history (90%) comparing to patients with history of periodontal disease (33,3%) (p=0,002**) (Table XXVII).

In the group of the patients with implant-supported FPD we identified only a single risk factor and therefore the multivariate analysis was not necessary. Multivariate analysis was used only for the group of patients with tooth-supported FPD.

For tooth-supported FPD a binary logistic regression model was constructed to assess the effects of variables identified as being responsible for statistically significant differences in prosthetic failure of the tooth-supported FPD– where only 2 of the identified risk factors were identified. The constructed model was statistically significant (p < .001 – Omnibus Test of Model Coefficients) and explains 43.5% of the variation in prosthetic failure (Nagelkerke R2), correctly classifying 80.8% of cases, compared to 69.2% of cases correctly classified initially, using only the constant, without any of the possible predictors.

Variables that showed statistically significant differences in prosthetic success of tooth-supported FPD were introduced into the multivariable logistic regression analysis. Age group and periodontal history were found predictors of prosthetic success. Compared with patients aged older than 60 years, those aged 40-60 years had worse prosthetic success (OR .093; p=.010*). Patients with periodontal history had significantly less prosthetic success (OR 18,546; p=.001**). Other variables (gender, location, periodontal history, smoking, oral hygiene, follow-up) did not show statistical significance relative to prosthetic success (Table XXVIII).

Table XXVI. Tooth-supported FPD: failure risk factors

Tooth-supported FPD Factors		PROSTHETIC SUCCESS Yes N	Yes %	No N	No %	Total N	Total %	Pearson Chi-squared	Failure risk OR / RR*	Failure risk 95% CI OR / RR*
Location	MD	26	68,4%	12	31,6%	38	100,0%	Chi^2 = ,043	-	-
	MX	10	71,4%	4	28,6%	14	100,0%	p = 1,000		
Location	1	2	50,0%	2	50,0%	4	100,0%	Chi^2 = 1,276	-	-
(quadrant)	2	8	80,0%	2	20,0%	10	100,0%	p = ,735		
	3	8	66,7%	4	33,3%	12	100,0%			
	4	18	69,2%	8	30,8%	26	100,0%			
Gender	F	18	60,0%	12	40,0%	30	100,0%	Chi^2 = 2,836	-	-
	M	18	81,8%	4	18,2%	22	100,0%	p = ,092		
Age	>60	20	83,3%	4	16,7%	24	100,0%	Chi^2 = 4,161	,267	,072 ÷ ,987
group	40-60	16	57,1%	12	42,9%	28	100,0%	p = ,041*		
Smoker	Yes	10	71,4%	4	28,6%	14	100,0%	Chi^2 = ,043	-	-
(1-10/day)	No	26	68,4%	12	31,6%	38	100,0%	p = 1,000		
Periodontal	Yes	10	45,5%	12	54,5%	22	100,0%	Chi^2 = 10,120	7,800	2,030 ÷ 29,975
history	No	26	86,7%	4	13,3%	30	100,0%	p = ,001**		
Oral hygiene (OHI-S)	0-3.0	28	77,8%	8	22,2%	36	100,0%	Chi^2 = 4,012	-	-
	3.1-6.0	8	50,0%	8	50,0%	16	100,0%	p = ,058		
Total		36	69,2%	16	30,8%	52	100,0%			

Table XXVII. Implant-supported FPD: failure risk factors

Implant-supported FPD Factors		PROSTHETIC SUCCESS Yes N	Yes %	No N	No %	Total N	Total %	Pearson Chi-squared	Failure risk OR / RR*	Failure risk 95% CI OR / RR*
Location	MD	14	63,6%	8	36,4%	22	100,0%	Chi^2 = ,857	-	-

Location (quadrant)	MX	8	80,0%	2	20,0%	10	100,0%	p = ,440		
	1	2	50,0%	2	50,0%	4	100,0%	Chi^2 = 3,762	-	-
	2	6	100,0%		0,0%	6	100,0%	p = ,288		
	3	6	60,0%	4	40,0%	10	100,0%			
	4	8	66,7%	4	33,3%	12	100,0%			
Gender	F	16	66,7%	8	33,3%	24	100,0%	Chi^2 = ,194	-	-
	M	6	75,0%	2	25,0%	8	100,0%	p = 1,000		
Age group	>60	20	71,4%	8	28,6%	28	100,0%	Chi^2 = ,748	-	-
	40-60	2	50,0%	2	50,0%	4	100,0%	p = ,572		
Smoking	Yes	2	50,0%	2	50,0%	4	100,0%	Chi^2 = ,748	-	-
	No	20	71,4%	8	28,6%	28	100,0%	p = ,572		
Periodontal	Yes	4	33,3%	8	66,7%	12	100,0%	Chi^2 = 11,210	18,000	2,717 ÷ 119,23
History	No	18	90,0%	2	10,0%	20	100,0%	p = ,002**		
Hygiene (mPI)	0-1	20	76,9%	6	23,1%	26	100,0%	Chi^2 = 4,311		
	2-3	2	33,3%	4	66,7%	6	100,0%	p = ,060		
Total		22	68,8%	10	31,3%	32	100,0%			

Table XXVIII. Multivariate analysis regarding
significant risk factors of prosthetic success for tooth-supported FPD

	Multivariate analysis– binomial logistic regression			
	Coeff. of model equation	p-Value	OR	95% CI OR
Age >60 ani	-2,375	,010*	,093	,015 ÷ ,570
Periodontal history	2,920	,001**	18,546	3,120 ÷ 110,239
Constant	-1,346	,017*	,260	

Discussions

The decision-making by dental professionals can be influenced by their biases, interests, and experiences; at the same time, data received from retrospective and prospective studies is considered an indirect experience able to affect decision-making processes (Lee et al., 2016). The treatment decisions as well as the selection of the pillar teeth and implant site abutments for fixed partial denture to patients with short span edentulousness should be based on scientific evidence provided by scientific dental research. In the decision-making process the practitioners must consider that the teeth with questionable prognosis and treatment requirements can reduce the prosthetic success of the tooth-supported FPD (Pjetursson and Heimisdottir, 2018; Sailer et al., 2018).

Literature data reports inferior survival and success rates of implant-supported FPD compared to the tooth-fixed partial dentures (Hanif et al., 2017; Zitzmann et al., 2009; Pol et al., 2018; Cristea et al., 2022). The longevity of the implant-supported FPD can be significantly decreased when biological complications and/or mechanical/technical complications occur (Hanif et al., 2017; Pjetursson et al., 2007). However, the treatment of posterior short edentulousness span by using tooth-supported FPD involves the preparation of the future teeth selected as bridge pillars, a procedure that makes these teeth more prone to the accumulation of bacterial plaque, tooth decay, periodontal disease, or periapical pathology in endodontically treated teeth (Zitzmann et al., 2009).

In this context, our research aimed to respond to a challenging issue for dentists discussing benefits and limits of the fixed prosthetic therapeutic approaches to patients with

posterior short span edentulousness. Considering survival rates of 3-units FPD, literature data reported 99% for tooth-supported FPD vs. 98,7% for implant-supported FPD in a study with follow-up 3,5 years (Pjetursson et al., 2007) and lower survival rates for 11 months higher follow-up (91,7% survival rate for tooth-supported FPD vs. 100% survival rate for implant-supported FPD) (Hanif et al., 2017). Higher mean follow-up (10,27 ± 0,496 years for tooth-supported FPD; 8,656 ± 0,718 years for implant-supported FPD) is an important parameter that contributed to the lower survival rates reported in our study (90,6% for tooth-supported FPD; 93,6% for implant-supported FPD). This result supports data reported by a study that highlighted the gradually decrease of survival of the teeth- vs. implant-supported FPD (Bart et al., 2012). Bart et al. (2012) reported survival rates of 90.4% at 10 years and 80.5% at 15 years for FPD supported either by natural tooth abutments or implants (Bart et al., 2012). Hawthan et al (2022) reported cumulative survival rates of 90.1% and 77.6% at 5- and 10-years follow-up, with significantly decreased rates at 67.9% and 52.1% after 15 and 20 years, respectively (Hawthan et al., 2022). However, the mean survival rates both for tooth- and implant-supported FPD found in our study are in range with those provided by studies based on 2-4 units FPD and similar mean follow-up. Tallarico et al. (2018) reported 89,2% survival rate of tooth-supported FPD and 86.7% survival rate of implant-supported FPD for 10-year follow-up (Tallarico et al., 2018). In our study, the prosthetic success rates were 63,6% for tooth-supported FPD and 75% for implant-supported FPD. These results were similar with other data reported by research group focused on FPDs. One study reported for 3-unit FPD, 91,7% prosthetic success of tooth-supported FPD and 87,5% prosthetic success of implant-supported FPD (Hanif et al., 2017). A systematic review also reported, at 10-year follow-up, 89,2% prosthetic success for tooth-supported FPD and 86,7% prosthetic success for implant-supported FPD (Tallarico et al., 2018).

Second part of the personal study highlighted several factors that have the potential to lead to FPD failures considering the limited availability of data regarding variables influencing tooth- or implant-supported complications (demographic parameters, location, periodontal history, smoking, bruxism, materials, status of the opposing arch) in patients with short edentulous span. The results of the present study suggest that the prosthetic success of both teeth- and implant-supported FPD is not significantly influenced by factors such as gender, location, smoking or oral hygiene. Literature data also reports that gender does not influence the prosthetic success of the tooth-supported FPD (Hawthan et al., 2022) and implant-supported FPD (Tallarico et al., 2018). The mandible location increases the failure rate, but without statistical significance, when compared to maxillary tooth-supported FPD (Hawthan et al., 2022). In our study, smoking was not significantly associated with prosthetic failure but failure rates are higher in smokers when compared to non-smokers both in tooth- and implant-supported FPD. Smoking changes the periodontal microbiota, affects the immune system, increases the incidence and progression of periodontitis while the periodontal disease is associated with higher risk of tooth loss (Leite et al., 2018; Souto et al., 2019). Smoking was highlighted as the main reason that decreased the survival rate of the tooth-support FPD failure (Hawthan et al., 2022). Also, smoking significantly decreases the prosthetic success of the implant-supported FPD for patients with a history of generalized aggressive periodontitis (De Boever et al., 2009). For patients with tooth-supported FPD, the failure rate was higher when oral hygiene was poor (OHI-S 3.1-6) when compared with patients with excellent or OHI-S 0-3. Poor oral hygiene is an associated risk indicator for implant-supported FPD (Takamoli et al., 2021). In our study, the age group influenced significantly the prosthetic success only in tooth-supported FPD. Patients more compliant to recall and maintenance sessions have better control of dental caries and periodontal disease and thus a lower rate of biological complications and prosthetic failures (Bidra et al., 2016). We also found that patients with a periodontal history had significantly lower rates of prosthetic success both in tooth- and implant-supported FPD

when compared with patients without a history of periodontal pathology. A systematic review also reported poorer survival rate and significantly higher risk of peri-implantitis for patients with implant-supported FPD (Carra et al., 2022). The incidence of peri-implantitis and peri-implant marginal bone loss increases significantly in patients with previous tooth loss due to periodontal disease (Schou et al., 2006; Schou, 2008). However, implant-prosthetic therapy in periodontitis-susceptible patients is not contraindicated if these patients are compliant with adequate infection control in individualized maintenance sessions (Carra et al., 2022). Regarding the group of tooth-supported FPD, in our study, the pillar teeth were both vital and endodontically treated. Though some studies reported non-vital pillar teeth as a risk factor in reduced dentition treated with FPD (Patel et al., 2014), a research group reported the absence of any significant influence of the pillar tooth vitality on the occurrence of tooth-supported FPD failures (Hawthan et al., 2022).

The differences in criteria systems of success and failure as well as different methods of evaluation used across various studies limit reliable interpretations of data and direct comparison between studies reports (Patel et al., 2014; Needleman et al., 2012). Moreover, some limits specific to the retrospective studies must be mentioned such as: absence of a standardized operatory procedure for all patients, possible lack of the data collected from patients' files, differences in mean follow-up between study groups, the absence of radiographic comparisons regarding marginal bone loss around pillar teeth and dental implants.

Conclusions

Similar rates of prosthetic success were recorded for tooth-supported FPD and implant-supported FPD. The prosthetic success of the tooth- and implant-supported FPD was not significantly influenced by factors such as gender, location, smoking or oral hygiene. Tooth-supported FPD in age group > 60 years have significantly higher prosthetic success when compared with age group 40-60 years. The patients with history of periodontal disease have significantly lower prosthetic success both in tooth- and implant-supported FPD when compared with patients without periodontal history.

1.3. MANAGEMENT OF SURGICAL AND IMPLANT-PROSTHETIC STAGES BY USING DIGITAL TOOLS AND TECHNIQUES

State of art

Digital expert systems are implemented successfully in the analysis and planning of treatments in the surgical and prosthetic stages of the implant-prosthetic therapy . New technologies are being created at a quick rate in the field of dentistry, which may assist a dentist in many ways. The benefits include improved visualisation potential, shorter operating time, more effective patient consultation, and more hopeful treatment outcomes. In implant-prosthetic therapy, these software applications represent necessary adjuvant tools in optimizing therapeutic decisions regarding the pro-implant and implant stages as well as in creating a therapeutic planning algorithm. The combined use of clinical, paraclinical and computerized examination allows the planning of specific prosthetic interventions at the level of dento-periodontal and muco- osseous support to correct negative clinical- biological indications, and to optimize the biomechanics of implant-prosthetic restorations (Forna, 2008).

Various software applications can be used to as data recording and databases and while expert systems (e.g. Prodent, Neo-Tech, Romania) can calculate biological indices and can recommend optimal treatment solutions both for pro-implant surgical procedures and

prosthetic stage. post-implant stage, respectively the recommendation of an optimal prosthetic solution. These applications are also useful in monitoring changes related to the biological components of the stomatognathic system in postimplant stage. PRODENT INDICI software application was used in the Faculty of Dentistry, UMF "Grigore T.Popa", Iasi (Romania) in studies that investigated dental and periodontal indices, the quality of mucous and bone support, occlusal and intermaxillary relations, in groups of partially edentulous patients demanding implant-prosthetic rehabilitation (Forna et al, 2017; Forna et al, 2018). Also, a research group highlighted the use of the tools of digital assessment combined with classic techniques to allow the dental practitioners more control over the implant treatment plan by creating ideal, virtual restorations and managing implant positions based on simplified, cost-effective techniques (Scherer, 2014). The limits of the use of digital systems are related to the need to develop an adequate planning protocol that includes appropriate acquisition/data manipulation, appropriate use of software tools for interpretation, and appropriate application of such systems during implant surgery (Mora et al, 2014).

A number of software applications in the proimplant stage are highlighted, including recognition of the site of implant surgery (dynamic viewing in all spatial planes), the possibility of pivoting implants in the mesio-distal, vestibulo-palatine / lingual, corono -apically, the possibility of choosing implants from the database in relation to the available bone volume (measured in the planning stage), the possibility of identifying anatomical obstacles, the possibility of determining peri-implant bone density, the possibility of determining the volume of bone grafts required in case of deficient bone field, management of implant relationships with adjacent structures (relationships with anatomical structures, angulation, inter-implant distance), the designing of the prosthetic project (Davarpanah et al, 2011).

New digital techniques based on CBCT images processing are introduced in the modern dentistry to optimize the implant-prosthetic planning (pro-implant and implant stage), to increase the accuracy of the dental implant positioning, and to improve the design of the future implant-prosthetic restoration. A review outlined the benefits of using CBCT technology for dental implant applications for increased accuracy of clinical decisions and avoidance of potential surgical and restorative complications (Ganz, 2011). The digital analysis of CBCT images has applications especially in endodontics, implantology and orthodontic therapy. In implant-prosthetic therapy, software application are used for the measurements of height and width of the alveolar bone, the measurement of osteodensity as well as for the visualization and evaluation of the distances to the tissues and areas (sinus, mandibular canal) that must be protected during surgical implant proceduresExpert applications for the assessment of mucosal and bone support, planning of bone addition procedures and positioning of dental implants laid the foundations of digital implantology (Implant 3D, Universe; NobleGuide, Nobel Biocare; Digital Smile Design, DSD; SimPlant, Dental Materialize; Virtual Implant Placement, BioHorizons; ImplantMaster, iDent; Implant 3D, Media Lab; EasyGuide, Keystone Dental).

The diagnostic and treatment planning stages plays a crucial role in the proper dental implants positioning in order to obtain aesthetic and functional results satisfactory for patients demanding implant-prosthetic therapy. Accurate implant positioning is esential in decreasing the post-implant complications and in ensuring high success rate of treatment.

Multiple factors can influence the actual implant position in conventional surgical approach (2D radiographs and freehand implant placement). A retrospective study revealed that the accuracy of freehand implant placement is influenced by factors such as adjacent tooth, implant quadrant, and location of the implant site, while the number of missing teeth does not influence amplitude of the angular and linear deviations (Tang et al, 2019). Freehand implant placement has high level of deviation between the planned and real implant positions in relation to anatomical conditions and oral surgeon/implantologist experience. 3D linear deviations between planned and postoperative implant positions were 1.22 ± 0.63 mm at the

entrance point (implant shoulder), 1.91 ± 1.17 mm at the apical point, while mean angular deviation was 7.93 ± 5.56° (Tang et al, 2019). Schnutenhaus et al (2021) reported mean values as follows: angular deviation 8.7 ± 4.8◦, deviation at the implant shoulder 1.62 ± 0.87 mm, apico-coronal deviation 0.95 ± 0.61 mm. Considering these data, freehand implant procedures can lead to prosthetic complications when the implant exit point is not properly located or if the implants are inserted with a high angular deviation (Schnutenhaus et al, 2021).

In order to minimize errors in implant placement, the implantologists and oral surgeons must consider various anatomical and prosthetic parameters including alveolar bone and anatomical restrictions (Diguardio et al, 2023). The use of implant planning software allows the simulation of the virtual implants by construction of a 3D model of the future implant surgical guide, which will be used in the implant surgery stage (Diguardio et al, 2023). Computer-guided implant placement is especially recommended in implant-prosthetic restorations planned and placed during implant placement, while an accurate implant placement is difficult to perform with the freehand method (Cattoni et al, 2021).

Virtual planning of future implants position allows immediate prosthetic loading with the decrease of surgical times, increase of the patients' comfort (Tahmaseb et al, 2014) and predictable surgical results (Hämmerlle et al, 2009). Most of research of this field of dentistry revealed that computer-aided implant surgery have high accuracy rates in terms of implant position, and angle, with significant reduction of intraoperative surgical complications and positioning errors of implants thus decreasing the failure risk in immediate-load restoration techniques (Gargallo-Albiol et al, 2019).

The amplitude of linear and angular implant deviations is influenced by multiple factors such as edentulous space type, type of support (teeth, oral mucosa, alveolarbone), number of templates, use of fixation pins, location (maxillary/mandible), surgical guide manufacturing technique, guiding system (static/dinamic), guided implant surgical technique (Sigcho et al, 2019; Van Assche et al, 2012).

Digital protocol of implant placement in partially edentulous patients has good implant survival rates, similar or better when compared to conventional protocols as well as decreased pain and discomfort in the immediate postoperative period (Hultin et al, 2012). Arisan et al (2013) revealed that computer-aided implant placement methods decrease the occurrence of implant positioning errors frequently associated with the freehand method especially when mucosa-supported stereolithographic surgical guides are used in suitable patients. When freehand implant placement was used, the risk of insufficient interimplant distance increases 1,42 times, improper parallelism increases 1,24 times comparing to computer-aided implant placement; also, significant higher statistical probability of positioning error was determined for the freehand method, when compared to implants placement with mucosa-supported guides (Arisan et al, 2013). According to a systematic review, the implant failure rate is almost 3 times lower (2.25%) in guided implant placement when compared to free-hand implant placement (6.42%) (Abdelhay et al, 2021). At 1-year follow-up, no significant differences were noted between groups of computer-guided implant placement and freehand implant placement. The mean marginal bone loss was 0.04 mm for the digital protocol and 0.01 mm for the conventional protocol group, while the mean pocket probing depth was 2.81 mm for the computer-guided group, and 2.50 mm for the conventional implant protocol group (Vercruyssen et al, 2014). A randomized controlled clinical trial evaluated compared clinical and radiological outcomes of guided and freehand implant placement after 3 years of follow-up. It was reported the absence of significant statistical differences at three years of loading between the mean marginal bone loss for the guided surgery group (0.7 ±1.3 mm) and the control group (0.5 ±0.6 mm), while the mean pocket probing depth was 3.0 ±1.3 mm for the

computer-guided group and 2.6 ±1.0 mm for the conventional group, with absence of significant differences (Bernard et al, 2019).

One research groups highlighted the absence of statistically significant differences between freehand implant placement and digital protocol for implant survival and implant success/failure rate with the exception of higher postoperative surgical pain and swelling at conventionally treated patients (Tallarico et al, 2018). Five years after loading, the mean marginal bone loss was 0.4 mm less in the computer-guided group than in the freehand group; patients self-reported statistically signficant higher post-surgical pain and swelling in patients in the freehand group. However, number of sessions and number of days from patient's recruitment to delivery of the definitive prosthesis, and the surgical and prosthetic complication rates, were not statistically significant different between freehand and computer-guided implant placement groups (Tallarico et al, 2018). A systematic review of literature revealed the absence of significant statistical differences between computer-guided implant surgery and freehand implant surgery related to the marginal bone loss (mean difference -0.11mm), mechanical complications, biological complications, and implant survival rate (Yogui et al, 2021). A comparison between computer-aided implant placement group and conventional implant stage (2D radiographs and freehand placement) reported the absence of significant differences related to quality-of-life parameters during and after surgery between groups, but statistical tests of patient-related outcome measures evaluated by questionnaires highlighted a patients' preference for digital protocols (Sancho-Puchades et al, 2019). The computer-aided implant placement is more accurate than the laboratory guide with respect to angular error and has significantly higher accuracy both in angular deviation and lateral deviation when compared to freehand implant placement (Chen et al, 2018).

3D Navigation Systems (i.e., Robodent, GmBh, Germany) are systems that use augmented reality. They assist dental surgeons and implantology specialists by providing images of operative sites that is then modified from a data source (Wang etal, 2017). Augmented Reality is used to assist the future positioning of the dental implants as to reduce the risk of failure, the time of execution and the costs. Dental implant placement guided by augmented reality method had better accuracy and lower working time, than the traditional 2D image navigation method. (Jiang et al, 2018). Augmented reality can also be used in orthognathic surgery allowing partial visual immersion employing a head-mounted display (Ayoub et al, 2019). 3D Navigation Systems has many applications both in planning and execution stages. Apart from planning stage, 3D navigation systems are especially useful in the navigation and the insertion of the implants, allowing the preview and order of the surgical guide as well as high accuracy during implant procedures, by interface guidance of the dental professionals. The advantages of the 3D navigation systems in implant stage are as follows:

- real-time visualization of the depth and angle of the burr;
- fully automatic recording of the patient and of the procedures applied;
- one software for planning and navigation;
- extensive collection of generic implants and implants;
- measurement and analysis of bone density.

Digital impression based on intraoral scanners is used in the modern dentistry due to benefits as follows: accuracy, lower working time, reliability with clinical workflows, higher acceptance from patients. Restorations manufactured with currently digital impression systems and intraoral scanners have clinically acceptable ranges of marginal gap in direct and indirect procedures (Takeuchi et al, 2018). A research proved higher accuracy and decreased working time for digital impression regarding the marginal and internal fit of CAD/CAM fabricated zirconia crowns and three-unit fixed dental prostheses, when compared with conventional procedure (Ahrberg et al, 2016).

The use of computers in the design and fabrication of dental prosthesis and instruments is now widespread. The fast growth of dental CAD/CAM technology may be traced back to the improvement of dental materials and the evolution of computer science. Chairside and laboratory CAD/CAM technologies have come a long way in the last couple of decades. In CAD/CAM systems, computers are utilized for data collection, product design, and manufacturing. These methods have been in use for quite some time in manufacturing, but it wasn't until the 1980s that they became practical for use in dentistry (Beldiman et al., 2022). The three parts of a CAD/CAM system are as follows:

- A scanner or other device used in digitization that converts physical item geometry into digital data for use in computerized processing.
- Information-handling applications.
- A method of making anything from a digital data collection (Spitznagel et al., 2018).

These days, a lot of porcelain, composite resin, and metal blocks are used using CAD/CAM technologies to make fixed prosthetic restorations. To avoid degradations like residual strain caused by the effects of processing and to provide reproducible processing, CAD/CAM technology is used to not only mill restorations into the desired shape but also to ensure the dental devices are of the highest quality possible by designing optimal shapes based on the material's characteristics. Unlike traditional powder build-up and baked porcelain goods, which typically include internal defects, milled items from a prefabricated ceramic block, the quality of which has been checked previously by the maker, have essentially no internal faults (Spitznagel et al., 2018).

Data collected during processing can be kept and monitored for as long as the device is in use. These qualities have not been accessible with the typical manufacturing techniques that are now in use, even though evidence is needed to estimate the prognosis of restorations over the functioning time. Because dental restorative and prosthetic devices made using CAD/CAM technology will need to work as an integral part of the body for longer as a result of the aging of the population, quality control will become increasingly important in the years to come.

Treatment of maxillofacial anomalies and procedures make substantial use of CAD/CAM methods and rapid prototyping (Bibb et al., 2006). 3D printing (Han et al., 2010) and digitally gathering 3D data from a patient's cast, establishing the insertion path, and defining the form of the framework's components are also employed in the design and production of removable partial denture metal frameworks. Model information is saved as stereolithography files and then used to make quick prototypes. Selective laser melting is then used to create the metal framework for the removable partial dentures (Al Mortadi et al., 2012). Metal-free dental materials have become more widely used thanks to the development of intraoral scanners (IOSs) and other advanced fabrication processes like CAD/CAM technologies and 3D printing, which have made it possible to replace traditional metal frameworks with more biomimetic and aesthetically pleasing alternatives (Alghazzawi, 2016; Colombo et al., 2017). Additionally, dentists have been able to reinterpret the operational technique to be less invasive thanks to the exceptional mechanical qualities of these new-generation materials. The Digital Smile Design favors the planning of prosthetic therapy and the design of the future prosthetic work in accordance with the aesthetic principles and the requirements of the patients, based on a motivational mock-up.

Literature data demonstrate the increase in the long-term success rate in digital-assisted implant-prosthetic therapy and justify the widespread expansion of the use of digital applications in current contemporary dental practice. Apart from major advantages (reliable decisions, accurate diagnostic and execution, procedures standardization), the dental professionals that intent to use these systems in their practice must consider some disadvantages and limits: the necessity of proper training period; complex systems and mechanisms; higher acquisition and maintenance costs. As the dental professionals are yet

reluctant to implement on large scale AI based digital systems in dentistry, it should be considered systems that combine both AI and human elements for easy processing of data collection and categorization becomes easy as well as for preservation of the human aspects of dental care (Tandon et al, 2020).

Research groups that investigate the benefits and limits of the computer planning in the implant-prosthetic therapy have objectives as follows:

- Introduction of an investigation algorithm, with real optimal relevance, in approaching a therapy as complex and correct as possible;
- Detection of the changes that occur during the application of implants and establishing parameters that can influence the choice of implant technique and the evolution of mucosal and bone support;
- The possibilities to use specific software, as a method for predicting and evaluating the evolution of the elements in the oral cavity;
- The choice of the therapeutic variants according to the results obtained from computerized planning;
- Permanent evaluation of the quality of the therapeutic act with the help of computerized quantification.

The conclusions drawn from literature data are as follows:

- Expert systems and 3D navigation systems can be used to optimize the alveolar bone rehabilitation, the implants positioning (associated to CAD-CAM manufacturing of the surgical guide), the periodontal procedures related to esthetic outcome, the design of the future prosthetic structure as well as the biomechanical factors.
- The combination of classic procedures and digital techniques increases significantly the long-term success of the implant-prosthetic therapy.
- Three-dimensional visualizations associated with a suitable computer application can perform a very accurate simulation of the application of the dental implants. Pre- and pro-prosthetic computer planning also plays an important role in reducing the risk of accidents and complications.
- The challenge for dental professionals is to learn the digital technologies and to integrate them into the current daily practice.

Publications on this topic:

1.Forna Norina, Costuleanu Marcel, Chetruş Viorica, **Agop-Forna Doriana**, Sălceanu Mihaela, Curcă Răzvan, Toader Bianca, Morhan Sebastian, Chirilă Adriana Măriuca, Lazaruc Dana. CBCT study regarding the gain of alveolar bone following guided bone regeneration with various grafting materials. *Rom.J.Med.Dent*.2019; 8(4): 60-70.

2.Norina Forna, Andrei Kozma, Claudiu Topoliceanu, Lorenza Donea, **Doriana Agop-Forna**. Digital Systems in Medical Science and Modern Dentistry. *Annals Series on Biological Sciences (Academy of Romanian Scientists)* 2021; 10(2): 38-47.

3.Dana Gabriela Budală, Zinovia Surlari, Florinel Cosmin Bida, Alice Arina Ciocan-Pendefunda, **Doriana Agop-Forna**. Digital instruments in dentistry-back to the future. *Rom. J. Oral Rehabil* 2023; 15(2): 310-318. FI=0,7

4.Cosmin Cretu, **Doriana Agop-Forna**, Dimitris Bardi, Ioana Cristea, Cristina Dascãlu, Siminiuc Petruţa, Norina Forna. Accuracy of computer-aided implant surgery. *Rom. J. Oral Rehabil* 2023; 15(2) FI=0,7

5.**Doriana Agop-Forna,** Cosmin Creţu, Norin Forna, Cristina Dascãlu, Claudiu Topoliceanu, Ggholamreza Shokrae, Stratulat Matei Dana, Norina Forna**.** Dental practice management software in the assessment of treatment needs of edentulous patients candidate to implant-prosthetic therapy. *Rom. J. Oral Rehabil* 2023; 15(2) FI=0,7

1.3.1. CBCT study regarding the gain of alveolar bone following guided bone regeneration with various grafting materials

The aim of study was to assess, in CBCT-based software application, the bone volum gain in guided bone regeneration techniques using various grafting materials.

Materials and method

In the study were included 68 edentulous patients candidates to dental implant (age 30-65; mean age 48,2); the patients were planned for pro-implant procedures by alveolar augmentation and guided tissues regeneration techniques with delayed implantation (6-8 months). The surgical procedures were performed by three oral surgeons with similar training and experience. The patients were selected from Clinical Base of Dental Education, Faculty of Dental Medicine, U.M.F. ″Gr.T.Popa″ Iasi and in private dental practice. The informed consent was obtained.

In relation with the selected addition bone materials, the patients were randomly divided in three study groups:

Study group 1 (23 patients):

- Xenograft OsteoBiol (Tecnoss) OsteoBiol properties: prehidrated cortical bone (90%) enriched with collagen (10%).

Study group 2 (21 patients):

- Xenograft SmartBone (IBI)

SmartBone properties: xenograft;

- bovine bone associated with biodegradable polymers (increase resistance to externalagents and prevent early resorption).

Study group 3 (24 patients):

- Xenograft Hypro-Oss (BioImplon) associated with PRGF (Endoret) (http://bti-biotechnologyinstitute.com/us/regenerative-medicine/endoret/).

The measurements of the alveolar bone parameters were performed using CBCT, both preoperatory and at 3-4 months postoperatory, with multiple plans images capturing and lower radiations dose than classic CT.

Software OnDemand3D was used to reconstruct DICOM data in tridimensional image of maxillary and mandibula, image that can be tridimensionally analysed, following the divisation in 0,5mm sections.

Based on 3D images, a software analysis can study accurately the maxillary and mandibular bone (volume bone, density bone, pathological areas).

Also the virtual planning of the implant treatment can be performed, the bone density around future implants or around areas with planned alveolar augmentation

The patients were investigated with CBCT (Promax 3D Mid, Planmeca Oy, Finlanda). The stages (bone parameters measuring) are as follows:

- reorientation of images accordingly to reference treated tissues areas;
- selection of bone parameters;
- CT parameters setting (1mm sections);
- - bidimensional osteodensitometry 2D for the selected section (Hounsfield units- HU).

Results

CBCT aspects of mucosal and bone support as well as the values of the bone parameters (osteodensity, height, width) are presented in figures 3.a-c.

Pre- operatory, the height mean values were 5,24mm for OsteoBiol group, 5,42mm for SmartBone group, and 5,15mm for Hypro- Oss/PRGF group.Post-operatory, the height mean values were 13,79mm for OsteoBiol group, 15,25mm for SmartBone group, and 16,43mm for Hypro-Oss/PRGF group.Pre-operatory, the width mean values were 5,73mm for OsteoBiol group, 6,83mm for SmartBone group, 6,35mm for Hypro-Oss/PRGF group. Post-operatory, the mean values of bone width were 7,69mm for OsteoBiol group, 8,66mm for SmartBone group, 8,65mm for Hypro- Oss/PRGF group. Pre-operatory, the mean values of osteodensity were 342,5 HU for OsteoBiol group, 442,06 HU for SmartBone group, and 423,34 HU for Hypro-Oss/PRGF group. Post-operatory, the mean values of osteodensity were 522,5 HU for OsteoBiol group, 666,56 HU for SmartBone group, and 574,73 HU for Hypro-Oss/PRGF group.The mean values of bone gain (height) were 8,55mm for OsteoBiol group, 9,83mm for SmartBone group, and 11,28mm for Hypro-Oss/PRGF group. The mean values of bone gain (horizontal plan) were 7,69mm for OsteoBiol group, 8,66mm for SmartBone group, and 8,65mm for Hypro-Oss/PRGF group. The mean values of osteodensity gain were 180 HU for OsteoBiol group,197,5 HU for SmartBone group, and 151,39 HU for Hypro-Oss/PRGF group.

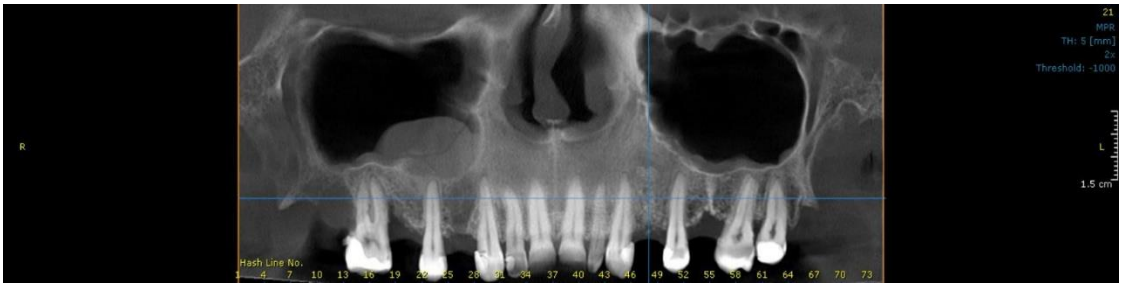
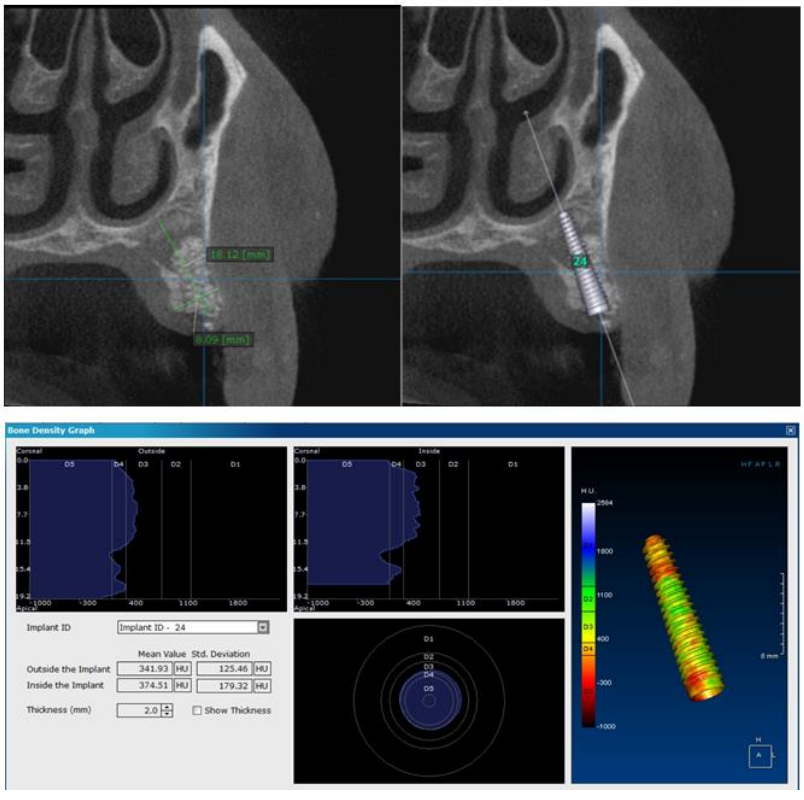


Fig. 3.a. Patient PH, age 38. Post-adition aspect 2.4.
(alveolar augmentation using xenograft Hypro-Oss and PRGF)



Figures 3.b-c. Post-adition parameters situs 2.4. (height, width, osteodensity)

Discussions

The personal study is relevant for the research field considering the low number of studies (9%) focused on the analysis of bone volum gain using CBCT images, in the pro-implant guided tissues regeneration techniques (Glavina et al, 2017).

The tissues graft materials used in the personal research are from xenografts category and are recommended by producers as safe, effective and biocompatible in the mucosal and bone rehabilitation procedures. OsteoBiol (Tecnoss) has a novel microporous structure that facilitates the formation of new bone, accelerates the bone regeneration processes but also is a material with progressive resorption. Due to its osteoconductivity the material preserves the bone shape and volume. Due to collagen content the material favourise the formation of clot and the invasion of the bone defect area with mesenchymal cells implied in the regeneration processes. Xenograft SmartBone (IBI) is a xenograft with additional polymers that ensure cells attachments hydrophilic properties. The materials has high strenght and a favourable microporous structure that ensure osseointegration and cells viability. Xenograft Hypro-Oss (BioImplon) is an innovative material produced by lyophilisation that allows the extension of the macro/microporous surface of the bone particles, high biocompatibility and aphinity for the new bone.Our data regarding bone parameters (height, density) sustain the literature data published by authors focused on guided tissues regeneration techniques in the pro- implant stage (Sagheb et al, 2017; Sârbu et al, 2016; Pieri et al, 2008; Aghaloo & Moy, 2007). Troeltzsch et al (2016) obtained for addition by xenografts a mean value of bone width gain 4.5 ± 1.0 mm, and vertical bone gain 3.7 ± 1.4 mm. Regarding the association of xenografts and PRF, Sagheb et al. (2017) determined a mean width bone gain of 5,5+/-1,9mm, and vertical bone gain of 6,5 +/-1,7 mm (15). Also, Torres et al. (2010), using xenografts associated with PRF, found mean width bone gain of 3,3 +/- 0,2 mm, and mean vertical bone augmentation of 3,9 +/-0,2 mm. The literature data demonstrate that xenograft materials change the osteodensity in the target area from 200HU to 1000 HU.The comparisons of the mean values of the vertical bone gain between the study groups, showed that bone reconstruction with xenograft associated with PRGF is an effective technique and demonstrates the biological properties of plasma rich in growth factors (Torres et al, 2010; Miyamoto et al, 2012; Li et al, 2013; Kawase et al, 2015).

Conclusions

- CBCT-based software application can determine horisontal and vertical alveolar bone gain as well as the increase of osteodensity following guided bone regeneration techniques.

- The highest mean values for parameter bone height (11,28 mm), in the alveolar augmentation procedures, were recorded in the study group that combined xenograft Hypro-Oss and PRGF, followed by xenograft SmartBone group (9,83 mm), and allogenuous material OsteoBiol (8,55 mm).

- The highest mean values for parameter bone width (2,00 mm), in the alveolar augmentation procedures, were recorded in the study group that combined xenograft Hypro-Oss and PRGF, followed by allogenuous material OsteoBiol group (1,96 mm), and xenograft OsteoBiol (1,83 mm).

- The changes of osteodensity, in the alveolar augmentation procedures, were highest in the xenograft SmartBone group (197,5HU) and allogenuous material OsteoBiol group (180HU), and the lowest osteodensity chages were recorded Hypro-Oss & PRGF test group (151,39HU).

1.3.2. Accuracy of computer-aided implant surgery

Aim of study was to assess the linear and angular discrepancies between planned and surgically placed implants using a dental-support 3D printed surgical guide.

Materials and method

The study was approved by University of Medicine and Pharmacy Grigore T.Popa Iasi (Romania) (289/10.04.2023). 13 partially patients with edentulousness in the posterior maxillary and/or mandibular areas were included in study. 20 implants were inserted. All patients were informed about study goals and signed informed consent.

Inclusion and exclusion criteria for patients in study group are exposed further. Inclusion criteria: age over 18 years, edentulous posterior maxillary/mandibular areas for more than 3 months, upper opening of the mouth wider than 50 mm, sufficient alveolar bone of implant sites, good general health. Exclusion criteria: Physical or psychological (disorders cardiac disease, chemotherapy, radiotherapy, bisphosphonate therapy, pregnancy, asthmatic problems, decompensated diabetes), heavy smoking (over 10 cigarettes/day). The stages of treatment protocol for computer-guided implant surgery are exposed further:

- Pre-operative Cone-beam computed tomography (CBCT) (Galileos Comfort Plus, Dentsply Sirona);
- Patient' muco-osseous support intraoral scanning (Prime Scan, Dentsply Sirona);
- The 3D STL files (intraoral scanning) were imported into virtual planning software to match the CBCT Dicom data;
- Implants positioning virtual planning (Galileos Implant, Dentsply Sirona);
- Design of the surgical guide with dental support (Blue Sky, Blue Sky Bio);
- Fabrication of surgical guides on biocompatible resin with a 3D printer (AZIGA Printer);
- Surgical-guided insertion of Noble implants (10-13mm/3,5-4,5mm) with 35–55 N/m torque and immediately loading with a provisional prosthesis;
- Postoperative CBCT.

Analysis of discrepancies between virtual planned implants and real implants was performed by OnDemand software. The differences in distance of the shoulder points (linear deviation at shoulder), apical point (linear deviation at apex) and between insertion angles (angular error) were measured (virtual implants vs. real implants) (figures 4.a-b). The analysis consisted of measurement of the linear deviations in horisontal plane (mesiodistal, buccolingual) and vertical plane (apicocoronal) at shoulder and apex as well as angular deviation. Superpositions of the virtual planned implant with real implant (post-operative CBCT) are exposed in figure 5.

The definitions of the analyzed parameters are given in Table XXIX. The terms "virtual implant" was usd for planned position of implant in pre-implant stage, wjile the term "inserted implant" was used for post-surgical implant positioning.

Table XXIX. Parameters for analyzing implant placement accuracy in computer-assisted implant surgery

Parameter	Linear deviation at entry point (mm) (Wang et al, 2022)	Linear deviation at apex (mm) (Wang etal, 2022)	Angular error (°) (Wang et al, 2022)
Definition	"3D distance between the apical center of the corresponding planned and placed implants"	"3D distance between the apical center of the corresponding planned and placed implants"	"3D angle between the longitudinal axes of the planned and placed implants hide full caption"

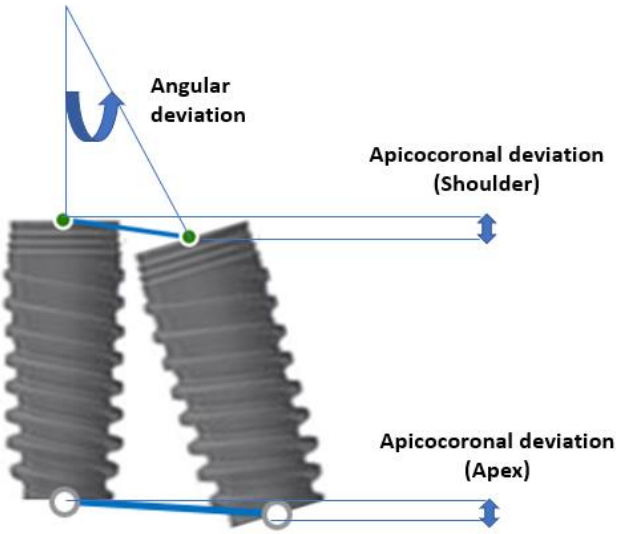


Fig.4.a.Parameters for analyzing implant placement accuracy in apicoronal plan

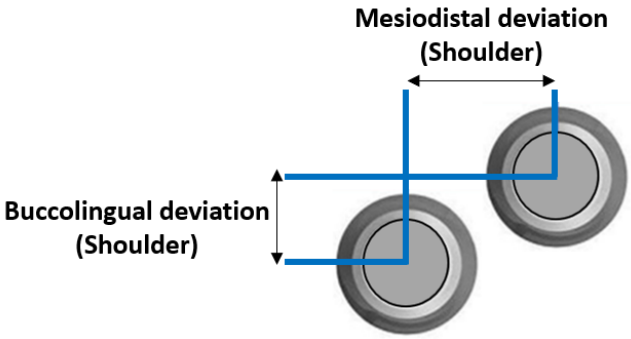


Fig.4.b. Parameters for analyzing implant placement accuracy in horizontal plan

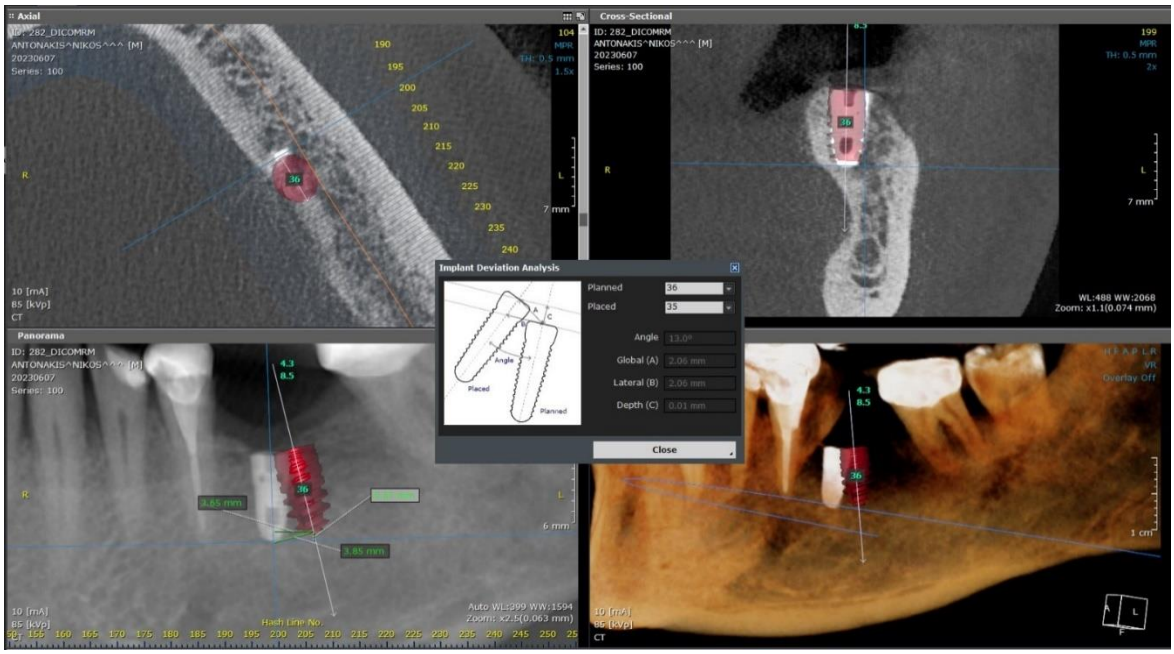


Fig.5. Superimposed CBCT images of virtual implant and inserted implant for measurement of linear and angular deviations.

Statistical Analysis

Statistical analysis was performed using the SPSS version 29.0 software package (SPSS Inc., Chicago, IL, USA). Categorical variables were presented as frequencies and percentages, and continuous variables as mean, standard deviation, minimal and maximal values.

Results

The mean, minimum, and maximum values of linear and angular deviations (between virtual implant and inserted implant) are exposed in Table XXX.

Table XXX. Linear and angular deviations between virtual implants and inserted implants

PARAMETER	DEVIATION	MEAN	SD	MIN	MAX
Angle	Angular deviation (^{0})	4,710	2,8501	0,60	9,80
Implant shoulder					
	Mesiodistal (mm)	0,623	0,2426	0,07	0,95
	Buccolingual (mm)	0,663	0,2290	0,11	0,95
	Apicocoronal (mm)	0,054	0,1155	-0,16	0,20
Implant apex					
	Mesiodistal (mm)	0,436	0,4347	0,01	1,45
	Buccolingual (mm)	0,663	0,3510	0,35	1,54
	Apicocoronal (mm)	-0,029	0,2820	-0,57	0,33

The measured linear deviations for implant shoulder were an average of 0.623 mm (mesiodistal), 0.663 mm (buccolingual) and 0.054 mm (apicocoronal), with minimun values of 0,07 mm (mesiodistal), 0,11 mm (buccolingual), and -0,16 mm (apicocoronal) and maximum values of 0,95 mm (mesiodistal), 0,95 mm (buccolingual), and -0,20 mm (apicocoronal).

The measured linear deviations for implant apex were an average of 0.436 mm (mesiodistal), 0.663 mm (buccolingual) and -0,029 mm (apicocoronal), with minimun values of 0,01 mm (mesiodistal), 0,35 mm (buccolingual), and -0,57 mm (apicocoronal) and maximum values of 1,45 mm (mesiodistal), 1,54 mm (buccolingual), and 0,33 mm (apicocoronal)

The measured angular deviations for implant shoulder were an average of 4.71^0, with minimun values of $0,60^0$, and maximum values of $9,80^0$.

Discussions

This study was performed in the context of the increasing interests of the dental practitioners and patients for the digital techniques in dentistry as well as increased predictability of the the surgical implant procedures to ensure long-term outcomes of the implant-prosthetic treatments. Since its introduction, computer-guided implant surgery was considered as a promising tool allowing to pre-view optimal implant insertion method, and planning the optimal implant dimensional parameters to perform an immediate-load provisional restoration, with lowest rates of post-operative complications (Tahmaseb et al, 2011). However, this technique has some limits such as potential damage to the alveolar bone and the inability to visualize the surgical anatomical landmarks potentially leading to errors risks especially in implant sites located on atrophic maxillary bone (Vinci et al, 2020).

Our study confirmed a risk of linear and angular deviations between the virtual plan and the actual implant position when surgical mucosa-supported templates are used, however with values in range of those reported by scientific literature. The mean values and SD of angular deviations and linear deviations at implant shoulder level and implant apex level, found in our study, are clinically acceptable allowing the avoidance of the root surfaces of the adjacent teeth and anatomical structures during the surgical implant procedures. To minimize research errors some factors and preventive measures were considered. The same experienced oral surgeon placed implants in all patients included in study group avoiding bias due to variations related to operator experience (Cushen & Turkyilmaz, 2013). The mouth opening over 50 mm was an inclusion factor to ensure correct angle of insertion of the implant drills. Surgical template was positioned with pins to increase its stability and to avoid any small deviations that may cause surgical errors and iatrogenic anatomical lesions. Finally, it were selected implant sites with adequate bone volume as atrophic bone areas can lead to micromovements of the surgical mucosa-supported template due to the resilience of the oral mucosa (D'haese et al, 2009).

Various research groups are interested to prospect angular and linear deviations between virtual implants and postsurgical implant positioning as these deviations are to be expected. The interest is explained by the correlation between angular and linear deviations and its roles in the protection of teeth adjacent to implant and important anatomical structures (Ma et al, 2018; Choi & Jeong, 2015). In the implant stage, an angular deviation of only 1^0 lead to 0.34 mm length deviation in the 10-mm fixture apical area, while an angular deviation of 5° makes 1.7 mm length deviation. Ideally, angular error must not overpass 3° to ensure the protection of the root surface of the adjacent tooth during surgical procedures, and less than 3° if the mandibular alveolar nerf is close to implant apex. Angular error of 5° will lead to damage for radicular tooth surface when the space between implant apex and tooth root was set to 1.5 mm (Choi & Jeong, 2015). An angular deviation less than 5° between the hex of fixture and hexagonal freedom of abutment is also requested to avoid loosening of implant and to ensure passive fit (Al Quran et al, 2012). When angular deviations overpass the recommended values, prosthodont clinician must take an impression after the implant placement, or use non-hexagonal implant fixture (Misch, 2014). A review of six *in vivo* studies reported apical deviations in range of 0.95-4.5 mm between virtual implants and actual postsurgical implants positions (D'haese et al, 2012a). Tahmaseb et al (2018) reviewed twenty clinical research on the accuracy of static computer-assisted implant (s-CAIS) surgery . The meta-analysis concluded a mean error of 1.2 mm (range between 1.04 mm-1.44 mm) at the entry point, 1.4 mm (range between 1.28 mm-1.58 mm) at the apical point and angular deviation of 3.5°(range between 3.0°-3.96°). Considering these accuracy values, the research group recommended a safety marge of minimum 2 mm. A review of eighteen retrospective and prospective studies reported for fully guided surgery statistically higher accuracy in angular, coronal, and apical deviation compared with pilot-drill guided surgery. Also, significantly lower angular deviation was found in implants placed using surgical guides designed and manufactured by CAD/CAM technique compared to the conventional surgical guides (Putra et al, 2022). A meta-analysis of Siqueira et al (2020) reported for fully-guided s-CAIS surgery mean angular deviation of 2.68° (range between 2.32°-3.03°), mean coronal deviation of 1.03 mm (range between 0.88-1.18 mm), apical deviation of 1.33 mm (range between 1.17-1.50 mm). Ma et al (2018) reported following mean values for CBCT analyses when virtual implants and real implants positions were compared: angle deviation: 4.74 ± 2.06°, coronal deviation: 1.37 ± 0.80 mm, and apical deviation: 1.77 ± 0.86 mm. A prospective study regarding the accuracy of mucosally supported surgical guides reported a mean angle deviation of 2.60° (range of 0.16-8.86°) at the entrance point. The range of values of the deviation at the entrance point were between 0.29 mm and 2.45 mm (mean 0.91 mm) while the mean value of the deviation at the apical point

was 1.13 mm (range of 0.32 mm-3.01 mm) (D'haese et al, 2012b). Ersoy et al (2008) compared the virtual implants with real placed implants showed mean angular deviation of 4.9^0, mean linear deviation of 1.22 mm at the implant neck and 1.51 mm at the implant apex. The angular deviation and linear deviation at the neck and apex of the placed implants were higher in maxillary areas (mean 5.31^0, 1.04 mm, and 1.57 mm, respectively) when compared to mandibulary locations (mean 4.44^0, 1.42 mm, and 1.44 mm, respectively).

In our study, linear and angular deviations are in range of literature data, despite the absence of a reference marker during CBCT exam. In a similar study that did not use reference marker during CBCT exam, Ma et al (2018) also reported higher angular deviations during overlapping pre-implant and post-implant CBCT. (Ma et al, 2018).The research in this field can provide for quantification of the potential impairment of treatment safety and reliability of the computer-guided implant surgical stage (Vasak et al, 2011). Literature data in this field give a perspective also on surgical and prosthodontical complications to provides awareness and reasons to implement this surgical technique in dental practice (D'haese et al, 2012a). A review concluded that deviations in 3D directions between virtual implants and real implant position as well as postsurgical complications request that clinicians must clearly understand the indications and benefits of this therapeutic approach to find the right candidates to computer-guided implant surgery (D'haese et al, 2012a; Van Assche et al, 2012).

Conclusions

Flapless digitally-assisted surgery with dental-supported surgical guides is a predictable procedure for implant surgical stage. Mean clinically acceptable liniar and angular deviation values between virtual implants and inserted implants were recorded. The maximum values of angle deviations highlight the need for flap surgery in areas with severe alveolar bone resorptions to prevent the errors in implant positioning.

1.3.3. Dental practice management software in the assessment of treatment needs of edentulous patients candidate to implant-prosthetic therapy

Aim of study was to individualize the way in which dental practice management software can contribute to increasing therapeutic efficiency in each clinical case, providing a synthesis of precise patient data and performed procedures at any given moment.

Materials and method

A statistical study was conducted based on selected data from the digital application Software FornaClinic, quantifying patient-related information, treatment types, quantification of clinical entities addressed, as well as aspects of general assessment.

The data were selected from the electronic records of registered patients and from subsections that provide conclusive data about each evaluated parameter.

The digital application is structured based on patient data, treatment types, treatment plans, preventive procedures, types of prosthetic restorations, imaging area, as well as other categories that complement a successful therapeutic management.

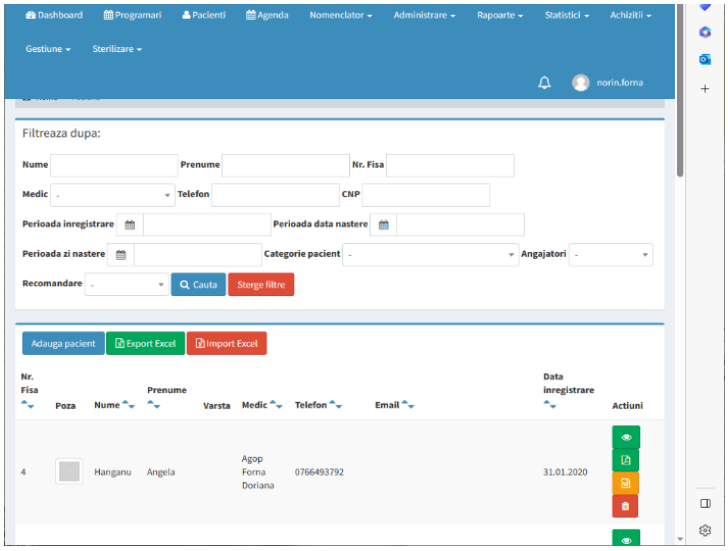


Fig. 6. Patients section: Viewing the electronic medical record of each registered patient – subsections: Patient data; Notes; Next visit; Correspondence; Schedules; Anamnesis; Recall treatments; Historic; Consultations; Treatment plans; Treatments; Prophylaxis; Laboratory work; Periodontology; Radiographs; Invoices; Receipts; Payment advances; Payment; Recipes; Documents; Custom forms; Dental subscriptions; Service subscriptions; Investigations; Operations; Services; Medical tests; Forms; Products

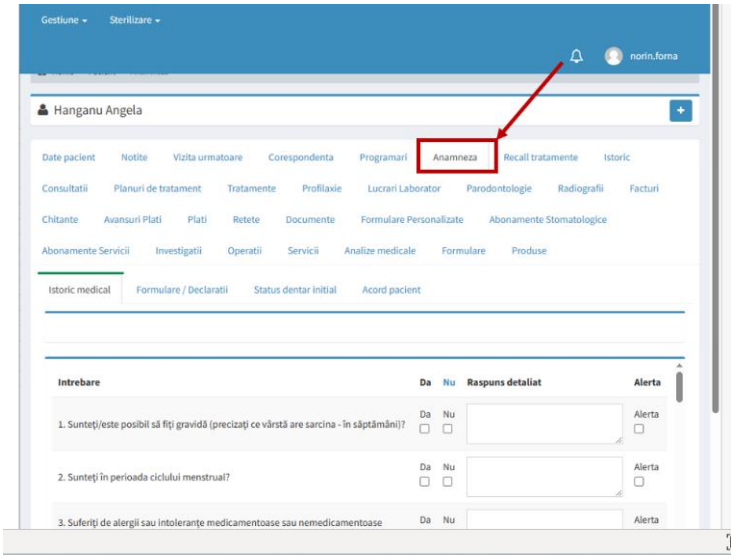


Fig. 7. Subsection "History": Relevant information is recorded by completing a standardized questionnaire with 12 categories of questions, each category containing its own list of dedicated questions; an alert tick can also be defined - in the case of patients with pathology with potential risk for the necessary dental treatment.

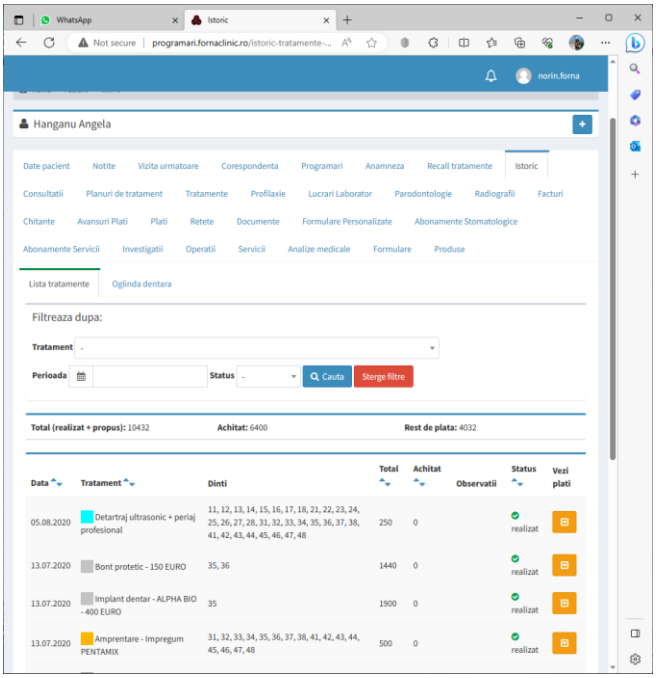


Fig. 8. Subsection "History": Enter the previously performed treatment.

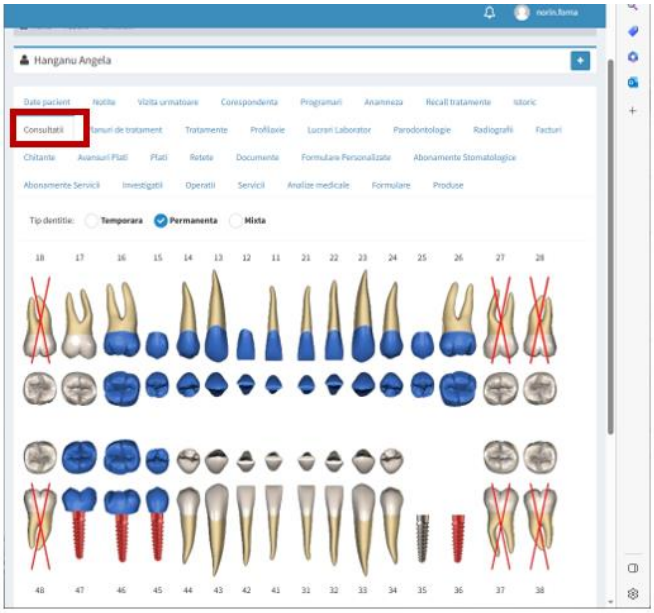


Fig. 9. Subsection "Consultations": The patient's dental mirror is marked.

Statistical processing was performed in SPSS 27.0.

Descriptive study: For qualitative data (whose values represent codes), frequency distributions were generated for the entire sample and compared across stratification variables using contingency tables. The determined values were graphically represented through histograms (in various forms), and for qualitative variables, Pie Charts were also used. For numerical data, standard descriptive statistics parameters were calculated (mean, standard error of the mean, standard deviation, variance, minimum and maximum values).

Analytical study: We used significance tests with a significance level of p = 0.05 for comparative analysis of the paired variables under investigation, both at the overall sample level and separately for subgroups. For comparing paired variables, we used the t-Student test under the assumption that the values follow a normal distribution (which was pretested using a goodness-of-fit test, such as the Kolmogorov-Smirnov test). If the values did not follow a normal distribution, we used the Wilcoxon test for paired samples for the same purpose.To test the differences between values of a qualitative variable across different groups, we used the Chi-square test.

Results

The analyzed patient sample has a relatively balanced gender distribution, with a slight prevalence of females (51.7% compared to 48.3%). There is a significant increase in the number of patients whose data has been stored in the digital application of the dental office from the year 2000 to 2023. Regarding the origin of the patients, we observe a distribution not only in the counties of Moldova but also in other areas of the country. The majority of patients, 97%, originate from Romania, while a percentage of 2.2% come from other countries such as England, Australia, Canada, France, Israel, Italy, Morocco, and the Republic of Moldova. The origin of patients is important because the patient's health behavior is somewhat influenced by the healthcare system of their respective country, which reflects in their approach to preventive oral health practices. Regarding the affiliation of patients who have visited the clinic in the last five years, two categories stand out: patients with a regular regime, accounting for 82.6%, and patients with a special regime, accounting for 17.4%. The special regime category includes patients from the implantology certification program, where advanced procedures such as sinus lift and implants are performed. This category also includes patients who participate on a voluntary basis, contributing to both their own treatment and the educational aspects of the clinic. Regarding the types of treatments conducted in the last five years, there is a prevalence

of advanced procedures such as dental implant placement. Within this category, the application of Biotec implants had the highest prevalence in 2020, followed by 2022, with significant values also observed in 2019 and 2021. The values for the current year are relatively lower, considering that the year is still ongoing.

From the category of procedures related to implant-prosthetic rehabilitation, the application of bone augmentation using various regenerative materials stands out. The highest number of procedures was recorded in 2021, followed by 2022, with similar values also observed in 2019. The same type of procedure is present in the current year but in a smaller proportion, as the year is still ongoing.

Procedures related to dental alveolar surgery, such as cystectomy, numbered 15 in 2022, according to the alveolar surgery registry. Regularization of the alveolar ridge was performed in 23 procedures in 2021. Extractions of single-rooted teeth were prevalent in 2022.

In terms of implant-prosthetic procedures, the application of Alfa Bio implants is notable, with a quantifiable percentage for 2023. A significant number of implants of this type prevailed in 2022 and 2019. Different types of impressions were used, with a prevalence of automatic mixing impressions.

"Reports" section presents a varied range of reports, also oriented mainly towards the economic efficiency of the clinic (Receipts, Daily receipts, Forecast of receipts, Payment of doctors, Patient invoices), but also towards the actual medical activity carried out in the clinic (Analysis of treatment plans, Patient treatments, Patient works) and for the administration of the activity (Patient appointments, Patient notes report, Patient task notes report, Treatment recall report, Medical analysis report, Tablet orders).

In order to generate a report on the treatments performed in the clinic, the following specifications can be provided: the patients for whom the report is desired, the doctor for whom the reporting is intended, the specific treatments to be tracked, and the reporting period. The treatments can be categorized and identified using specific color codes for simplicity. The categories include:

- Consultation
- General Dentistry / Prophylaxis
- Cariology
- Endodontics
- Surgery
- Implantology
- Laser Therapy
- Periodontology
- Esthetics
- Fixed Prosthodontics - Tooth
- Removable Dentures
- Fixed Prosthodontics - Implant
- Prosthodontics
- Orthodontics and Dentofacial Orthopedics

Regarding the clinical entities addressed in the clinic, there is a prevalence of implantology procedures, accounting for 19.3% of the total treatments. Fixed prosthodontics on implants follows with a percentage of 10.6%, and prosthetics on natural teeth with a percentage of 7.1%. It is important to mention the presence of laser therapy procedures, which offer advanced therapies that provide precision and comfort for the patients.

Regarding implantology procedures, there is a prevalence of Biotec dental implants, known for their high degree of biocompatibility, followed by Nova dental implants. Noris implants are also used in a significant proportion, along with a considerable number of Alpha Bio dental implants. Pre-implantation procedures such as sinus lift were performed with a significant number of cases, often combined with bone regeneration materials and collagen membranes. In terms of surgical procedures, a significant number of root extractions were performed, followed by decapitations, cystectomies, bone grafting procedures, and the use of Jason membranes. Odontectomies of wisdom teeth and impacted canines were also performed in quantifiable proportions.

Fig.10.a-f. Distribution of the therapeutic procedures carried out in the Clinic in the last 5 years

In terms of prosthetic field preparation, bone exostosis modeling, alveolar ridge regularization, and vestibuloplasties were performed in a significant number of cases.Regarding fixed prosthodontics procedures, there is a significant number of impressions taken using Impregum, a high-precision material, with the auto-mixing technique using the Pentamix equipment. Additionally, there is a notable number of cementations using various types of cements. In terms of removable dentures, there is a prevalence of partial acrylic dentures, followed by complete acrylic dentures. Representative cases also include completely acrylic dentures screw-retained on implants and removable partial dentures with skeletal frameworks. Regarding fixed prosthodontics, a wide range of procedures are observed, including provisional prostheses, ceramic crowns on metal frameworks, ceramic crowns on

zirconia frameworks, and all-ceramic crowns. Additionally, the use of bruxism splints is notable, as they play a crucial role in managing the negative effects of bruxism on the longevity of fixed prostheses. A significant number of procedures are involved in fixed prosthodontics on implants, which correlates with the number of implants placed. There is a notable prevalence of ceramic crowns on metal frameworks on implants, ceramic crowns on zirconia frameworks on implants, and all-zirconia crowns on implants. Additionally, quantifiable proportions are observed for temporary crowns using prefabricated resin materials. Similarly, there is a significant number of procedures in general dentistry, with a notable prevalence of laser therapies. Among these, important procedures include laser biostimulation, laser decontamination, laser excision of epulis, and laser frenectomy. These high-precision procedures ensure rapid healing and provide patients with a high level of comfort. In the field of conservative dentistry, there is a prevalence of medium-sized physiognomic restorations in permanent teeth, followed by deep physiognomic restorations in permanent teeth. Other notable categories of procedures include restorations reinforced with intracanal posts and remineralization therapies. Equally noteworthy are the procedures in endodontics and periodontology, which are essential in any comprehensive oral rehabilitation and esthetic treatment. Endodontic therapies, performed under the microscope or using rotary techniques, are prevalent. They are followed by significant procedures in the field of gingivectomies and open-field periodontal curettage.

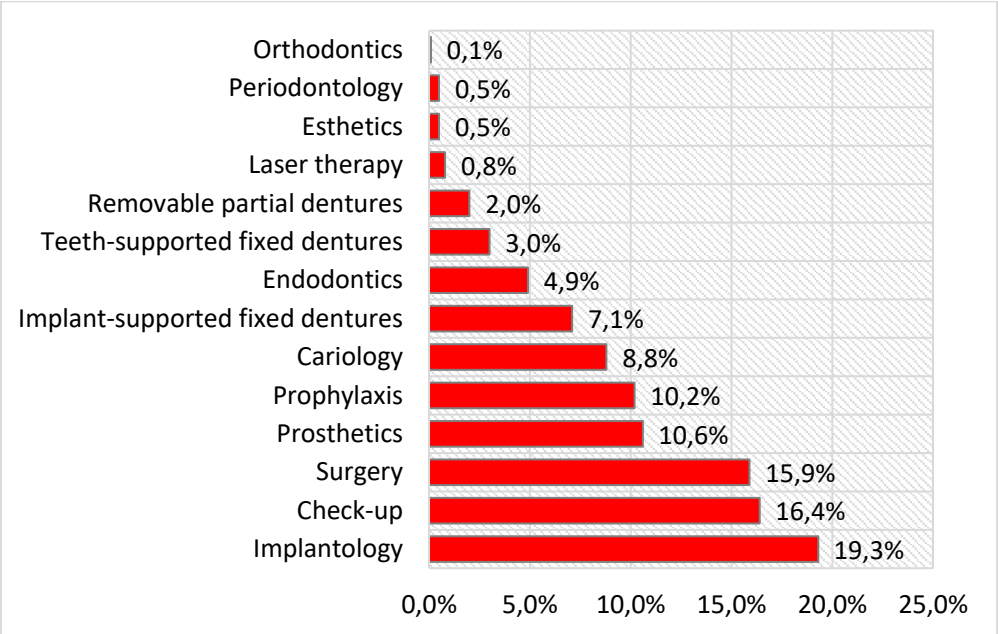


Fig.11. Categories of treatments for
edentulous patients candidate to implant-prosthetic therapy

Discussions

The development of cutting-edge studies in the complex field of implant-prosthetic rehabilitation, based on simulation elements and clinical applications, incorporating the established correlations between specific clinical cases, implant techniques, biomaterials, and types of prosthesis, can be found in numerous digital applications.

Contemporary dental practice brings to our attention the presence of digital equipment in a large number of dental offices, which provides enhanced ergonomics and precision in achieving the current standards in this complex field, particularly in digital imaging. By utilizing digital applications in dental offices, dentists have the opportunity to make extremely precise diagnoses while reducing therapeutic procedures through an ergonomic approach.

The new direction in dentistry requires a revision of biological and biomechanical norms under the impact of increasingly demanding aesthetic requirements from patients. However, aesthetic considerations should not be pursued at the expense of long-term oral health or compromise the functional efficiency of the stomatognathic system.

Conclusions

- Software applications play a crucial role in achieving optimal management both in therapeutic aspects and at the clinic level where the software application is implemented as a daily approach.
- The data stored in software applications are extremely useful for both patients and healthcare professionals, providing a clear overview of the prevalence of procedures and materials used at any given moment.
- From conducted statistical studies, there is a notable prevalence of implantology and implant-prosthetic rehabilitation procedures. A significant percentage of procedures fall within the realm of advanced preparations, such as augmentation with various types of bio-oss and membranes, as well as the prevalence of lateral sinus lift procedures.
- In terms of prosthodontics procedures, there is a prevalence of ceramic crowns on metal frameworks, followed by ceramic restorations on zirconia infrastructure. Implant-supported prostheses are present in a quantifiable proportion.

1.4. CLINICAL AND RADIOLOGIC STUDIES ON POST-TREATMENT EVOLUTION IN IMPLANT-PROSTHETIC THERAPY

State of art

The implant-prosthetic therapy is widely used in the oral rehabilitation of edentulous patients (Forna et al., 2011). Success and failure are dynamic conditions linked to time and require periodic evaluation.The main criteria to evaluate the quality of health of the dental implant are mobility and pain, the presence of any of them compromises the implant to a great extent and in many cases its removal is indicated. Implant failure is easier to describe and leads to the analysis of a series of clinical parameters and indices. The presence of pain, mobility, progressive uncontrolled bone loss and peri-implant radiolucent image confirm implant failure in most cases (Corona et al, 2015; Guzman et al, 2015; Tamez et al, 2017; Pérez et al., 2018).

The success of the implant-prosthetic treatment is largely associated with the quality of implants' osseointegration as well as the accuracy of implant placement and the design of the future implant-supported bridge. Osseointegration involves complex physiological processes similar to those related to bone fracture (von Wilmowsky et al., 2014). In the first stage, the blood clot serves as a matrix for neo-angiogenesis, collagen matrix formation, invasion of osteoclasts, and bone formation (Terheyden et al., 2012). After implant loading, the mechanical stimulus is transmitted to the adjacent bone, leading to bone remodeling. In the final stage, approximately 60-70% of the implant surface becomes covered by bone. The literature frequently mentions factors that can influence implant osseointegration, such as the quality of the treatment plan, implant surgical procedures, accuracy of implant placement using surgical guides, and loading protocol (Calin et al., 2016; Sîrbu, 2018; Holban et al., 2016).

Retrospective and prospective research brought substantial evidence showing that implant-supported fixed partial dentures (FPD) are a reliable treatment option for the replacement of missing posterior teeth. Numerous research groups reported high rates of surviving implants, regardless of the functional status of the implant-supported FPD or patient

satisfaction (Hanif et al, 2017). However, the implants osseointegration and the long- term success rate of the implant-supported fixed partial dentures may be affected by various biological, mechanical or technical complications (Hanif et al, 2017; Lee et al,2017; Heydecke et al, 2012). (Academy of Osseointegration, 2010). Biological complications are negative events that affect the peri-implant tissues (pain, infection, suppuration, mobility, peri- implant bone resorption, dysesthesia.); mechanical/technical complications are negative events that affect the exoprosthesis, either to the prefabricated components (mechanical complications) or to the covering material (technical complications) (Academy of Osseointegration, 2010). The relation between biological and mechanical/technical complications is bidirectional (biologic complications can lead to mechanical/technical complications and vice versa) (Moreno, 2021). In this context, 8th European Workshop on Periodontology recommended the inclusion of the biological and mechanical-technical complications rates in the goals of the research focused on the assessment of the implant-prosthetic success (Tomasi & Derks, 2022; Tonetti et al, 2012). Inflammation (47%) and overloading (53%) are the main causal factors of the early and late implants failure (Han et al,2014). Complications are considered minor if they require 60 minutes or less for repair, and major if more time is needed for repair or if the implant-prosthetic component need to be sent to the dental laboratory (de Boever et al, 2006). Biological complications are a result of bacterial infections, microbial plaque buildup, and progressive bone loss (Berglundh et al,2002; Quirynen et al, 2002). Early biological failures are attributed to the placing of dental implants under improper aseptic measures while late complications (peri-implantitis) are associated to microbial plaque buildup because of poor oral hygiene and non-compliance of patients to the periodontal and peri-implant maintenance sessions (Hanif et al, 2017). While dental practitioners have a lot of data regarding the risk of biological complications (peri-implantitis) in implant- prosthetic therapy, the number of studies focused on the mechanical risks (risk of a complication or failure of a prefabricated component due to mechanical forces) and technical risks (risk of a complication or failure of the laboratory-fabricated superstructure or its materials) (Silva & Brägger, 2009) are significantly lower. Mechanical complications are usually a consequence of biomechanical overloading (Hanif et al, 2017). Risk factors in the onset of the biomechanical overloading include improper implant position/angulation (cuspal or implant inclination, horizontal or apical offset of implant), insufficient posterior support as well as inadequate poor volume of alveolar bone or the presence of excessive forces in patients with bruxism (Haifa et al, 2017). The technical complications are a relevant issue in implant-prosthetic therapy by implant-supported FPD as compared to the implant-supported removable prosthesis (Heydecke et al, 2012).

The therapeutic complexity of the clinical cases with partial edentulousness involves the etiopathogenic individualization of the cases and completion through fixed partial dentures (FPD) with support on natural teeth or dental implants (Forna, 2011). However, not every patient is a candidate for dental implants, in the context where severe bone loss associated with complex medical history are risk factors for the success of implant-prosthetic therapy (Pol et al, 2022). Fixed partial dentures with teeth support involve the preparation of the adjacent teeth adjacent, a process that makes these abutment teeth more prone to the accumulation of bacterial plaque, tooth decay or periodontal disease, or even to the periapical pathology following endodontic treatment (Pjetursson et al, 2018). Fixed partial dentures with implant support have advantages of avoiding the involvement of adjacent teeth and preventing alveolar bone loss. Although multiple risk factors can decrease the probability of teeth survival, the survival and success rates of dental implants are inferior to the survival rates of healthy natural teeth, considering the risk of implants biological and technical complications (Pjetursson et al, 2007, 2012; Pol et al, 2018, 2022).The implant material, surface design, and microtopography also play a role in accelerating the osseointegration process (Val et al., 2017). It is important to consider these factors as approximately 1-2% of implants show unsatisfactory

osseointegration, leading to potential failures (Chrcanovic et al., 2014). Additionally, secondary failures can occur due to peri-implantitis in approximately 5% of patients treated with implant-prosthetic restorations (Chrcanovic et al., 2014). To reduce the risk of failures, the use of dental implants with bioactive surfaces is recommended, especially for high-risk patients (Gomez-deDiego et al., 2014).

Most dental implants are manufactured from Ti-6Al-4V, an alloy known for its high fatigue resistance, corrosion resistance, and low density (Olmedo et al., 2009). Implant design is an important factor influencing primary stability and peri-implant stress distribution (Van de Velde et al., 2010). Surface treatments can enhance the bioactivity of the implant surface and promote greater extent of osseointegration. As peri-implant bone resorption and incomplete osseointegration are the main causes of implant failures, research groups and implantologists focus on clinical and paraclinical studies that evaluate peri-implant bone changes and the success/failure rate of implant systems made from various materials with different macro and micro designs and geometries (Mathieu et al., 2014).

Publications on this topic:

1.Dima Cosmin, **Agop-Forna Doriana**, Forna Norina. Clinical and paraclinical study regarding periimplant bone changes and survival rate of three dental implant systems. *Romanian Journal of Medical and Dental Education* 2019; Vol. 8, No. 4: 34-41.
2.Dimitrios Bardis, **Doriana Agop-Forna**, Cristina Dascălu, Ioana Cristea, Norina Forna. Biological and mechanical-technical complications of posterior metal-ceramic implant-supported fixed partial dentures: a retrospective study. *Rom. J. Oral Rehabil.* 2022; 14(3): 18-26.
3.Ioana Cristea, **Doriana Agop-Forna**, Cristina Dascălu, Dimitrios Bardis, Claudiu Topoliceanu, Norina Forna. Survival and prosthetic success of fixed partial dentures supported by either abutment teeth or implants: a retrospective study. *Rom. J. Oral Rehabil* 2022; 14(3): 40-47.

1.4.1. Clinical and paraclinical study regarding periimplant bone changes and survival rate of three dental implant systems

Aim of the study was to assess the periimplant bone changes and the survival rate at 12-months of functional loading of three dental implants systems.

Materials and Method

The study was performed on 30 mandibular edentulous patients (15 males, 15 females; aged between 35 and 48 years). The patients were divided in three groups accordingly to the dental implant system (9-Any Ridge, Megagen; 11- MIS Seven; 10- MIS C1). MIS implant systems are manufactured from Ti-6AL-4V and AnyRidge (Megagen) is manufactured from pure Ti. All the investigated implants have bioactive surfaces obtained by sand-blasting and acid-etching.

Each implant system was placed in 10 mandibular molars sites and 10 mandibular premolars sites that allowed the use of implants of at least 10 mm length and 4 mm diameter. It were investigated 60 implants sites (20- Any Ridge, Megagen; 20- MIS Seven; 20- MIS C1). The occlusal loading was applied at 4-5 months after the implant placement.

The occlusal loading was applied at 4-5 months after the implant placement. CBCT images were recorded immediately post-implantation and at 12- months follow-up after functional loading.

The implants survival rate was established by clinical and paraclinical exams. The peri-implant vertical resorption and the changes of bone density were measured by using CBCT images and software application OnDemand.

Results

Figures 12.a-c show the results regarding the vertical periimplant bone resorption for the three dental implant systems at 12-months follow-up.

Figures 13.a-b show the results regarding the increase of periimplant bone density for the three dental implant systems at 12-months follow-up.

Figure 14 shows the results regarding the survival rate of the three dental implant systems at 12-months follow-up.

The increase of the periimplant bone density at 12-months follow-up was as follows: 604 HU for molars sites and 669 HU for premolars sites to the implant system AnyRidge (Megagen); 616 HU for molars sites and 690 HU for premolars sites to the implant system MIS C1; 586 HU for molars sites and 663 HU for premolars sites to the implant system MIS Seven.

The vertical periimplant bone resorption at 12-months follow-up was as follows:

- 0.32 mm for molars sites and 0.33 mm for premolars sites to the implant system AnyRidge (Megagen);
- 0.30 mm for molars sites and 0.32 mm for premolars sites to the implant system MIS C1;
- 0.33mm for molars sites and 0.35mm for premolars sites to the implant system MIS Seven; systems were 100% at 12-months follow-up.

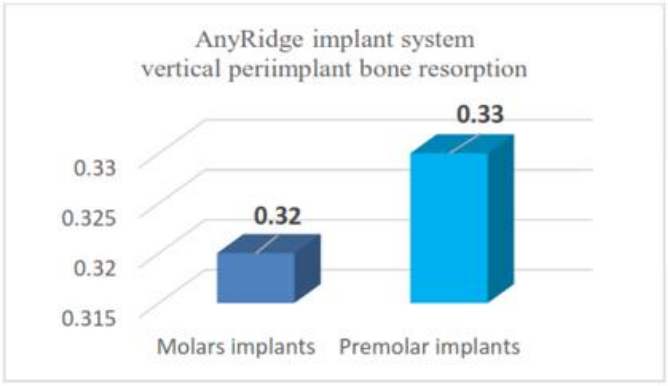


Fig.12.a. Vertical periimplant bone resorption- AnyRidge (Megagen) (12-months follow-up)

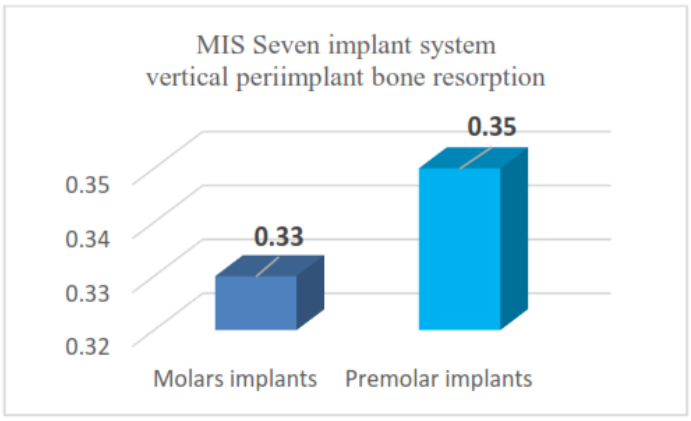


Fig.12.b. Vertical periimplant bone resorption- MIS Seven (12-months follow-up)

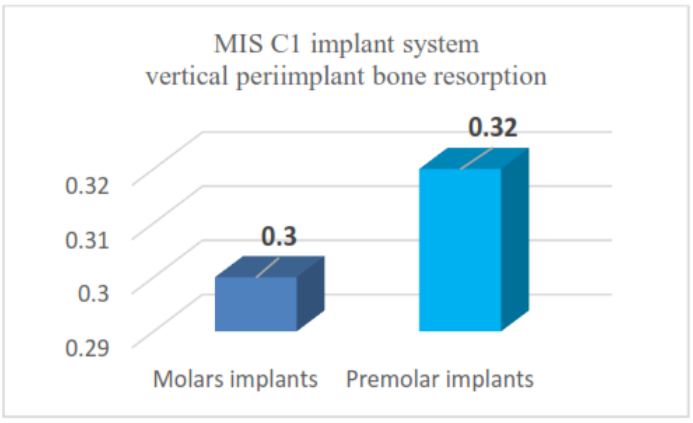


Fig.12.c. Vertical periimplant bone resorption- MIS C1 (12-months follow-up)

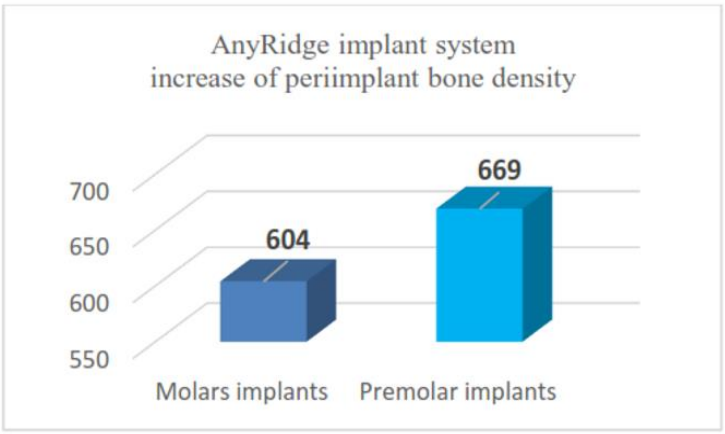


Fig.13.a. Changes of periimplant bone density- AnyRidge (Megagen) (12-months follow-up)

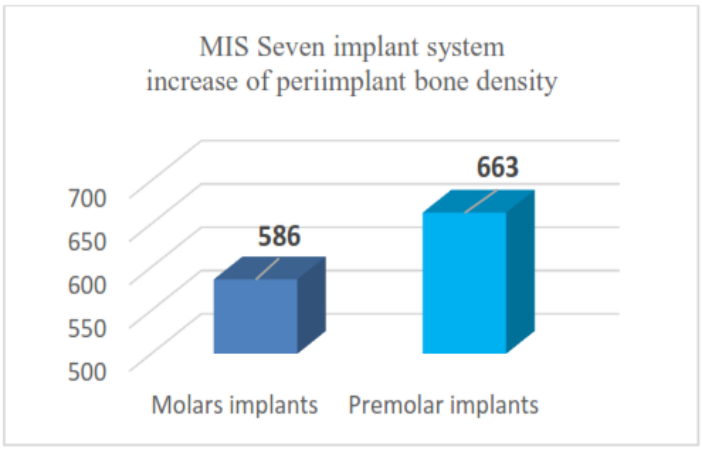


Fig.13.b. Changes of periimplant bone density- MIS Seven(12-months follow-up)

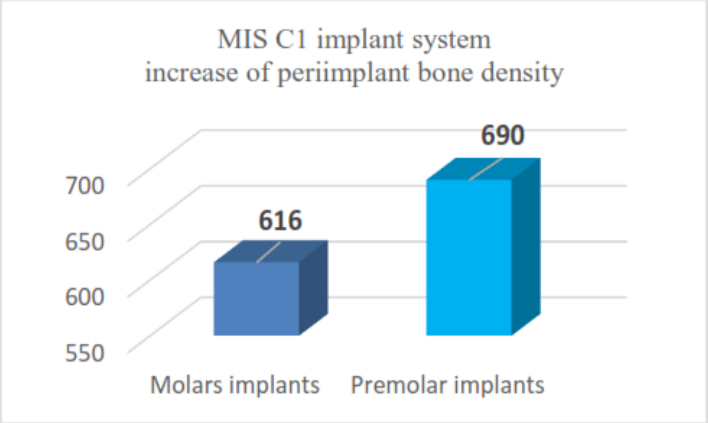


Fig.13.c. Changes of periimplant bone density-MIS C1 (12-months follow-up)

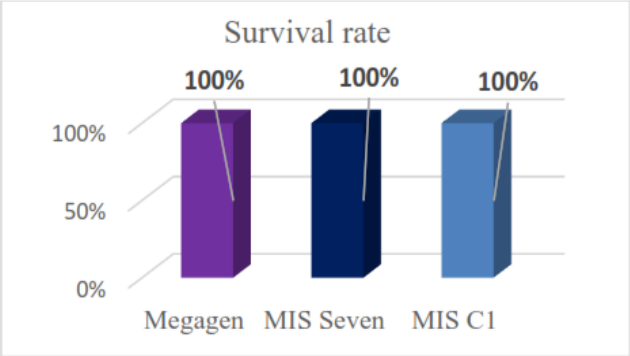


Fig.14. Survival rate (12-months follow-up)

Discussions

The results of our study revealed the absence of significant differences regarding the vertical periimplant bone resorption as well as significant increase of the osteo-density at 12 months follow-up, for all the investigated dental implant systems (De Almeida et al., 2010; Calì et al., 2018). Regarding the influence of materials, MIS implant systems are manufactured from Ti-6Al-4V alloy and AnyRidge (Megagen) is manufactured from pure Ti (De Almeida et al., 2010; Calì et al., 2018).

FEA studies indicate low differences regarding Young modulus and Poisson coefficient for Ti-6Al-4V and pure Ti, suggesting that all the investigated implant systems have the ability to resist deformation and increase stress transmitted in the surrounding bone as they act as rigid bodies (Geng et al., 2004; De Almeida et al., 2010).

In our study, the vertical bone resorption was concentrated at the crestal bone level, which is in agreement with several finite element analysis studies that demonstrated higher stress distribution at this level (Geng et al., 2004; Calì et al., 2018).

All three implant systems were submitted to similar procedures to obtain bioactive surfaces, such as sandblasting and acid etching. Additionally, the surface of the AnyRidge (Megagen) implant is covered with a nano-layer of calcium ions by Xpeed technology (De Almeida et al., 2010; Calì et al., 2018).

The success of osseointegration at 12 months follow-up for all the bioactive implant systems supports the conclusions of previous research that compared dental implants with modified surfaces to classic implant systems, suggesting that implants with bioactive surfaces have low bacterial adhesion and promote the recruitment, adhesion, and growth of osteoblasts and fibroblasts (Smeets et al., 2016).

From a design point of view, all implant systems have geometry and design features that favor the decrease of periimplant stress levels and uniform distribution of stress in the periimplant area. For example, the MIS C1 implant is characterized by a 6-degree conical connection that ensures a secure fit between the abutment and implant, minimizing micro-movements and reducing bone loss at the crestal level. It also has a dual thread design that increases bone-to-implant contact and facilitates osseointegration. The MIS C1 implant's platform-switched configuration further reduces bone loss compared to non-platform-switched implants (De Almeida et al., 2010; Calì et al., 2018).

The MIS Seven implant is a tapered implant with microthreads at the cortical region, a V-shaped thread, flat apex, and micro-rings on the implant neck. These design features aim to improve bone-to-implant contact at the crestal zone, reduce pressure on the cortical bone, and minimize resorption at the implant neck (De Almeida et al., 2010; Calì et al., 2018).

The AnyRidge (Megagen) implant is a tapered implant with a plateau thread, dome-shaped apex, and microthreads with variable diameters, allowing the implant to match the patients' bone density. The presence of microthreads at the implant crestal region may decrease cortical stress, reduce bone loss, and promote osteogenesis (De Almeida et al., 2010; Calì et al., 2018; Shin et al., 2006; Geng et al., 2004).

The success rate of delayed implants placed in healed extraction sites supports the findings of similar research studies (Antetomaso & Kumar, 2018).

The results regarding vertical peri-implant bone resorption and survival rates are consistent with literature data (Esposito et al., 2013; Streckbein et al., 2014), or even superior when compared with other studies focused on different categories of bioactive dental implants (Mendonca et al., 2008; Ostman et al., 2013). However, the relationship between clinical success and dental implant materials, design, and surface bioactivity is still a topic that requires further investigation (Gumeniuc, 2013; Mertens & Steveling, 2011; Fischer & Stenberg, 2012).

Further studies are needed to investigate periimplant bone evolution and survival rates after 5-10 years of follow-up, as there are many parameters that can vary and periimplant bone resorption tends to be significantly higher in long-term studies (Gumeniuc, 2013; Mertens & Steveling, 2011; Fischer & Stenberg, 2012).

Conclusion

The use of the bioactive implants systems Any Ridge (Megagen), MIS Seven and MIS C1 is associated with low vertical bone resorption, the increase of the peri-implant bone density and 100% survival rate at 12 months follow-up.

1.4.2. Biological and mechanical-technical complications of posterior metal-ceramic implant-supported fixed partial dentures: a retrospective study.

Aims of study:

- Assessment of the implants biological complications rates in partially posterior edentulous patients with implant-supported fixed partial dentures (FPD);
- Assessment of the implants/FPD mechanical-technical complications rates in partially posterior edentulous patients with implant- supported fixed partial dentures.

Materials and method

The research was designed as a retrospective study with a study group of 67 patients (age parameters: mean age 63,88 ± 11,70 yr, range 40-86 yr ; gender : males-20, females- 47) with maxillary and mandibular posterior partial edentations treated by 3-5 units implant-

supported fixed partial dentures (76 FPD; 178 implants) with mean follow-up 7,89 yr (range 3-17 yr) (Table XXXI). Inclusion and exclusion criteria are exposed further. Inclusion criteria: patients' age over 18 yr; maxillary and mandibular edentation (class Kennedy I and II); prosthetic treatment with implant-supported fixed partial dentures; follow-up >3 years from prosthetic reconstruction. Exclusion criteria: systemic diseases affecting abutment implants (non- controlled diabetes, osteoporosis, metabolic disorders); non-compliance to periodontal maintenance sessions. The study was performed accordingly to the requirements of the 1975 Helsinki Declaration revised in 2008 and CONSORT Guidelines. Written informed consent was obtained from all patients before enrollment.

The data regarding biological complications of implants and technical complications of implants and implant- supported FPD were collected from patient files and radiographic examens. The biologic and technical complications rates as well as the implants survival and success rate were calculated for overall patients as well as in relation to demographic and individual patients' parameters. Implant "survival" is defined as implant still in mouth at the examination session, regardless of the prosthesis status or patient satisfaction. Any implant requiring additional treatment is considered "surviving" implant (Negm, 2016). Implant "success" is associated with implants that are functional and satisfactory. Criteria for implant success are as follows: immobility, absence of peri-implant radiolucency, width of the attached gingiva ≥2mm, absence of peri-implant infection (Kartha et al, 2013).

Biological complications refer to adverse soft tissues' reactions, sensory disturbances, progressive marginal loss (associated to peri-implantitis) and loss of implant osseointegration (Hanif et al, 2017).

The definitions of peri-implantitis and peri-implant mucositis were adopted from Lanz (2015), Heitz-Meyfeld et al (2018) and Renvert et al (2019).

Peri- implantitis was recorded for sites where there was bleeding on probing associated with peri-implant pocket depth ≥ 5 mm, and radiographically visible peri-implant bone lysis ≥ 2,5 mm.

Peri-implant mucositis was diagnosed by the presence of peri-implant soft tissue inflammation with bleeding on probing, associated with a peri-implant sulcus depth <5 mm and no peri-implant bone loss.

The definitions of the mechanical and technical complications were adopted from Hanifa et al (2017).

The technical complications (FPD) include fracture/chipping of veneering ceramic and fracture of framework of fixed partial denture.

The mechanical complications (FPD, implants) are considered the loss of screw hole access material, screw loosening, screw fracture or implant fracture (Haifa et al, 2017).

Table XXXI. Distribution of patients in study group

	N (%)
Overall	67 (100%)
Age group, N(%)	
40-60 yr	19 (28,4%)
>60	48 (71,6%)
Smoking status, N(%)	
Non-smokers	49 (73,1%)
Smokers	18 (26,9%)
Periodontal history, N(%)	
Yes	18 (26,9%)

No	49 (73,1%)
Oral hygiene (mPI), N(%)	
0	37 (55,2%)
1	24 (35,8%)
2	3 (4,5%)
3	3 (4,5%)
Follow-up (yr), N(%)	
3-5 yr	32 (47,8%)
6-10 yr	18 (26,9%)
>10 yr	17 (25,4%)
Edentation location, N(%)	
Mx	37 (55,2%)
Md	24 (35,8%)
Md + Mx	6 (9,0%)

The results regarding the implants survival and success rate as well as the rates of the biological and technical complications are exposed in table XXXII and figures 15-17.

Implants survival rates were 96,6% (91% at patient level; 92,1% at FPD level).

Implants failures rates were:

- 4,5% at patient level;
- 7,9% at FPD level;
- 1,7% at implant level.

The rates of biological complications (peri-implantitis) were 13,5% at implant level (17,9% at patient level; 15,8% at FPD level).

The prevalence of peri-implant mucositis was 21,9% at implant level (17,9% at patient level; 23,7% at FPD level).

The rates of mechanical/technical complications were:

- 35,8% at patient level,
- 35,5% at FPD level,
- 28,7% at implant level.

The most frequent mechanical/technical complications were loss of screw access hole material (31,3% at patient level; 31,6% at FPD level), followed by ceramic veneers fracture/chipping (13,4% at patient level;11,8% at FPD level), screw loosening (13,4% at patient level; 15,8% at FPD level; 8,4% at implant level), screw fracture (4,5% at patient level; 3,9% at FPD level; 1,7% at implant fracture), implant fracture (4,5% at patient level; 3,9% at FPD level; 1,7% at implant level), FPD framework fracture (4,5% at patient level; 3,9% at FPD level).

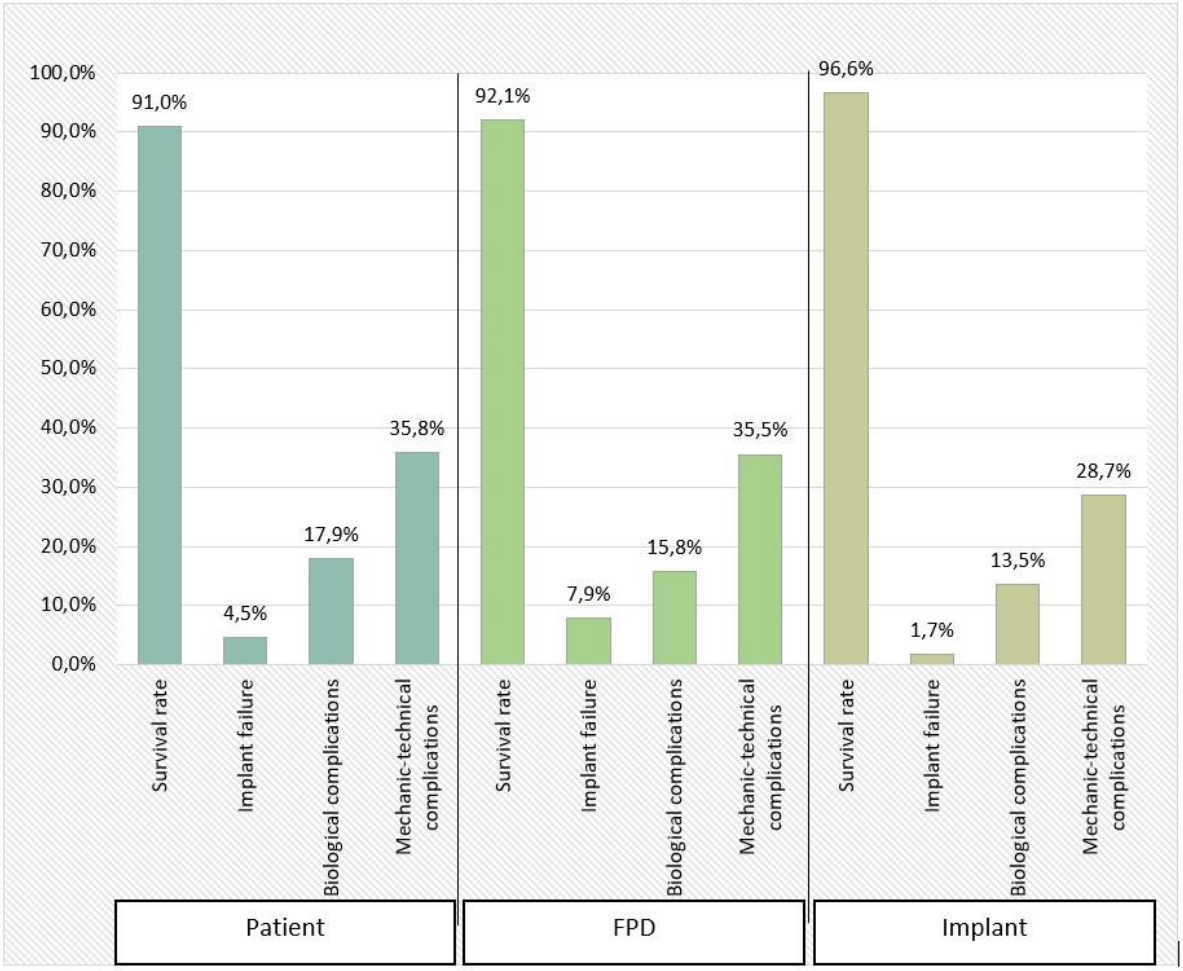


Fig. 15. Data regarding implant survival/failure rate,
biological and mechanical/technical complications (at patient/FPD/implant level)

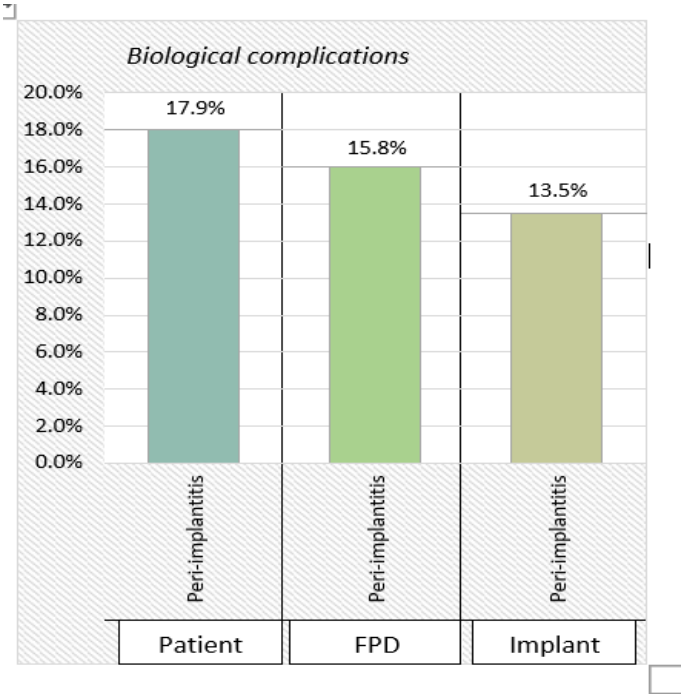


Fig. 16. Data regarding biological complications (peri-implantitis)
at patient/FPD/implant level

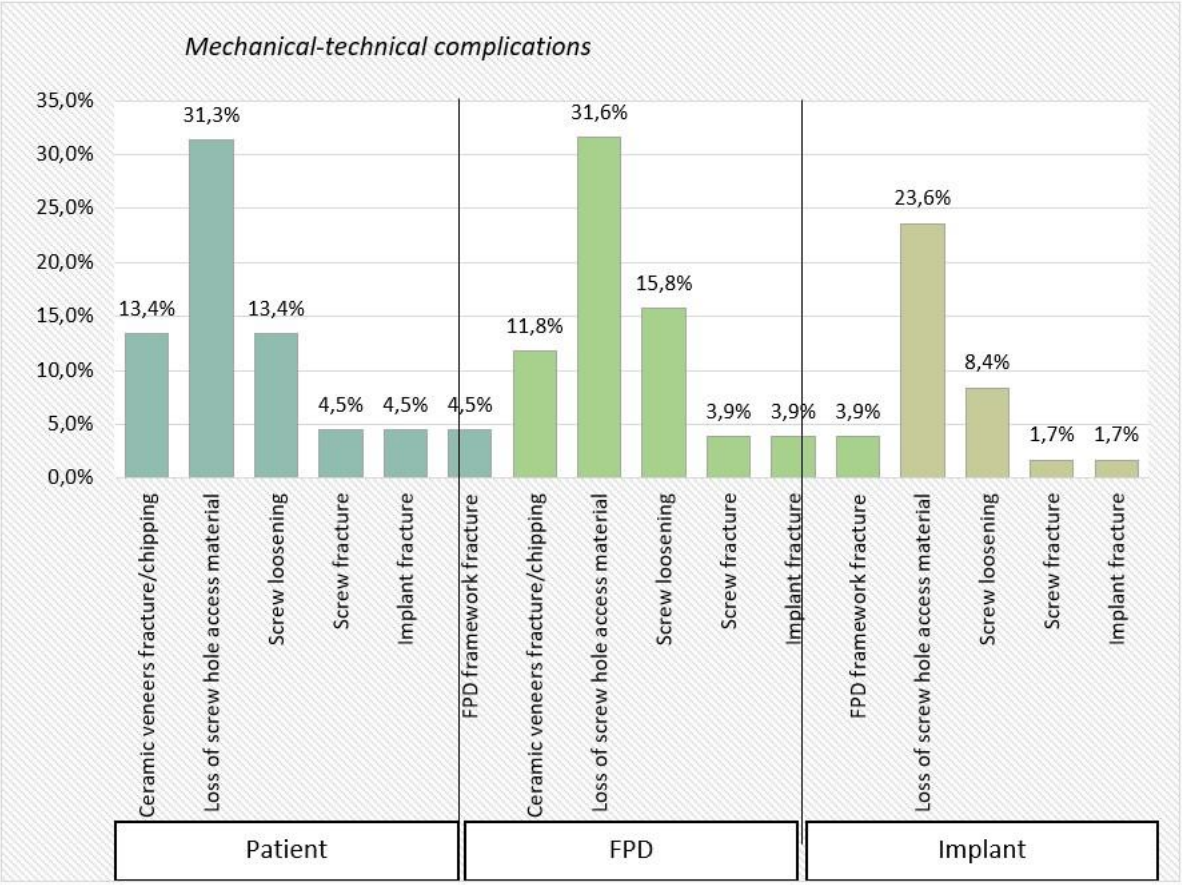


Fig. 17. Data regarding mechanical/technical complications at patient/FPD/implant level

Table XXXII. Biological and mechanical/technical complications rates (at patient/FPD/implant level)

	Patients	FPD	Implants
N	67 (100%)	76 (100%)	178 (100%)
Biological complications (peri-implantitis)	12 (17,9%)	12 (15,8%)	24 (13,5%)
Mechanical/technical complications	24 (35,8%)	27 (35,5%)	51 (28,7%)
Ceramic veneers fracture/chipping	9 (13,4%)	9 (11,8%)	
FPD framework fracture	3 (4,5%)	3 (3,9%)	
Loss of screw access hole	21 (31,3%)	24 (31,6%)	42 (23,6%)
Screw loosening	9 (13,4%)	12 (15,8%)	15 (8,4%)
Screw fracture	3 (4,5%)	3 (3,9%)	3 (1,7%)
Implant fracture	3 (4,5%)	3 (3,9%)	3 (1,7%)

Discussions

Biological and mechanical/technical complications in metal-ceramic implant-supported fixed partial dentures have a direct influence on the decrease of the success rate of the implant-prosthetic therapy. This personal study evaluated the rates of the biological and mechanical/technical complications at implant, FPD and patient level.

The rates of peri-implantitis (13,5% at implant level; 17,9% at patient level) reported in our study were in range with literature data for implant-supported FPD with mean follow-up >5-year.

Lee et al (2017) performed a systematic review of the prevalence of peri- implant pathology at the implant and patient level, including only clinical trials with a mean follow-up period of at least 3 years. The weighted average prevalence of peri-implantitis at implant and subject level was 9,25% and 19,83%, respectively. The weighted mean prevalence of peri-implant mucositis based on implant and patient was 29,48% and 46,83%, respectively. The research group concluded that the prevalence of peri-implantitis has increased over time; the prevalence of peri- implantitis and peri-mucositis does not show a high level of association, these values being influenced by distinct variables.

The reported rates of the biological complications in fixed partial dentures with implant support were reviewed by Wada et al (2021).

The prevalence of peri-mucositis ranged from 23,9% to 88,0% at the patient level and from 9,7% to 81,0% at the implant level, while peri-implantitis prevalence varied between 8,9%-45,0% at the patient level and 4,8%-23,0% at the implant level.

The highest rates of peri-implantitis were reported by Derks et al (2016) with 24,9% at implant level and 45% at patient level (mean follow-up 8,9yr), followed by Aguirre-Zorzano et al (2015) with 9,8% at implant level and 15,1% at patient level (mean follow-up 5,3yr), and Dalago et al (2017) with 7,3% at implant level and 16,4% at patient level (mean follow-up 5,6yr).

When biological complications in the implant-supported fixed partial dentures are reported as „soft tissue inflammation", the range of frequencies is higher (20,2% to 53,0%) at 5 years follow-up (Heydecke et al, 2012).

Mechanical and technical complications are a major risk in implant dentistry leading to increased rates of repairs and remakes as well as the drainage of time and financial resources for patients (Salvi & Brägger, 2009).

In our study, the prevalence of the mechanical and technical complications was 28,7% at implant level, and 35,8% at patient level. These data confirmed reports of reviews of literature (Heydecke et al, 2012, Hanif et al, 2017; Sailer et al, 2018). The frequency of the loss of screw access hole material, fracture or chipping of ceramic veneers, screw loosening, screw or implant fractures was reported by a few studies with a minimum 5-years follow-up.

Kreissl et al, (2007) found screw loosening (6,7%) followed by screw fracture (3,9%) as the most frequent mechanical complications, while fracture/chipping of the veneering ceramic was the most frequent technical complication (5,7% of FPD). A systematic review performed by Heydecke et al (2012) highlighted the ceramic veneers fractures as the most frequent complication in implant-supported FPD (frequency up to 58,1%) at 5 years follow-up, followed by abutment screw loosening and/or abutment screw fracture (3,2%- 16,0%). Sailer et al (2018) reported for 5-year follow-up 11,6% rate of ceramic veneers fracture/chipping but only 0.2% of the metal-ceramic implant-supported FPD failed and had to be replaced due to this technical complication.

Despite these data, practitioners must consider the possibility to prevent most of these complications by proper selection of patients, individualized treatment planning considering the specific risk factors as well as interdisciplinary collaboration in the treatment of the complex cases (Negm, 2016).

Comparison and interpretation of the reported data must be done with caution due to the heterogeneity of definitions and studies design proposed by different research groups (Heydecke et al, 2012; Lee et al, 2017; Wada et al, 2021).

Conclusions

- Implants abutments of 3-5 units fixed partial dentures exhibited very high survival rates (96,6%); however, rates of biological complications (peri-implantitis) were 13,5% at implant level and 28,7% of implants had at least one mechanical complication.

- The most frequent mechanical/technical complications were the loss of screw access hole material, followed by ceramic veneers fracture/chipping, and screw loosening.

- Diagnostic of complications and additional intervention are required in early stages to prevent the failure of the implant-prosthetic therapy.

1.4.3. Survival and prosthetic success of fixed partial dentures supported by either abutment teeth or implants: a retrospective study

Aims of study :

- Comparison of the survival and prosthetic success rates of the metal-ceramic FPD with support on natural teeth versus dental implants.
- Evaluation of the survival and prosthetic success rates of the metal-ceramic FPD (with support either on natural teeth and implants) in relation to individual patients' parameters.

Materials and method

The research was designed as a retrospective study including 126 edentulous patients (mean age 60,48 ± 11,459 yr ; gender 46/80) treated by metal- ceramic fixed partial dentures with natural teeth or dental implants support.

Inclusion criteria:

- age >18 years;
- reduced posterior edentation;
- prosthetic treatment with metal- ceramic FPD with centric pontic or cantilever type;
- follow-up >5 years from prosthetic reconstruction.

Exclusion criteria:

- systemic pathology that could affect abutment teeth or implants (non-compliant to periodontal maintenance sessions.

The study was performed accordingly to the requirements of the 1975 Helsinki Declaration revised in 2008 and CONSORT Guidelines. Written informed consent was obtained from all patients before enrollment. The patients were divided in two study groups:

- Study group A (n=74)- metal-ceramic implants- supported FPD (n=88);
- Study group B (n=52)- metal-ceramic teeth- supported FPD (n=64)

The data regarding biological complications of abutments and FPD and mechanical/technical complications of FPD were collected from patient files and radiographic examens. All patients were examined during the yearly regular visit for FPD, abutments, surrounding hard and soft tissues and patient satisfaction.

The prosthetic success rates were calculated for each study group as well as in relation to demographic and individual patients' parameters.

A surviving FPD is defined as the FPD remaining in situ with or without modification for the entire monitoring period (Sailer et al, 2018).

Features of the study groups (parameters of patients and fixed partial dentures) are exposed in tables XXXIII and XXXIV. There were no significant differences in demographic parameters (gender, age groups) both in overall patients and between study groups.

Table XXXIII. Study groups features- demographic and individual parameters (Group A- Teeth-supported FPD vs. Group B- Implant-supported FPD)

	Study group A	Study group B	Total	p
Ns (%)	74 (58,7%)	52 (41,3%)	126 (100%)	
Age, m ± SD	58,35 ± 11,228	63,50 ± 11,203	60,48 ± 11,459	
Age group, Ns(%)				,086
40-60 yr	34 (45,9%)	16 (30,8%)	50 (39,7%)	
>60 yr	40 (54,1%)	36 (69,2%)	76 (60,3%)	
Gendre, Ns(%)				,262
M	30 (40,5%)	16 (30,8%)	46 (36,5%)	
F	44 (59,5%)	36 (69,2%)	80 (63,5%)	
Smoking, Ns(%)				,647
No	54 (73,0%)	36 (69,2%)	90 (71,4%)	
Yes	20 (27,0%)	16 (30,8%)	36 (28,6%)	
Periodontal disease history, Ns(%)				,009**
Yes	34 (45,9%)	12 (23,1%)	46 (36,5%)	
No	40 (54,1%)	40 (76,9%)	80 (63,5%)	
Oral hygiene (mPI), Ns(%)				,005**
0	28 (37,8%)	26 (50,0%)	54 (42,9%)	
1	20 (27,0%)	22 (42,3%)	42 (33,3%)	
2	16 (21,6%)	2 (3,8%)	18 (14,3%)	
3	10 (13,5%)	2 (3,8%)	12 (9,5%)	

Table XXXIV. Study groups features- parameters of fixed partial dentures (Group A- Teeth-supported FPD vs. Group B- Implants-supported FPD)

	Study group A	Study group B	Total
Ns (%)	88 (57,9%)	64 (42,1%)	152 (100%)
Fixed prostheses, Ns(%)			
Classic FPD	80 (90,9%)	54 (84,4%)	134 (88,2%)
FPD- cantilever type	8 (9,1%)	10 (15,6%)	18 (11,8%)
Units number (report abutment/pontic), Ns(%)			
Cantilever FPD 2/1 (D)	54 (2,3%)	-	54 (1,3%)
Cantilever FPD 2/1 (M)	4 (4,5%)	-	4 (2,6%)
Cantilever FPD 2/3 (M)	54 (2,3%)	-	54 (1,3%)
Classic FPD 3 (2/1)	52 (59,1%)	38 (59,4%)	90 (59,2%)
Classic FPD 4 (2/2)	18 (20,5%)	4 (6,3%)	22 (14,5%)
Classic FPD 4 (3/1)	8 (9,1%)	20 (31,3%)	28 (18,4%)
Classic FPD 5 (2/3)	2 (2,3%)	-	54 (1,3%)
Classic FPD 5 (4/1)	-	2 (3,1%)	54 (1,3%)
Follow-up (yr), Ns(%)			
5-10	32 (36,4%)	46 (71,9%)	78 (51,3%)
>10	56 (63,6%)	18 (28,1%)	74 (48,7%)
Location, Ns(%)			
MD	58 (65,9%)	32 (50,0%)	90 (59,2%)
MX	30 (34,1%)	32 (50,0%)	62 (40,8%)
Location (quadrant), Ns(%)			
1	16 (18,2%)	12 (18,8%)	28 (18,4%)
2	14 (15,9%)	20 (31,3%)	34 (22,4%)
3	22 (25,0%)	14 (21,9%)	36 (23,7%)
4	36 (40,9%)	18 (28,1%)	54 (35,5%)

Results

Survival rates were 92,1% for overall patients (fixed partial dentures supported by abutments either teeth or implants) (fig. 18.a).

Survival rate of teeth- supported FPD was 90,6% while survival rate of implants-supported FPD was 93,2% (fig. 18.b).

The prosthetic success was 68,4% for overall patients (fixed partial dentures supported by abutments either teeth or implants) (fig. 19.a).

The prosthetic success of teeth-supported FPD was 63,6%, while prosthetic success of implants-supported FPD was 75% (fig. 19.b).

The statistical analysis found the absence of significant statistical differences between the group of teeth-supported FPD and implant- supported FPD, regarding the rates of survival (p=0,564) (Table XXXV).

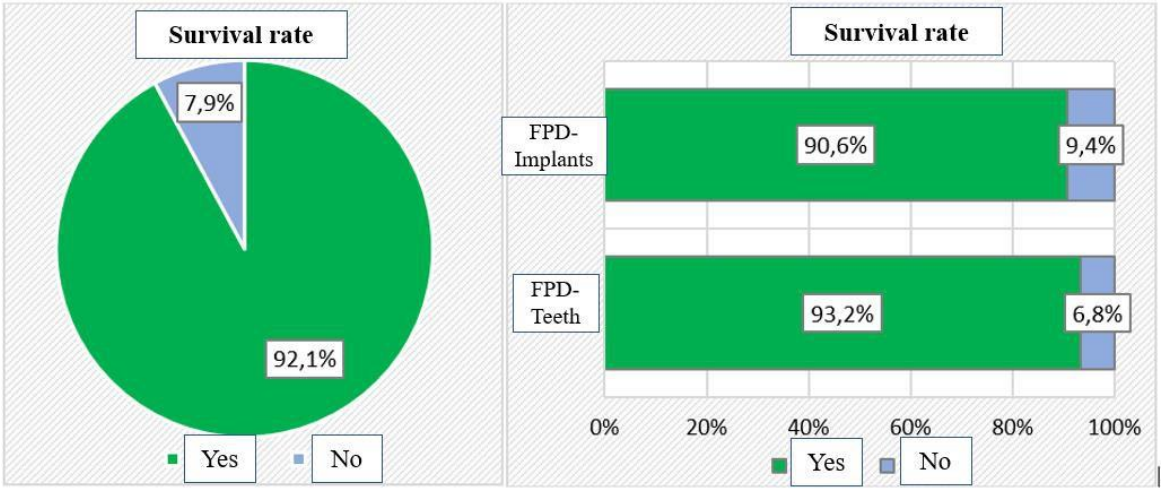
The statistical analysis found the absence of significant statistical differences between the group of teeth-supported FPD and implant- supported FPD, regarding the prosthetic success (p= 0,137) (Table XXXVI).

Table XXXV. Rate of survival
(teeth-supported FPD vs. implant-supported FPD)

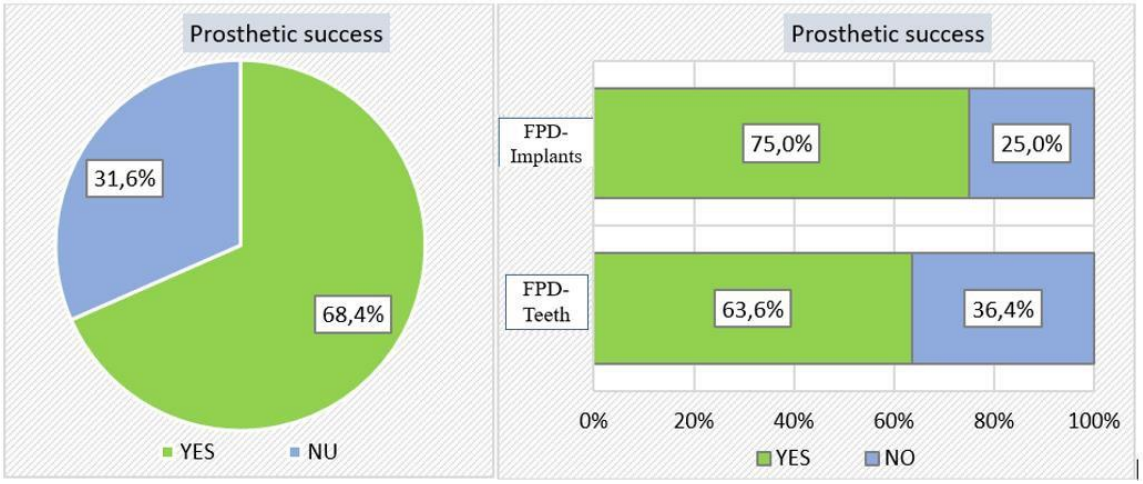
Survival, Ns(%)	Group A (teeth-supported FPD)	Group A (implant-supported FPD)	Total	Pearson Chi-pătrat	p
YES	82 (93,2%)	58 (90,6%)	140 (92,1%)	,333	,564
NO	6 (6,8%)	6 (9,4%)	12 (7,9%)		

Table XXXVI. Rate of prosthetic success
(teeth-supported FPD vs. implant-supported FPD)

Prosthetic success, Ns(%)	Group A (teeth-supported FPD)	Group A (implant-supported FPD)	Total	Pearson Chi-pătrat	p
YES	56 (63,6%)	48 (75,0%)	104 (68,4%)	2,214	,137
NO	32 (36,4%)	16 (25,0%)	48 (31,6%)		



Figures 18.a-b. Survival rates
(overall; teeth-supported FPD; implants-supported FPD)



Figures 19.a-b. Prosthetic success
(overall; teeth-supported FPD; implants-supported FPD)

Discussions

Our research aimed to compare survival and prosthetic success of the FPD supported by either natural teeth or dental implants. The prosthetic success was considered for surviving FPD without complications. This definition of the prosthetic success is valid despite the recommendation of some research group for using USPHS modified criteria (Pol et al, 2022; Spies et al, 2018; Naenni et al,2015). In both classification systems, the prosthetic success is considered when FPD are free of framework fracture, veneering fracture/chipping, loosening of the restoration, loss of screw access hole, occlusal wear, poor marginal adaptation, poor anatomical form. The inclusion of patients treated by same practitioner allowed the evaluation of subjects treated by a standardized protocol.

There is a large amount of information on dental implant- supported restorations, in contrast to the limited information available on the clinical performance of teeth-supported restorations. A few reviews (Le et al, 2015; Pjetursson et al, 2018) highlighted the fact that a small number of studies compared the survival and success rate of the FPD with teeth support versus implants support (Pjetursson et al, 2004, 2007; Pol et al,2022).

Our results showed non-significant statistical differences between the survival rates of the two categories of FPD, while prosthetic success was higher for implant- supported FPD. These results support data reported by of Pol et al (2018, 2022) regarding the similar clinical performance of fixed partial dentures supported by abutments either teeth or dental implants. Also, a review by Sailer et al (2018) reported, for an estimated 5-year complication rate for metal-ceramic FPD, a total complications rate of 15.1%; 84.9% of the metal-ceramic implant-supported FPD were free of biological or mechanical/technical complications at the end of the monitoring period. In our study, total complications rate of implant- supported FPD was 25%; the higher mean value can be explained by higher follow-up period, as 71,9% of FPDs were assessed after 5-10 year of follow-up, and 28,1% had a follow-up >10 year. For a mean follow-up of 41 months, Pol et al (2018) reported a 99% survival rate for teeth-supported FPD, and 98,7% survival rate for implant- supported FPD. A second study (Pol et al,2022), with a mean follow-up of 52 months, found out a 91,7% survival rate for teeth- supported FPD, and 100% survival rate for implant-supported FPD. Survival rates recorded in our study were lower (90,6% for teeth-supported FPD; 93,6% for implant-supported FPD). Two factors can contribute to these differences: higher mean follow-up of prosthetic reconstructions in our study (36,4% 5-10 yr follow-up; 63,6% >10 yr follow-up); 3-units FPD (Pol et al,2022) vs. 3-5 units FPD in our personal study. For higher mean follow-up, Tallarico et al. (2018) reported 89,2% 10-year survival of teeth supported FPD and 86.7% 10-year survival of implant-

supported FPD. The survival rates of teeth-supported FPD decreased gradually with time at (Bart et al,2012). A systematic review of Heydecke et al (2012) regarding studies performed on 2-4 implants FPD, reported a survival rate of 98.9% (98.5–99.3%) at 5 years and a 97,8% survival rate > 10 years (96.9–97.6%). Using modified USPHS criteria, Pol et al (2022) reported 87,5% prosthetic success (scores Alpha and Bravo) for implant-supported FPD and 91,7% prosthetic success for teeth-supported FPD. In our study, prosthetic success rates were lower for both FPD categories (75% for implant-supported FPD, 63,6% for teeth- supported FPD). The factors reminded previously can also contribute to the differences between rates of prosthetic success. Tallarico et al. (2018) reported in a systematic review as follows: 10-year survival of teeth supported FPD was 89.2% compared to 86.7% for implant-supported fixed partial prosthetic restorations. Despite the high survival rates, Tallarico et al (2018) reported frequent biological and technical complications in the case of 10- year survival implant-supported FPD (38.7%) when compared to teeth-supported FPD (15.7%). Bart et al (2012) evaluated biological and technical complications for teeth-supported FPD with 7-19 years (mean: 14 years). It was reported high survival rates (90.4% at 10 years; 80.5% at 15 years). 79,7% of all FPD remained free from any complication/failure at 10 years and only 34.6% at 15 years. The research group concluded that freedom from complications and failures was drastically decreased for teeth-supported FPD in function for longer than 10 years (Bart et al,2012). Multiple factors that can lead to failure (incorrect/incomplete assessment of the patient, non-compliance with the operating and maintenance protocol, failure to identify some risk factors as history of periodontitis/smoking, incorrect choice of the implant type, biomechanical features). In the interpretation of the results reported by various systematic reviews of the literature, the definitions of success and survival, respectively the criteria used to evaluate the data differ greatly between different studies (Meijer et al, 2007; Patel et al, 2014). Prosthetic success rate can be overestimated, considering fixed prosthetic restorations that are found in situ but need replacement (Needleman et al., 2012).

Conclusions

- Survival rates of teeth- and implants-supported FPD were high (93,2% vs. 90,6%, respectively) for both categories of prosthetic restorations.
- Higher rates of prosthetic success were recorded for implant- supported FPD (75%) comparing to teeth-supported FPD patients (63,6%).
- Implant-supported fixed prosthetic restorations are a valid therapeutic solution in patients with short edentation and poor prognostic of abutment.

Chapter 2

CLINICAL AND EXPERIMENTAL STUDIES ON BIOMATERIALS USED IN ALVEOLAR BONE RECONSTRUCTION IN IMPLANT-PROSTHETIC THERAPY

2.1. *IN VIVO* STUDIES ON THE SUCCESS OF DIFFERENT BONE REGENERATION BIOMATERIALS IN ALVEOLAR BONE RECONSTRUCTION BY GUIDED BONE REGENERATION TECHNIQUE

State of art:

The implant-prosthetic treatment plan must pay particular attention to the alveolar bone reconstruction stage through guided bone regeneration techniques that will ensure the optimal positioning of dental implants in the context of restoring biomechanical and functional conditions through fixed or removable prosthetic restorations with implant support. A functional and stable mandibular implant-prosthetic restoration in posterior area can be compromised in the long term due to shape and orientation of the residual alveolar bone, improper sagittal intermaxillary relationships as well as the presence of mandibular inferior nerves. These clinical situations require the enhancement of the alveolar bone volume and quality for long-term success of the implant-prosthetic therapy. However, the high density and low vascularization of the mandibular cortical bone can hinder an effective grafting on the mandible body or regeneration processes of some bone chambers ().

The selection of techniques and materials must be performed in relation to the local, loco-regional and systemic parameters and the possible therapeutic solutions (Forna et al., 2011). The choice of the guided regeneration techniques, surgical protocol, bone addition materials and barrier membranes influence directly and indirectly the dental implants success rate as well as intensity and distribution of the occlusal forces that will be transmitted to future prosthetic restoration and mucosal and bone support. The accurate selection of both alveolar bone reconstructive techniques and graft materials in the proimplant stage has a major importance in the success rate of implant-prosthetic therapy as mechanical stability of the dental implants is highly correlated with osseointegration (Javed et al, 2013).

The long-term success of implant- prosthetic therapy is highly dependent by implant osseointegration ("direct structural and functional connection between surface alveolar bone and the surface of a loadbearing artificial implant") in alveolar bone with optimal volume and quality (Goto, 2014; Sheikh et al, 2015). Bone reconstruction is requested in patients with bone volume reduced due to tooth loss before implant placement, or due to periodontitis or trauma (Javed et al, 2013), to allow proper implants positioning and long-term outcome of the implant-prosthetic therapy (Tolstunov et al, 2019; Urban & Monje, 2019; Wessing et al, 2018).

Patients with complications of partial edentation (masticatory and physiognomic disorders, dental migration, periodontal disorders, occlusal imbalances) represent a challenge for specialists in prosthetics, implantology and oral surgery. Guided bone regeneration techniques use a wide range of grafting materials (autologous bone, allografts, xenografts, alloplastic materials) and resorbable and non-resorbable membranes. These techniques can be performed, in relation to local conditions and pathology, through standard bone addition protocols, in combination with sinus lifting techniques or through specific techniques (S-

GBR). The loss of vertical alveolar bone height conducts to surgical difficulties and anatomical limitations (Rochietta et al, 2008). The proper use of the guided tissues regeneration techniques and materials for patients candidate to dental implants represents a major factor for the long-term success of implant-prosthetic restorations (Sheikh et al., 2015). The aim is to increase the graft integration rate by stimulating vascularization and cellular migration phenomena of osteogenic cells among the graft particles. Many techniques have proved success both in horizontal (Elnayef et al, 2015; Gorgis et al, 2021) andvertical (Plonka et al, 2018; Khoury et al, 2019) augmentation of the atrophic maxillary and mandible.

Various biomaterials applied into the alveolar bone defects and considered on-the-board options include autogenic, allogenic, xenografts, and synthetic biomaterials (Kumar et al, 2013). The categories of the bone grafting biomaterials used in the alveolar reconstruction are as follows (Mittal et al, 2016):

- autogenous grafts- obtained from the same patient, taken from one site and placed in implant site, having the advantage of including minerals, collagen, active osteoblasts and bone morphogenic proteins that contributes to the formation of new bone by osteogenesis and osteoinduction;
- allograft bones- obtained from individuals of the same specimen, usually the source is cadaver bone, in the form of freeze-dried bone or demineralized freeze-dried bone; the disadvantages would be little or no osteogenicity, increased immunogenic potential, higher resorbtion rate than autogenous bone;
- alloplastic grafts- synthetic biocompatible and osteoconductive materials (hydroxiapatite, calcium phosphates, bioactive glasses, biocompatible composite polymers); nowadays are recommended some advanced synthetic bioactive resorbable bone graft materials with similar properties as the host bone;
- xenografts- obtained from the inorganic portion of animal bones (most common source is bovine bone); the inorganic components provide a natural matrix and a source of calcium; the disadvantage is the abssence of osteogenicity and low resorption rate. The autogenic grafts are recommended for the absence of immunological responses and high-volume augmented bone, while they exhibit higher infection rate. Xenografts (bovine, porcine origin) are largely used due to their low- content inflammatory reactions, high longevity (Nistor, 2017). Alloplastic grafts (hydroxyapatite, tricalcium phosphate, bioactive glass) have the advantages of high volume available, low amount of residual graft (tricalcium phosphate) and higher new-born bone tissue comparing to xenografts (Murphy et al, 2016). Most studies investigated graft materials as Bio-Oss (from xenograft category) and β-TCP (from alloplastic grafts). The research groups consider these materials as the most predictable, sustainable, and with the least infection rates in implant therapy (Sawada et al, 2018; Shamsoddin et al, 2019).

The kit for PRGF obtained by Endoret (BTI) technology contains single use kits (1 Kit: 4 tubes for collecting blood / 2 tubes for fractions preparation/ 1 activator / 1 seringe/ transferring sonde/ winged for blood collection). Endoret technology allows the blood collection during one single session and manufacturing of PRGF in four formulas. PRGF formulas (Endoret product):

- Liquid (plasma obtained from fraction 2, activated with Endoret activator based on calcium chlorure)- for submucosal infiltration and the activation of dental implants for the osseointegration acceleration;
- Graft produced by combination of Hypro-Oss with fraction 2 (plasma activated with Endoret activator based on calcium chlorure)- for the rehabilitation of bone deffect;
- Fibrine membrane:

An updated classification of the bone addition biomaterials was proposed by Zhao et al, (2021). In this classification the bone grafting materials are divided in five categories:

1. Natural bone. Bone substitute materials:
    - Autogenous bone;
    - Allograft materials (demineralized bone matrix);
    - Xenograft materials (bovine or porcine bone, chitosan);
    - Phytogenic materials (materials based on corals or various species of algae).
2. Synthetic bone substitutes
    - Hydroxyapatite;
    - Ceramic beta-tricalcium phosphate;
    - Calcium sulfate;
    - Polymers;
    - Calcium phosphate cements;
    - Metals.
3. Composite bone substitutes:
    - NanoBone;
    - Fortoss Vital;
    - SmartBone.
4. Bone substitutes with infusion of vital osteogenic cells:
    - Dent osteotransplantation;
    - Bioseed-Oral Bone.
5. Bone substitutes with growth factors:
    - Osigraft;
    - Augmentation;
    - Infused.

The surgical techniques used for the reconstruction of implant sites with grafting biomaterials are the following (Bucur, 2012): bone augmentation techniques (onlay/inlay bone blocks); guided bone regeneration techniques (GBR); sinus lifting associated with bone addition techniques; apposition grafting (appositional osteoplasty); interposition grafting (interpositional osteoplasty); addition techniques with subperiosteal tunneling; surgical techniques of alveolar bone expansion; surgical techniques of alveolar bone elongation; distraction osteogenesis. In vertical alveolar ridge augmentation, the height of alveolar bone (< 4, 4-6, > 6 mm) is a factor that influence the decision tree that include sections where clinician must consider anatomical, clinical, and patient-related factors influencing for guidance in the optimal treatment modality and sequence for predictable management of resorbed alveolar ridge (Plonka et al, 2018). In horizontal augmentation clinician must consider both the bone width available at the site of implant placement ($\geq$ 3.5 mm, <3.5 mm, 4-5 mm) as well as bone thickness, implant site position, availability of autogenous bone to choose the most predictable horizontal ridge augmentation procedure (Fu & Wang, 2011).

Guided tissue regeneration techniques use grafting materials with an osteogenic, osteoinductive or osteoconductive role that allow restoration of resorbed implant sites. Sealing the alveolar bone addition materials as rigorously as possible and ensuring the closure of the flap with tension-free sutures are requested conditions for the formation of a very good quality bone (Urban et al,2019). GBR technique involves the use of membranes as a barrier to epithelial proliferation and as a stimulating environment for osteogenesis allowing tissues to regenerate the bone defect by blocking invasion with unwanted cells (Khojasteh et al, 2017). Non-resorbable titanium, zirconium or titanium-reinforced membranes (with potential for wound infection after exposure of e-PTFE membranes) or resorbable membranes (reduced ability to create and maintain bone regeneration compartment space, rapid degradation) are highlighted in a systematic review of GBR techniques used in pro- implant stage (Liu & Kerns,

2014). Guided bone regeneration of posterior maxillary areas can be combined with sinus lifting technique in the case of implant sites with reduced height and thickness in the posterior areas of the maxillary arch as follows: post-extraction, severe periodontal damage, severe bone resorption, reduced distance between the highest point of the alveolar ridge and the sinus floor, the extension of the sinus in the area initially occupied by the dental roots (Esposito et al, 2010; 2014). The sinus lifting technique has the following advantages: obtaining a sufficient bone volume; stability and mechanical resistance of the graft; implants have minimal exposure; reducing the rate of postoperative complications; stability of dental implants) (Hansen et al, 2011). However, according to Kang et al (2019), sinus lifting, bone grafting, and vertical ridge augmentation performed simultaneously increase the postoperative complications rate and decreases the implant survival. This research group recommends delayed implant placement when alveolar augmentation must be combined with sinus lifting.

S-GBR technique ("Screw-Guided Bone Regeneration") allows excellent results for mandibular edentulous patients with moderate or severe atrophy of the alveolar bone (Toeroek et al, 2013 a,b). S- GBR technique uses a membrane delimiting the regenerative bone compartment supported by osteosynthesis screws or dental implants. S-GBR technique is mainly recommended for horizontal augmentation of mandibular alveolar bone with moderate or severe horizontal resorption, using a combination of autologous bone, xenografts, resorbable or non-resorbable membranes. S-GBR technique allows to maintain the regenerative bone space due to osteosynthesis screws that support the space of the bone regeneration compartment, while pericardial membraneto protect the area from regeneration from soft tissue invasion). Excellent results were recorded at 24 month post-operatory by research groups assessing implant- prosthetic therapy with alveolar bone reconstruction by S-GBR technique (Török et al, 2021; Agop-Forna et al, 2021; Toeroek et al, 2013 a, b). Considering these issues, we focused our research on a particular technique used in our dental practice that allows us to obtain excellent results for mandibular edentulous patients with mild- to-moderate atrophy of alveolar bone (Toeroek et al, 2013a,b). S-GBR is mostly recommended to the lateral augmentation of the mandibular alveolar bone with moderate or severe horizontal resorption, by using a combination of autograft, xenograft, resorbable or non-resorbable membranes. Other GBR techniques use non-resorbable titanium-, zirconium-, or titanium-reinforced membranes (with potential for wound infection following the exposure of e-PTFE membranes) or resorbable membranes (poor space-making ability, fast degradation) (Liu et al, 2008). The significant difference between S-GBR technique and other techniques used in the horizontal augmentation of the alveolar crest is the system used for the maintenance of the regenerative bone space (osteosynthesis screws as space holders, pericardium membrane to protect the graft material from soft tissue invasion), with lower rate of complications.

Every surgical technique has advantages and disadvantages, but specialists should give priority to those procedures which are easy-to-use (according to the practical experience of the clinician), less invasive, have lower risk of complications, and allow osteointegration of dental implants within the shortest post-operatory time (Chiapasco et al, 2009). Data are controversial regarding the success rate on medium and long term due to low quality of methodology (poor sample size, undefined success criteria, short-term follow-up) (Chiapasco et al, 2009). A scientifically validated opinion on which is the best technique and grafting materials is hard to obtain, especially in posterior mandible area. Due to vertical and horizontal bone resorption, augmentation procedures require a minimal surgical technique aiming to avoid soft tissue dehiscence above the bone regeneration compartment. The use of minimally invasive tunneling technique in the reconstruction of horizontally bone defects is associated with difficulty in the positioning and maintenance of the grafted bone in coronal position to increase the area of the peri-implant soft tissues (Le et al, 2008). The success of the lateral ridge

augmentation depends on the experience of operator and by ability to stabilize and maintain the graft at the alveolar crest. In large alveolar defects the maintaining of the stability of the grafted areas becomes even more difficult when using this technique (Le et al, 2008). The success of GBR techniques is more predictable when used to patients with mild to moderate horizontal alveolar bone resorption and small edentulous span that allows simultaneous placement of implants. Variants of GBR techniques that use tenting mechanisms can prevent collapse of the soft tissues and bone resorption (Le et al, 2008). The comparisons and interpretation of the literature data is difficult due to differences in parameters such as the alveolar bone location, treatment protocol, treatment duration and postoperative check-up, as well as different criteria for evaluation (Zhang et al, 2022).

Publications on this topic:

1.Török, B.; Török, R.; Dohan Ehrenfest, D.M.; **Agop-Forna, D**.; Dascălu, C.; Forna, N.C. Study of Immediate Implants Placed in Mandibular Alveolar Bone Reconstructed with Screw-Guided Bone Regeneration Technique: A 24-Months Follow-Up. *Appl. Sci*. 2021, 11, 6054. https://doi.org/10.3390/app11136054 FI=2,7
2.**Agop-Forna, D**.; Török, R.; Török, B.; Dragomir, R.; Ehrenfest, D.M.D.; Dascălu, C.; Stelea, C.G. Postoperative Study of Bone Gain in Mandibular Alveolar Bone Reconstructed with Screw-Guided Bone Regeneration Technique and Porcine-Derived Xenograft in 42 Edentulous Patient Candidates for Implant-Prosthetic Therapy. *Appl. Sci*. 2021, 11, 9826. FI=2,7
3.**Doriana Agop-Forna**, Roland Török, Bianca Török, Cosmin Cretu, Cristian Budacu, Norina Forna. Guided bone regeneration techniques in alveolar bone reconstruction. *Rom. J. Oral Rehabil 2022*; 14(4): 176-186. FI=0,7

2.1.1. Immediate Implants Placed in Mandibular Alveolar Bone Reconstructed with Screw-Guided Bone Regeneration Technique: A 24-Months Follow-Up.

Aim of study was to test whether implants inserted in posterior mandible sites augmented with porcine-derived xenograft in screw-guided bone regeneration technique differ from implants placed in non-grafted sites regarding success rate, survival rate, interproximal marginal bone level (MBL), and clinical parameters of peri-implant soft tissues.

Materials and method

Patient Selection and Study Design

The prospective cohort study was conducted at Implant Institute Török (Nuernberg, Germany) between December 2017 and December 2020. The study adhered to the ethical values of the Declaration of Helsinki and received approval of ethics committee of U.M.F. "Grigore T.Popa" Iasi (Romania) (Nr. 10833) Among the patients who visited the dental clinic, 20 edentulous patients (mean age 59.45 ± 15.220) were selected (Table XXXVII). All patients involved in study received information about the objectives of the research and gave informed consent. Inclusion criteria (test group) were age >18 years; partially edentulous posterior mandible; severe horizontal resorption of ridges; treatment with fixed implant-supported prosthesis. Additional inclusion criteria for control group: alveolar bone of minimum 10 mm length and minimum 3.8 mm diameter. Exclusion criteria were: insufficient alveolar bone for implant-prosthetic therapy; history of untreated periodontal disease; history

of smoking; decompensated metabolic diseases; pregnancy; history of bisphosphonates therapy; severe bruxism; non-collaborative patients. The selected patients were grouped as follows:

- Test group (n = 10; 30 implants): simultaneous implant placement with ridge augmentation by S-GBR technique.
- Control group (n = 10; 32 implants): implant placement in naturally healed sites (non-grafted).

The components of the study design (population, intervention, comparison, outcomes) are exposed in Table XXXVIII.

Table XXXVII. Characteristics of test and control group.

	Test Group (S-GBR Sites)	Control Group (Non-Grafted Sites)	Total
N of subjects (Ns)	10	10	40
N of sites (Ni)	30	32	124
Mean age (range)	(62.30 ± 16.059)	(56.60 ± 14.159)	(59.45 ± 15.220)
Gender			
Men, Ns (Ni)	4 (12)	6 (18)	10 (30)
Women, Ns (Ni)	6 (18)	4 (14)	10 (32)

N, number; Ns, number of subjects; Ni, number of sites (implants).

Table XXXVIII. PICO components in study design

Component	Description
Population (P)	Mandibular edentulous patients requiring bone grafting and dental implants
Intervention (I)	Augmentation of alveolar bone by S-GBR technique. Immediate implant placement in grafted sites
Comparison (C)	Implant placement in non-grafted sites
Outcomes (O)	Primary outcomes: implants success; implants survival Secondary outcomes: clinical parameters of soft tissues: mPI, mGI, probing depth (mm), keratinized mucosa (mm), occurrence of peri-mucositis/peri-implantitis (%); marginal-bone-level (MBL) (mm);

Surgical Procedures

The same surgeon (T.R.), with over 20 years of experience, performed alveolar augmentation and implant procedures. For all patients, systemic antibiotics were given prophylactic preoperatively and at 4 days postoperatively. The procedures of dental implants insertion for test group and control were as follows:

(a) Dental implants placement simultaneously with alveolar augmentation by SGBR technique (xenograft, or a mixture with autogenous bone; porcine collagen membrane) (test group);

(b) Standard dental implants placement (control group).

The stages of the surgical protocol of S-GBR technique and immediate implant placement are described further.

1. Analysis of alveolar ridge parameters and the decision to apply the S-GBR technique;
2. Placement of screws for osteosynthesis at the level of the vestibular face of the alveolar ridge, at an angle of 45^0 in relation to the alveolar ridge;
3. The space created by the screws is filled with xenograft bone substitute (do not cover with the non-resorbable membrane)
4. The entire area is covered with resorbable collagen membrane (protection of the surgical site, stimulation of healing processes);
5. Monitoring the clinical aspect of the grafted area at 6-7 months;

6. Reopening the site and checking the unformed bone tissue in the inter-screw spaces;
7. Removal of osteosynthesis screws.

Prosthetic loading was carried out after 14–16 weeks following implants placement in the mandible. Each patient was included in a maintenance program consisting of oral hygiene and recall visit every 6 months.

Results Analysis

The clinical and radiographic analysis of the parameters related to the primary out- comes and secondary outcomes was performed by one investigator (T.B) at 24-months post-loading. Criteria for the success of S-GBR grafting procedure were: absence of fistula, flow out from mucosal dehiscence of the particles of the graft material, or the chronic inflammation.

Buser criteria, used to define the implant success, are as follows: the absence of pain, the absence of implant mobility, the absence of recurrent peri-implant infection, the absence of peri-implant radiolucency at 6 months and 24 months post-loading (Buser et al, 19990.

Diagnostic of peri-implant mucositis (Berglundh et al, 2018; Heitz-Mayfeld et al, 2020):

(1) Clinical inflammation signs (erythema, swelling, bleeding on probing at force not overpassing 0.25 N, and/or suppuration) (Lang et al, 2011)

(2) Mild increase of probing depth.

(3) Absence of peri-implant bone loss (after post-loading stage of bone remodeling).

Diagnostic of peri-implantitis (Berglundh et al, 2018; Heitz-Mayfeld et al, 2020):

(1) Clinical inflammation signs (erythema, swelling, bleeding on probing and/or suppuration);

(2) Probing depth >3 mm, and/or recession of the mucosal margin.

(3) Loss of peri-implant bone >3 mm (from implant shoulder).

Indices mPI and mGI were used to evaluate the status of the peri-implant soft tissues (Tables XXXIX and XL) (Mombelli et al, 1987, 1998; Salvi et a, 2004). Probing Depth (PD) (mm) was evaluated with periodontal probe (Click-Probe®, Kerr, Bioggio, Switzerland).

Table XXXIX. mPI Indice (peri-implant bacterial plaque accumulation

Score	Description
0	Undetected bacterial plaque
1	Bacterial plaque detected by peri-implant probing
2	Bacterial plaque detected by visual inspection
3	Peri-implant abundant white materia

Table XL. mGI Indice (peri-implant soft tissues status).

Score	Description
0	No bleeding when the periodontal probe is passed along the peri-implant mucosal margin
1	Isolated bleeding spots
2	Bleeding line on mucosal margin
3	Heavy bleeding; profuse bleeding

Keratinized Mucosa (KM) (mm) was measured with periodontal probe (Click-Probe®, Kerr) as the distance between the mucogingival junction and the most coronal point of the keratinized mucosa in the center of the implant-prosthetic restoration

The marginal bone loss at buccal area (MBL) at 24-months follow-up was measured on

CBCT as the distance between the connection implant-abutment and the peri-implant MBL.

Statistical Analysis

Using the statistical software G*Power (Version 3.1.9, Heinrich-Heine-University, Düsseldorf, Germany), a sample of 9 subjects in each group was calculated as minimum number required to determine a significant statistical difference in marginal bone level loss, success rate and survival rate of implants (80% power, 5% confidence level). Considering a dropout rate of 10% during the study period, 10 subjects were included in each group. The frequencies distributions were calculated for qualitative variables, while the aver- ages and standard deviations for the quantitative ones. The normality of data distribution was checked by Shapiro–Wilks test. The comparison of the quantitative variables between test group and control was performed by using t-test and Mann-Whitney test. The com- parison of the qualitative variables between test group and control was performed by using Chi-squared test. The significance level was set at $p < 0.05$. Statistical analysis was performed using SPSS version 27.0 for Windows (IBM, Armonk, NY. USA).

Results

Plaque levels (mPI) were significantly higher ($p = 0.046$) in S-GBR group (0.97 ± 0.882 mm) when compared with control (0.66 ± 0.695 mm) (Table V).

Keratinized mucosa width (KM) was higher in S-GBR group (4.13 ± 1.033 mm) than control (3.34 ± 0.821 mm), with statistically significant differences ($p = 0.000$) (Table XLI).

Probing depth (PD) width was higher in S-GBR group (3.50 ± 1.372 mm) than control (2.56 ± 1.332 mm), with statistically significant differences ($p = 0.000$) (Table XLI).

Modified gingival index (mGI) was higher among implants placed in S-GBR group (0.90 ± 1.020 mm) than control (0.56 ± 0.794 mm), although differences were not statistically significant between groups (p-0.061) (Table XLI).

The difference between the average bone loss (MBL) for implants in Group S-GBR (2.20 ± 1.867 mm) and for implants placed in non-grafted sites (Group B: 1.09 ± 1.678 mm) was statistically significant ($p = 0.000$) (Table XLI).

Table XLI. Clinical parameters and radiographic results at 24-months follow-up.

	S-GBR Group	Control	p-Value
Mean Plaque Index (mPI) (mm)	0.97 ± 0.882 (SD)	0.66 ± 0.695 (SD)	0.046 *
Keratinized mucosa (KM)	4.13 ± 1.033 (SD)	3.34 ± 0.821 (SD)	0.000 **
Probing Depth (PD) (mm)	3.50 ± 1.372 (SD)	2.56 ± 1.332 (SD)	0.000 **
Mean mGI	0.90 ± 1.020 (SD)	0.56 ± 0.794 (SD)	0.061
mGI (scores)			
Score 0	43.3%	56.3%	
Score 1	36.7%	37.5%	0.075
Score 2	6.7%	0.0%	
Score 3	13.3%	6.3%	
MBL (mm)	2.20 ± 1.867 (SD)	1.09 ± 1.678 (SD)	0.000 **

* Statistically significant, $p < 0.05$; ** Statistically highly significant, $p < 0.01$.

The success rate and the survival rate were higher for control when compared with S-GBR group after 24-months follow-up (Table XLII).

Table XLII. Success rate and survival rate at 24-months follow-up.

	S-GBR Group	Control	p-Value
Success rate	76.7%	90.6%	0.001 **
Survival rate	86.7%	93.8%	0.182

** Statistically highly significant, $p < 0.01$.

The overall implant success rate at 24-month follow-up was 76.7% in S-GBR group and 90.6% in control group, with significant differences between groups ($p = 0.001$).

The survival rate after 24-month follow-up was 86.7% in S-GBR group and 93.8% in control group, without statistically significant differences although differences between groups ($p = 0.182$).

Discussions

This study compared clinical and radiographic parameters of the implant-supported fixed restorations, following immediate implants placement in sites grafted by the S- GBR technique.

A condition of the implants success rate when placed in grafted sites is the absence of post-operatory early complications due to exposure or improper stabilization of bone graft as well as to post-operatory infection. In our study, post-grafting complications, that could interfere with implants osseointegration processes, were absent. The absence of the risk factors (due to the selection criteria of patients) could contribute significantly in maximizing the rate of the grafting procedures success (Moy et al, 2019). However, Dastaran et al. (2019) found that the implant survival rate is not influenced by alveolar bone augmentation, despite higher complications rate for implants inserted in sites with vertical and horizontal resorption.

The S-GBR technique was performed using mixed grafts (autologous bone and bovine bone). Based on reviewed studies, with a follow-up of minimum 3–5 years, Elakkiya et al. (2017) recommend the replacement of allografts and xenografts with autologous bone in the implant sites with medium and severe bone resorption (Ellakiya et al, 2017). Xenografts can delay bone formation in comparison to the naturally healed sites, but also preserve the alveolar ridge and stimulate bone formation as to enable placement of implants with a high success rate in mandibular implant-prosthetic restorations (Li et al, 2013).

Our study investigated the success rate and survival rate of immediate implants placed in alveolar bone reconstructed by the S-GBR technique. Immediate implant placement simultaneously with alveolar bone grafting had been well investigated in some systematic review. One study reported, at 20-month follow-up, the absence of statistically significant differences regarding various clinical parameters of the peri-implant soft tissue and peri-implant marginal bone loss, between the immediate implants and delayed implants (Pellicer-Chover et al, 2014).

In our study, we found a higher probing depth ($p = 0.000$), mGI index ($p = 0.061$), and average bone loss ($p = 0.000$) for immediate implants placed in grafted sites, when compared with naturally healed sites at 24-month follow-up. However, implant placement simultaneous with horizontal ridge augmentation is recommended when possible as implant survival rates are similar to subsequent implant placement (Wessing et al, 2018). We found after 24-month follow-up an implant success rate of 76.7% in the S-GBR group, while the survival rate was 86.7%. The statistical analysis revealed the lack of significant statistical differences regarding the survival rate, but statistically significant differences for success rate when comparing S-GBR sites and non-grafted sites.

According to a comprehensive review of studies, implants placed with GBR techniques had a mean 95.5% rate of survival for follow-ups of 5–74 months (Aghaloo et al, 2007). The survival rate of the implants inserted in augmented sites, irrespective of the surgical technique, ranged from 91.7% to 100%, while survival rates for non-grafted sites ranged between 93.2% and 100% at follow-up periods of 1–5 years (Donos et al, 2008). A review of studies with 1–3 years follow-up found non-significant changes in peri-implant soft tissue clinical parameters and marginal bone levels when lateral bone augmentation techniques are used (Schwarz et al,

2018). The implant survival rate for the alveolar bone submitted to lateral ridge augmentation was 97% to 100% at 6–12 months of follow-up (Elnayef et al, 2018).

At 24 months follow-up, the probing depth and the peri-implant marginal bone loss are higher than the control group. This result is correlated with a higher resorption rate of the augmented alveolar area when compared with the implants placed in naturally healed alveolar bone. However, S-GBR is an augmentation technique with a very low rate of complications (Toeroek et al, 2013). The only complication could be the exposure of the osteosynthesis screw, managed by taking out the screw without any need for anesthesia.

An interesting research issue would be the comparison of the results obtained with the S-GBR technique and immediate implantation when used in combination with different graft materials. Further studies will be published by our research group to report the influence of the graft material on the success and survival rate of dental implants placed in mandibular alveolar bone.

The S-GBR technique is an easy method to regenerate the bone around implants and can be used in the daily work by every practitioner. The big advantage of this method is the low complication rate and the protection offered by the osteosynthesis screws to the augmented side against the compression forces in the oral cavity.

The comparison and interpretation of the results with those reported by the literature must be done with caution as various factors impact the long-term success of the implant-prosthetic restorations (Schwarz et al., 2018; Elnayef et al., 2018; Sakka et al., 2012; Smeets et al., 2016; Topalo, 2019; Ionescu et al., 2019).

Literature data is scarce in studies investigating the results of the implant-prosthetic treatments in simultaneous approach (augmentation technique combined with immediate implantation). Also, the success of the dental implants following immediate implantation in mandibular sites reconstructed with S-GBR technique, was not yet investigated.

Further studies can highlight the benefits and limits of this augmentation technique and can establish specific clinical situations when this technique can be recommended.

The limitations of this study are related to insufficient follow-up which is not enough to establish long-term survival rate of the implants, low sample size, and possible subjective bias of the investigators.

Conclusions

- The reconstruction of the alveolar bone using S-GBR technique and porcine-derived xenograft is a valid guided bone regeneration strategy for mandibular alveolar bone with severe horizontal resorption.

- The selection of S-GBR technique and grafting biomaterials should be based on specific indications as implants placed in grafted sites recorded worse marginal success rate, survival rate and bone resorption than those placed in non-grafted sites.

2.1.2. Postoperative Study of Bone Gain in Mandibular Alveolar Bone Reconstructed with Screw-Guided Bone Regeneration Technique and Porcine-Derived Xenograft in 42 Edentulous Patient Candidates for Implant-Prosthetic Therapy

Aim of study was to test whether alveolar bone gain (width and osteodensity) in mandible implant sites, augmented by the screw-guided bone regeneration (S-GBR) technique and the porcine- derived xenograft, differ from that of the mandible sites reconstructed with S-GBR and the bovine- derived xenograft.

Materials and method

Patients Selection Study Design

The prospective cohort study was conducted at the Implant Institute Török (Nuern- berg, Germany) between December 2018 and May 2020. The study adhered to the ethical values of the Declaration of Helsinki and received the approval of the ethics committee of UMF "Grigore T. Popa", Ias, i, Romania (Nr.10833). Among the patients who visited the dental clinic, 42 edentulous patients (mean age 54, 60 ± 14, 90; age 40–79) were selected. All patients involved in the study received information about the objectives of the research and gave informed consent. Inclusion criteria (test group) were as follows: age > 18 years; partially edentulous posterior and anterior mandible; moderate or severe horizontal and vertical resorption of ridges; treatment with fixed implant-supported prosthesis. Exclusion criteria were as follows: history of untreated periodontal disease; history of smoking, alco- hol, drugs consumed; immunosuppression; decompensated metabolic diseases; pregnancy; history of bisphosphonates therapy; severe bruxism; noncompliant patients. The selected patients were grouped as follows:

•Test group (n = 20; 36 implants sites): implant sites augmentation with S-GBR technique and porcine-derived xenograft THE Graft (Purgo Biologics, Seongnam- si, Korea);

•Control group (n = 22; 50 implants sites): implant sites augmentation with S-GBR tech- nique and bovine-derived xenograft CompactBone B (Dentegris GmBH, Rheinberg, Germany).

The characteristics of the test and control groups are shown in Table XLIII. The components of the study design (population, intervention, comparison, and outcomes) are shown in Table XLIV.

Table XLIII. Characteristics of test and control group

	Test Group (S-GBR + Bovine-Derived Xenograft)	Control Group (S-GBR + Porcine-Derived Xenograft)	Total
N of subjects (Ns)	20 (47.6%)	22 (52.4%)	42
N of sites (Ni)	36 (41.9%)	50 (58.1%)	86 (100.0%)
Age groups			
age 40–59, Ni (%)	16 (44.4%)	24 (48.0%)	40 (46.5%)
age 60–79, Ni (%)	20 (55.6%)	26 (52.0%)	46 (53.5%)
Gender			
M, Ni (%)	16 (44.4%)	24 (48.0%)	40 (46.5%)
F, Ni (%)	20 (55.6%)	26 (52.0%)	46 (53.5%)
Dental group			
Anterior, Ni (%)	10 (27.8%)	16 (32.0%)	26 (30.2%)
Posterior, Ni (%)	26 (72.2%)	34 (68.0%)	60 (69.8%)

N—number; Ns—number of subjects; Ni—number of implant sites (dental implants).

Table XLIV. Study design (PICO). Components.

Component	Description
Population (P)	Mandibular edentulous patients requiring alveolar bone grafting and implant-prosthetic therapy
Intervention (I)	1. Control group: Alveolar bone augmentation by S-GBR technique with bovine-derived xenograft (CompactBone). Immediate implant placement. 2. Test group: Alveolar bone augmentation by S-GBR with porcine-derived xenograft (Purgo). Immediate implant placement.
Comparison (C)	1. Intra-group: gender; age group; location 2. Inter-groups: Control (S-GBR + bovine-derived xenograft) vs. Test (S-GBR + porcine-derived xenograft)
Outcome (O)	Bone gain at 6 months follow-up (width and osteodensity)

Description of Surgical Protocol

The same surgeon (T.R.), with over 20 years of experience in alveolar bone augmentation techniques and implant-prosthetic therapy, performed the S-GBR technique and the immediate implant placement. For all patients, systemic antibiotics were given prophylactically preoperatively and at 4 days postoperatively. The surgical procedures for the test group and the control group were as follows:

(a) Dental implants placement simultaneously with alveolar augmentation by S-GBR technique (mixture of autogenous bone with autogenous bone 90:10; porcine pericar- dial collagen membrane) (test group);

(b) Dental implants placement simultaneously with alveolar augmentation by S-GBR technique (mixture of bovine xenograft with autogenous bone 90:10; porcine pericar- dial collagen membrane) (control group).

The stages of the surgical protocol of S-GBR technique and immediate implant placement are described further.

1. Analysis of alveolar ridge parameters and the decision to apply the S-GBR technique;
2. Placement of screws for osteosynthesis at the level of the vestibular face of the alveolar ridge, at an angle of 45^0 in relation to the alveolar ridge;
3. The space created by the screws is filled with xenograft bone substitute (do not cover with the non-resorbable membrane)
4. The entire area is covered with resorbable collagen membrane (protection of the surgical site, stimulation of healing processes);
5. Monitoring the clinical aspect of the grafted area at 6-7 months;
6. Reopening the site and checking the unformed bone tissue in the inter-screw spaces;
7. Removal of osteosynthesis screws.

Prosthetic loading was carried out after 14–16 weeks following implants placement in the mandible. Each patient was included in a maintenance program consisting of oral hygiene and recall visit every 6 months.

Evaluation of Clinical and Bone Parameters

The evaluation of the preoperative clinical parameters and at 6 months follow-up was performed by one investigator (T.B.). Criteria for the success of S-GBR grafting procedure were as follows: absence of fistula; flow out of the particles of the graft material; chronic inflammation. Implant success was defined according to Buser criteria: absent pain; lack of implant mobility or recurrent peri-implant infection; absence of peri-implant radiolucency at 6 months post-loading (Buser et al, 1999).

The CBCT exam (Sirona Orthophos XG) was used to record width and osteodensity values of the implant sites. CBCT scanning conditions were a s follows: 85 kV, 6 mA, 14.4 s irradiation time, 25–1025 µSv irradiation dose, and 1 mm slices thickness. CBCT images

were stored in DICOM file. An independent radiologist that was not involved in the study performed all the bone parameters measurements (preoperative, 6 months follow-up).

Standardized measurements were taken for alveolar width preoperative and at 6 months postoperative. Implant sites width was measured before teeth extractions and 6 months after augmentation procedures. The osteodensity bone values were evaluated immediately after implant placement and at 6 months follow-up. Sidexis XG/ DVT (Densply/Sirona) software was used for the measurement of the width alveolar bone parameters at baseline and at 6 months follow-up. Width measurements were taken 3 mm, 5 mm, and 10 mm, respectively, from the crest at 3 intervals: the mesiodistal midpoint of the edentulous area and 3 mm mesial and distal to the midpoint. A mean value of width was calculated for each implant site preoperatively and at 6 months postoperatively. NNT Viewer/CT (NewTom) software was used to record the osteodensity values at baseline and at 6 months postoperative. The measurement of the preoperative osteodensity was performed immediately after implant placement and at 6 months follow-up. The bone density was measured in the areas adjacent to the implant, to the midpoint level.

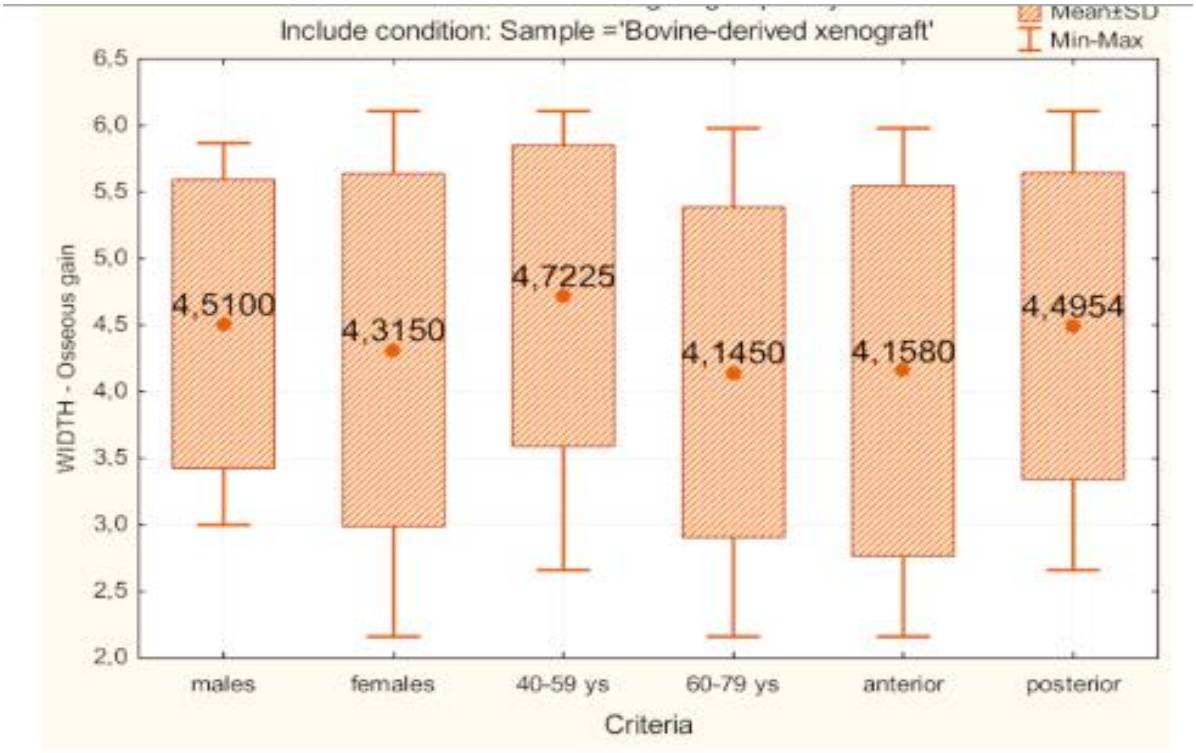
Statistical Analysis

Statistical tests were used to compare the bone gain of the implant sites (width and osteodensity) at 6 months postoperative. The frequencies distributions were calculated for qualitative variables, while the averages and standard deviations were calculated for the quantitative variables. The normality of data distribution was checked with the Shapiro–Wilk test. The comparison of the quantitative variables between the test group and the control group was performed by using a t-test and the Mann–Whitney test. The comparison of the qualitative variables between the test group and the control group was performed by using the chi-square test. We tested whether the differences recorded between preoperative and postoperative values for the three parameters (width and osteodensity) were statistically significant. The Wilcoxon test was used for paired samples. The significance level was set at $p < 0.05$. Statistical analysis was performed using SPSS version 27.0 for Windows (IBM, Armonk, NY, USA).

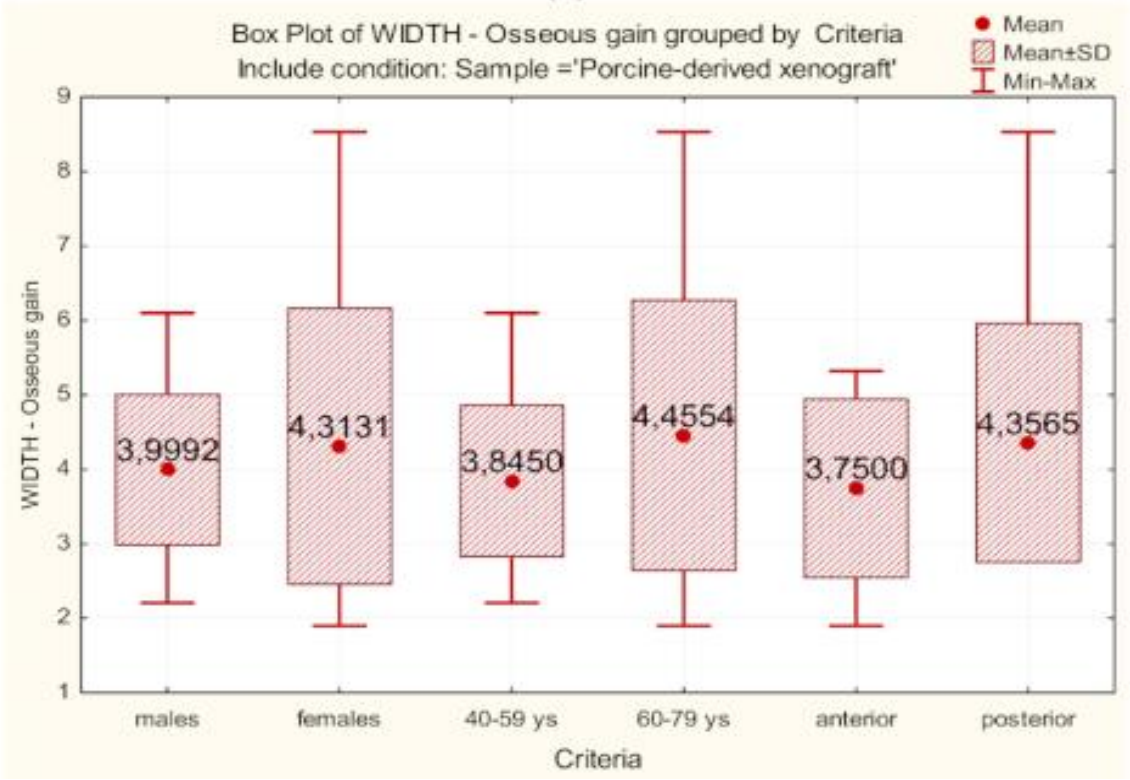
Results

We compared, at the intra-group level, the average values of the bone gain (width and osteodensity) for sex, age groups, and the location of the augmented implant sites. The bone gain (width) values for each group are presented in figures 20.a-b. In the control group (S-GBR + bovine xenograft), the bone gain (width) was higher in male patients (4.5100 mm vs. 4.3150 mm), age group 40–59 years (4.7225 mm vs. 4.1450 mm), and the posterior dental group (4.4954 mm vs. 4.1580 mm). In the test group (S-GBR + porcine xenograft), the bone gain (width) was higher in female patients (6.4885 mm vs. 5.2075 mm), age group 60–79 (6.5185 mm vs. 5.1750 mm), and the posterior dental group(6.0971 mm vs. 5.3988 mm). The bone gain (osteodensity) values for each group are presented in figures 21.a-b. In the control group (S-GBR + bovine xenograft), the bone gain (osteodensity) was higher in female patients (319.90 HU vs. 4.3150 mm), age group 40–59 years (303.00 HU vs.255.90 HU), and the anterior dental group (334.60 HU vs. 254.61 HU). In the test group (S-GBR + porcine xenograft), the bone gain (osteodensity) was higher in male patients (268.50 vs. 241.07 HU), age group 40–59 years (279.91 HU vs. 230.53 HU), and the posterior dental group (270.70 HU vs. 219.25 HU).

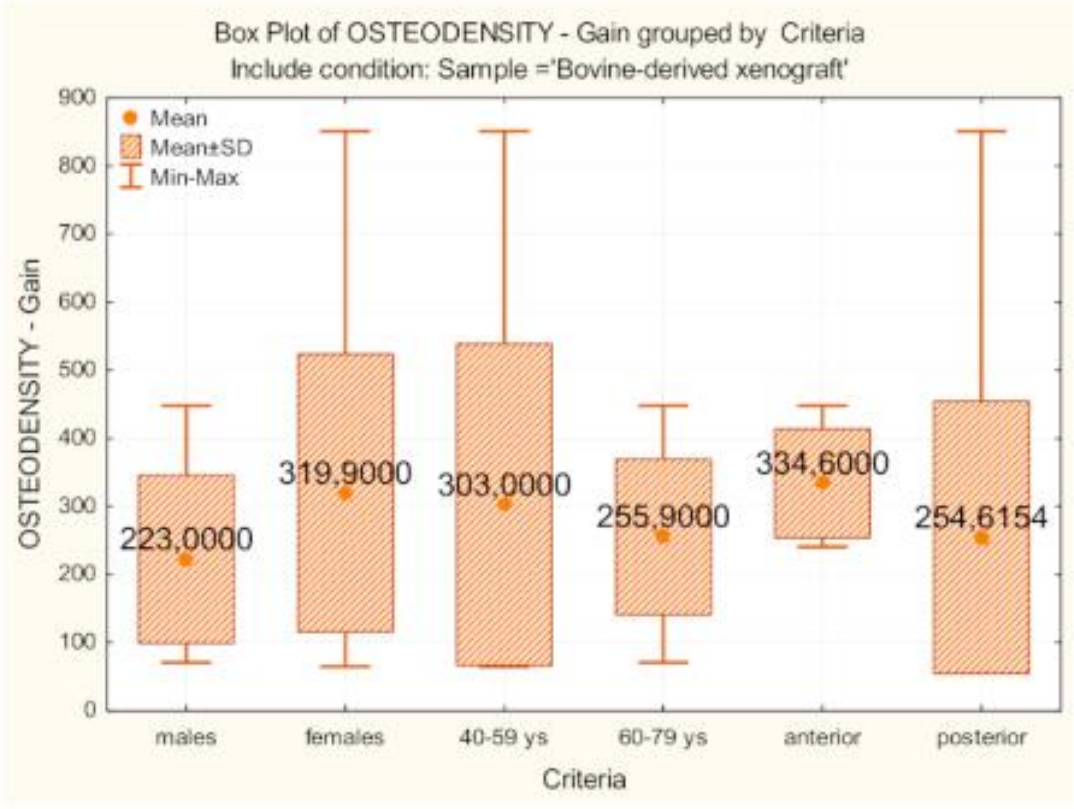
Intergroup comparisons regarding the bone gain (width and osteodensity) are pre- sented in Figure 3.a,b. The mean values (control group vs. test group) are as follows: width (4.107 mm vs. 4.1624 mm); osteodensity (276.83 HU vs. 254.24 HU).



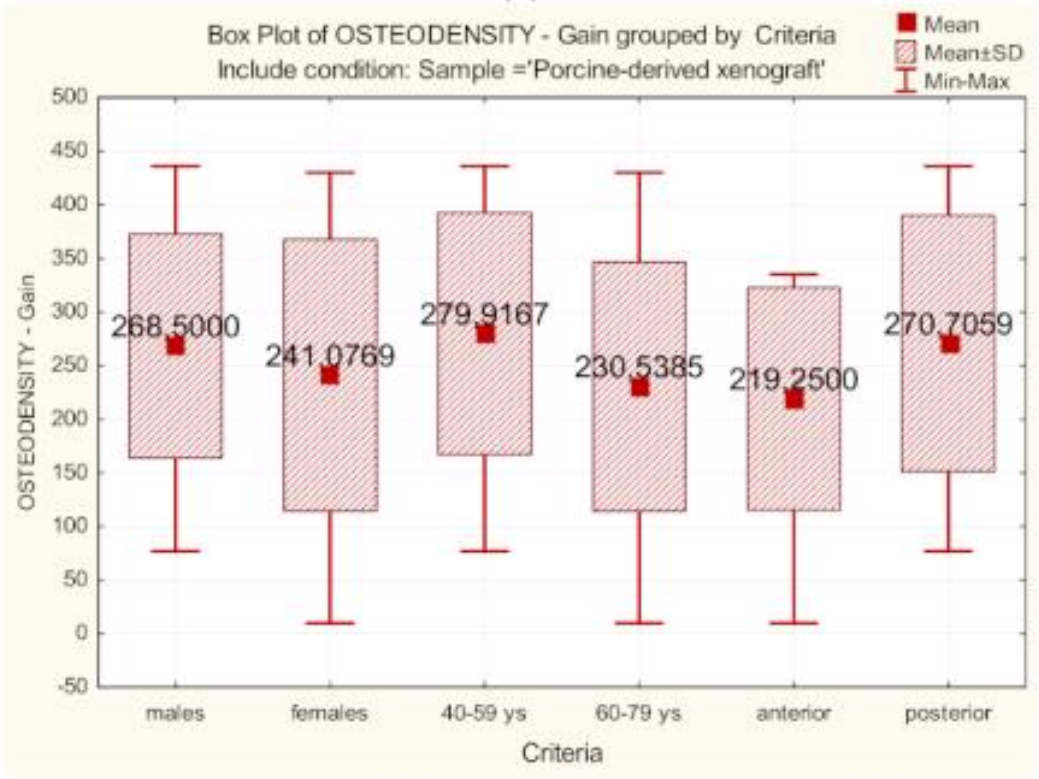
(a)



Figures 20.a-b. (a) Comparisons of bone gain (width) for sex, age groups, location of implant sites. Control group (S-GBR + bovine-derived xenograft). (b) Comparisons of bone gain (width) for sex, age groups, location of implant sites. Test group (S-GBR + porcine-derived xenograft).



(a)



(b)

Figures 21.a-b. (a) Comparisons of bone gain (osteodensity) for sex, age groups, location of implant sites. Control group (S-GBR + bovine-derived xenograft). (b) Comparisons of bone gain (osteodensity) for sex, age groups, location of implant sites. Test group (S-GBR + porcine-derived xenograft).

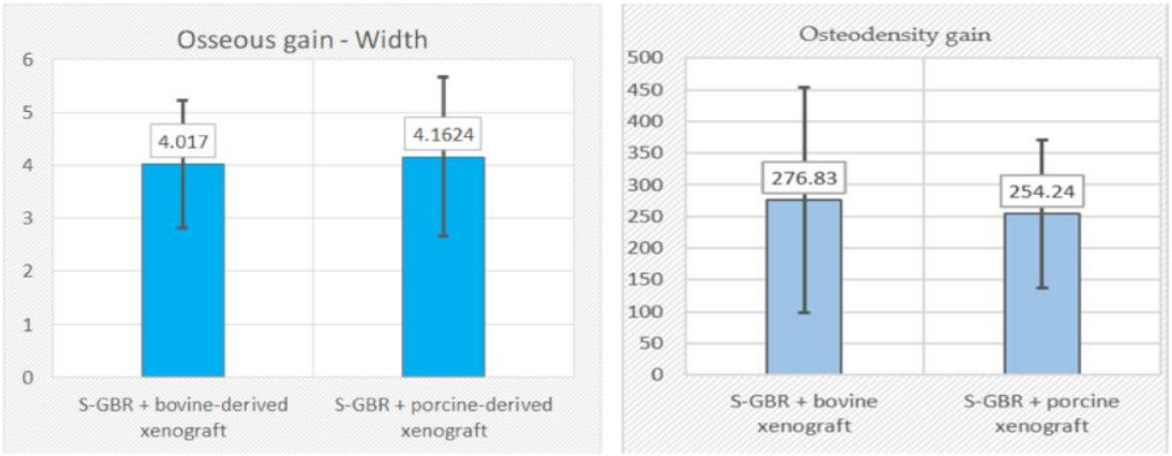


Figure 22. (a,b) Intergroup comparisons of bone gain (width, osteodensity) at 6 months follow-up. (S-GBR + bovine-derived xenograft group vs. S-GBR + porcine-derived xenograft group.).

The statistical analysis found the absence of statistically significant differences between the two groups regarding the bone gain at 6 months follow-up (width, osteodensity) (Table XLV).

Table XLV. Statistical comparisons between control and test groups (Width; Osteodensity)

	Group	Shapiro–Wilk Test		Mann–Whitney/ t-Student	
		Statistics	Sig. *p*	U/t Student	Sig. *p*
WIDTH– Bone gain	Control	0.938	0.045 *	738,000	0.156
	Test	0.890	0.000 **		
OSTEODENSITY– Bone gain	Control	0.823	0.000 **	896,000	0.972
	Test	0.964	0.125		

* Statistically significant, $p < 0.05$; ** Statistically highly significant, $p < 0.01$.

Discussions

Despite the numerous studies investigating the alveolar bone augmentation with xenografts of bovine origin, only a few have investigated the predictability and stability of the functional and aesthetic outcome following alveolar bone regeneration procedures with porcine-derived xenografts. A research group has highlighted the fear of patients regarding the possibility of transmitting bovine spongiform encephalopathy (BSE) with degenerative effects in the human brain through xenografts of bovine origin (Kim et al, 2016). The risk of foreign body reaction, at intervals of 2 to 10 years, must also be considered for bovine xenografts due to the absence of the biodegradation of the inorganic particles (Rodriguez et al, 2019). Other benefits of the porcine-derived xenografts are the similar anatomical, physiological, and genetic structure to human bone tissue, and the low risk of transmission of diseases from pig to human (Salamanca et al, 2015; Bracey et al, 2018).

We performed an immediate implant placement with simultaneous augmentation procedures, as the literature data report similar implant survival rates for immediate and delayed implant placements (Wessing et al, 2018). The survival rate of implants in the control and test groups was 100% at 6 months follow-up. The implant survival rate in the implant sites reconstructed by lateral ridge augmentation ranged from 97% to 100% at 6–12 months of follow-up (Elnayef et al, 2018).

Suggestions were made for the complete replacement of the xenografts with autologous bone in the implant sites with medium and severe alveolar resorption (Elakkiya et al,

2017). How- ever, we performed the augmentation procedures with a combination of autologous bone and xenografts in both the control group (bovine xenograft) and the test group (porcine xenograft) due to the limits of the autogenous bone as a unique graft material (i.e., morbidity at the donor site, lower availability, and dehiscence risk of the wound) (Herford & Nguyen, 2015). Moreover, some patients prefer nonautogenous bone grafts with fewer postoperative healing days, less pain, and a shorter recovery time (Chavda & Levin, 2018). Xenografts have many benefits when used in guided bone regeneration techniques due to their biocompatibility, osteoconduction, the low resorption rates, as well as their ability to maintain the volume of the regenerative compartment (Li et al, 2013). Porcine-derived bone graft materials have been recently promoted as alternative materi- als to autogenous bone in augmentation procedures due to their good physicochemical properties, high biocompatibility, their osteoconductive properties, and the development of different formulations that stimulate bone regeneration processes (Falacho et al, 2021; Salamanca et al, 2018).

Bone gains were recorded at 6 months follow-up in both groups of implant sites (control and test groups) for both measured parameters (width and osteodensity). The mean values found in our study for bone gains following the augmentation procedures and the immediate implant placement (S-GBR + bovine-derived xenograft vs. S-GBR + porcine-derived xenograft) are as follows: width (4.107 mm vs. 4.1624 mm); osteodensity (276.83 HU vs. 254.24 HU). The horizontal bone gain (width) was similar and without significant statistical differences between the implant sites reconstructed by the S-GBR technique and the bovine-derived xenograft and those reconstructed by the S-GBR technique and the porcine-derived xenograft. However, the osteodensity gain was higher in the implant sites reconstructed with the bovine-derived xenograft, but without significant statistical differences in comparison with the test group. These results could be related to the differences related to the structure and the physicochemical properties between the two categories of the xenografts. The porcine-derived xenograft used in the personal study (Purgo, Purgos Biologics, Seongnam-si, Korea) has a high degree of porosity (78.4%), a large specific surface area (SSA; 69.9 m2/g), a high degree of surface roughness (4.47 μm), and a significant percentage of pores with a diameter <100-nm. The degree of porosity is higher than that detected in the case of the bovine-derived xenografts and very close to the porosity of the human trabecular bone (79.3%), while the micropores and macropores play a crucial role in new bone formation (Lee et al, 2014). The osteoblasts have higher proliferation rates, higher rates of alkaline phosphatase synthesis, and mineral deposition on the extracellular matrix if they adhere to surfaces with micropores less than 100 nm diameter (Webster et al, 2000). The degree of hydrophilicity and the surface energy of the porcine-derived xenograft leads to high protein absorption rates, increased cell adhesion rates, and the stimulation of cell proliferation processes (Kubies et al, 2011; Rupp et al, 2014).

The statistical tests determined the absence of significant statistical differences be-tween the control and test groups at 6 months follow-up for all measured alveolar bone parameters. The average results of the horizontal bone gains (width) for the bovine-derived xenograft augmentation procedures obtained in our study were comparable with data reported by similar research (Elnayef et al,2018; Troeltzch et al, 2016; Urban et al, 2013; Mordenfeld et al, 2014; De Santis et al, 2021). Elnayef et al. (2018) have reported in a comprehen- sive review of the literature a net horizontal bone gain at follow-up of 2.86 ± 0.23 mm. Troeltzsch et al. (2016) have reported in a systematic review a mean horizontal gain of 4.5 ± 1.0 mm after alveolar bone augmentation techniques with mixtures of autogenous bone and xenogeneic grafting material. Urban et al. (2013) have found an average value of 5.68 mm horizontal bone gain in the lateral ridge augmentation techniques performed with autogenous bone and bovine bone-derived xenografts. Mordenfield et al. (2014) have reported for lateral ridge augmentation with bovine-derived xenograft and autoge- nous bone (90:10) a mean value of

the horizontal bone gain of 5.7 ± 1.0 mm. De Santis et al. (2021) have found a mean horizontal gain of 3.6 ± 0.8 mm and a mean vertical gain of 5.2 ± 1.1 mm in the augmentation of the mandibular alveolar defects using a combination of autogenous bone and bovine xenografts. Isik et al. (2021) have recorded, at 6 months follow-up, in a study that investigated the effectiveness of horizontal augmentation with the bovine-derived xenograft, the increase of the alveolar bone width with 1.34 ± 0.14 mm, 2.49 ± 0.24 mm, and 2.97 ± 0.24 mm at 2 mm, 4 mm, and 6 mm, respectively, below to the implant shoulder. Uzbek et al. (2014) have reported a significant increase of the osteodensity mean values (390 HU) following the alveolar augmentation procedures with the bovine-derived xenograft. A systematic review of the effectiveness of the natural and synthetic bone grafts used in the alveolar bone augmentation reported the absence of significant differences in the percentage of new bone between any two grafts and recommended the use of any category of xenografts in the enhancement of alveolar bone quality and volume prior to the insertion of the dental implants (Papageorgiou et al, 2016). Moreover, a recent review performed by Zaki et al. (2021) has highlighted the contribution of the guided bone regeneration procedures used during the immediate implant placement in the decrease of the horizontal buccal bone resorption and the improvement of the peri-implant soft tissue esthetics.

Most studies that investigate the effectiveness of the horizontal and vertical alveolar augmentation procedures are especially focused on the quantitative parameters (i.e., the vertical and horizontal bone gain). Bone quality, changes in the bone density, the volume of the bone defect, the proportion between autogenous bones, other graft materials when mixed grafts are used, and the type of membrane should also be defined so that oral sur- geons can make optimal decisions when performing alveolar bone regeneration techniques.

The limitations of this study are related to the low sample size, the low postoperative follow-up, and the possible subjective bias of the investigators during the stage of bone parameters measurements. Within these limitations, the data reported could contribute to a better understanding of the benefits of porcine-derived xenografts when used in guided bone regeneration techniques for the reconstruction of the implant sites and imme- diate implantation, as the literature data is scarce in studies comparing porcine-derived xenografts with other categories of additional materials, as well as in research focused on augmentation techniques combined with immediate implantation.

Conclusions

The horizontal bone and osteodensity gains in the porcine-derived group were simi- lar and without significant statistical differences when compared with the implant sites reconstructed with the bovine-derived xenografts group at 6 months postoperatively. The reconstruction of the mandibular alveolar bone by the S-GBR technique and the porcine-derived xenografts is a valid bone regeneration strategy for edentulous patients with moderate/severe horizontal resorption of the mandibular alveolar bone.

2.2. *IN VITRO* STUDIES ON GRAFTING BIOMATERIALS USED IN GUIDED BONE REGENERATION TECHNIQUES

State of art:

Bone defects resulting from trauma, tumor resection, or congenital abnormalities pose significant challenges in maxillofacial and orthopedic surgery. To restore the structure and function of the affected area, various biomaterials have been developed for bone reconstruction [Lu et al. 2013].

Biomaterials used in guided bone regeneration techniques are divided in four categories of bone grafts (autogenous bone, xenografts, alloplastic grafts) combined with barrier membranes. The placement of a barrier membrane to avoid the penetration of the non-osteogenic components (epithelial and connective tissue cells) in the bone compartment and interfering with bone regeneration processes is the primary principle of guided bone regeneration technique (Sasaki et al, 2021; Elgali et al, 2017). The barrier membranes used in the guided tissues regeneration techniques are bioactively components while the molecular and cellular activities inside the membrane are linked to the stimulation of the alveolar bone regeneration (Sasaki et al, 2021; Omar et al, 2019).

Intraoral bone reconstruction is a crucial aspect of oral and maxillofacial surgery, aimed at restoring the form, function, and aesthetics of the jawbone following trauma, tumor resection, or congenital defects. A variety of bone reconstruction materials are available, each possessing unique characteristics that influence their clinical performance and outcomes. Understanding the specific properties and capabilities of these materials is essential for making informed decisions regarding their selection and application in oral reconstructive procedures. This paper presents a comparative study on the characteristics of intraoral bone reconstruction materials, focusing on their physical, mechanical, and biological properties.

Bone reconstruction materials can be broadly classified into autogenous, allogeneic, xenogeneic, and synthetic types, each with its advantages and limitations. Autogenous grafts, such as autologous bone, have long been considered the gold standard due to their excellent osteogenic, osteoinductive, and osteoconductive properties [Calori GM et al.2011]. However, their limited availability, donor site morbidity, and associated surgical complications have led to the development of alternative materials.

Allogeneic grafts, obtained from human donors, offer a viable alternative to autogenous grafts, providing structural support and serving as a scaffold for new bone formation (Tsuchiya H. et al.2003). Xenogeneic grafts, derived from animal sources, possess osteoconductive properties and are widely used in bone reconstruction procedures (Schwartz Z et al. 1996). Synthetic bone substitutes, such as calcium phosphates and bioactive ceramics, offer predictable resorption rates, tunable physical properties, and the potential for functionalization to enhance biological interactions (Bose S et al. 2012). In recent years, biodegradable biomaterials have gained significant attention due to their ability to provide temporary support during the healing process and subsequently degrade, eliminating the need for implant removal (Böstman et al.2000). Among the biodegradable materials, magnesium-based alloys have shown promise for bone reconstruction applications due to their biocompatibility, mechanical properties, and biodegradability (Li et al. 2008).

The characteristics of bone reconstruction materials play a crucial role in their clinical applicability and success. Parameters such as biocompatibility, biodegradability, osteoconductivity, mechanical strength, and osseointegration potential determine the material's ability to facilitate new bone formation and maintain long-term stability. Comparative studies that systematically evaluate these characteristics provide valuable insights into material selection, surgical techniques, and treatment outcomes.

Ultimately, an in-depth understanding of the characteristics of intraoral bone reconstruction materials will contribute to improved treatment planning, surgical outcomes, and patient satisfaction. By advancing our knowledge in this field, we can enhance the success rates of bone reconstruction procedures, optimize the choice of materials based on individual patient needs, and contribute to the continuous evolution of oral and maxillofacial surgery.

The properties of an ideal membrane material are as follows: biocompatibility allowing tissue integration, space creation and maintenance inside bone deffect, selective permeability, excellent handling properties (Naung et al, 2019).

The barrier membranes are divided in two categories: resorbable collagen membranes and non-resorbable membranes such as dense-polytetrafluoroethylene (d-PTFE), expanded-polytetrafluoroethylene (e-PTFE), titanium mesh, and titanium-reinforced polytetrafluoroethylene (Sasaki et al, 2021; Soldatos et al, 2017). The resorbable membranes used in the guided bone regeneration techniques are natural and artificial polymer membranes (Zhang et al, 2022).

The wide variety of commercial barrier membranes presents a challenge for oral surgeons and implantologists regarding the selection of the optimal resorbable or non-resorbable barrier membrane in a specific clinical situation. Most studies reported similar outcomes regarding the level of vertical and lateral bone gain in guided bone regeneration techniques performed with both resorbable and non-resorbable membranes (Patil et al, 2023). In this context, clinicians must understand the physicochemical, mecanical and biologic properties of different materials in relation to their tissue origin (Caballé-Serrano et al, 2019). However, in the interpretation of the literature data provided by studies focused on the role of membranes in the guided tissue regeneration techniques, we must consider the relation between clinical outcomes and the clinician performance and experience, as well as medical history, periodontal history, oral hygiene or smoking (Zhang et al, 2022).

The non-resorbable membranes have clinical advantages and limits. Clinical advantages are as follows: ability to retain their structural integrity during implantation, biocompatibility, capacity to maintain the space inside bone deffect, decrease of the flap reflection, preservation of the keratinized gingival tissues. Limits are related to the potential for tissue irritation, the need for second surgical session for membrane removal, and the potential for bacterial growth on the membrane surface (Sasaki et al, 2021). Due to limits of the non-resorbable membranes, collagen membranes are still the most frequent used in the guided bone regeneration techniques due to scientific background and extensive clinical validation (Ren et al, 2022). The great advantages of the resorbable collagen membranes are hydrophilicity and easy of handling. Other benefits include (Zhang et al, 2022; Allaudin et al.,2022):

- low cost:
- guide for soft tissue healing;
- increased biocompatibility;
- protection of the immature bone tissue from soft tissue invasion;
- impermeable to cells, but permeable to nutrients;
- resorption capacity through enzymatic degradation without causing tissue irritation.

The limits of the native collagen membranes are the inability to maintain the proper space needed to cover severe bone defects (Soldatos et al, 2017; Turri etal, 2021).

The modified collagen membranes by crosslinking can provide better results in soft tissues and bone regeneration, due to better mechanical strength and degradation cycle (Ren et al, 2022). Despite excellent biocompatibility, unpredictable degradation profile of the collagen membranes can reduce the effectiveness of the guided bone regeneration techniques (Bozkurt et al, 2014). Large variations were reported regarding the biological behaviour of barrier membranes, due to differences related to their origin and

structure, which reflect on their clinical performance (Sbricoli et al, 2020). In this context, new resorbable membranes with dense collagen fibers provide better fitting to the bone and soft tissues, easier handling during suture stage, better membrane-bone and membrane-periosteum interface, and better protection of implant site from infection in case of accidental exposure by avoidance of membrane infection (Kilinc & Ataol, 2017). The mechanical and physicochemical properties of the resorbable membranes varies widely between commercial products. The importance of *in vitro* studies is highlighted by the influence of these properties on the clinical handling and long-term implant survival and success. Research groups highlights the need for more *in vitro* studies regarding adsorption, integration capacity and rate of degradation of the resorbable barrier membranes for better understanding of their clinical and biological behavior (Ren et al, 2022; Sbricoli et al, 2020; Caballé-Serrano et al, 2019).

Publications on this topic:

Doriana Agop Forna, Claudiu Topoliceanu, Ovidiu Stamatin, Corneliu Munteanu, Norina Forna. The biomechanical characteristics of intraoral bone reconstruction materials *Rom. J. Oral Rehabil 2023*;

Doriana Agop Forna, Corneliu Munteanu, Ovidiu Stamatin, Norin Forna, Marcelin Berchea, Siminiuc Petruta, Hutanu Vasile, Norina Forna. **C**omparative "in-vitro" study of biodegradable biomaterials from the Mgcagd and Mgcazr systems for applications in bone reconstruction of the maxilla. *Rom. J. Oral Rehabil 2023*; 15(2): 126-136.

Doriana Agop Forna, Alina Robu, Cristian Budacu, Marta Petre, Cristina Iordache, Claudiu Topoliceanu, Ovidiu Stamatin, Iulian Antoniac, Norina Forna. Study regarding the role of barrier membranes in guided bone regeneration techniques. *Rom. J. Oral Rehabil 2023*; 15(2): 13-25.

2.2.1. The biomechanical characteristics of intraoral bone reconstruction materials

Aim of study was to to conduct a comparative analysis of the characteristics of various intraoral bone reconstruction materials, considering their physical, mechanical, and biological attributes.

Materials and method

A comprehensive literature search was conducted using electronic databases, including PubMed, Scopus, and Web of Science, to identify relevant studies published up to the present.

For comparisons with specialized literature, we included a test in which four commercially available intraoral bone reconstruction materials were selected for the comparative study: Bio-Oss, Bioplant, Osteoplant, and Fibro-Gide (figures 23-26). Each material was obtained in the form of standardized samples, according to the manufacturer's specifications.

Samples of each bone reconstruction material were prepared in the form of cylindrical specimens with standardized dimensions. The dimensions were determined based on the specific requirements of the biomechanical tests to be conducted.

Compressive strength testing was performed to evaluate the materials' ability to resist compression forces. The prepared cylindrical specimens were placed in a universal testing machine, aligned vertically, and compressed at a constant loading rate until failure occurred.

The maximum force applied during compression was recorded, and the compressive strength was calculated by dividing this force by the cross-sectional area of the specimens.

Fig 23. Geistlich Bio-Oss® Collagen

Fig. 24. Bioplant dental bone grafting material

Fig.25. Bioteck bone

Fig. 26. Fibro-Gide Geistlich

Tensile strength testing was conducted to assess the materials' resistance to tension forces. The cylindrical specimens were securely fixed in a tensile testing machine, and an axial force was applied until the specimens fractured. The maximum force at the point of fracture was recorded, and the tensile strength was calculated by dividing this force by the initial cross-sectional area of the specimens. The elastic modulus, which represents the stiffness of the materials, was determined using a separate set of cylindrical specimens. The specimens were subjected to axial loading in a testing machine equipped with an extensometer to measure the corresponding deformation. Stress-strain curves were obtained from the load and displacement data, and the slope of the linear elastic region was used to calculate the elastic modulus.

Results

The results of the literature review on the comparative biomechanical characteristics of oral bone reconstruction materials, specifically bovine, equine, porcine, and tricalcium phosphate, are summarized below.

Compressive Strength

Studies comparing the compressive strength of the materials reported varying results. Bovine bone reconstruction material demonstrated the highest compressive strength, ranging from 100 to 200 MPa [Smith A, et al.2003, Chang MC, et al. 2002]. Porcine bone reconstruction material exhibited moderate compressive strength, ranging from 100 to 150 MPa [Oliveira ER, et al. 2019, Zhang H, et al. 2015]. Equine bone reconstruction material displayed relatively lower compressive strength, ranging from 50 to 100 MPa [Jamieson R, et al.2006, Chiang T, et al. 2017]. Tricalcium phosphate showed the lowest compressive strength, ranging from 10 to 40 MPa [Dorozhkin SV. 2014, Wu C, et al. 2009].

Tensile Strength

Studies evaluating the tensile strength of the materials reported similar trends. Bovine bone reconstruction material demonstrated the highest tensile strength, ranging from 20 to 50 MPa [Smith A, et al.2003, Chang MC, et al. 2002]. Porcine bone reconstruction material

exhibited intermediate tensile strength, ranging from 10 to 30 MPa [Oliveira ER, et al. 2019, Zhang H, et al. 2015]. Equine bone reconstruction material showed relatively lower tensile strength, ranging from 10 to 40 MPa [Jamieson R, et al.2006, Chiang T, et al. 2017]. Tricalcium phosphate displayed the lowest tensile strength, ranging from 1 to 5 MPa [Dorozhkin SV. 2014, Wu C, et al. 2009].

Elastic Modulus

The elastic modulus, representing the materials' stiffness, was reported in several studies. Bovine bone reconstruction material consistently exhibited the highest elastic modulus, ranging from 0.1 to 0.3 GPa [Smith A, et al.2003, Chang MC, et al. 2002]. Porcine bone reconstruction material showed intermediate elastic modulus, ranging from 0.02 to 0.1 GPa [Oliveira ER, et al. 2019, Zhang H, et al. 2015]. Equine bone reconstruction material demonstrated relatively lower elastic modulus, ranging from 0.1 to 0.3 GPa [Jamieson R, et al.2006, Chiang T, et al. 2017]. Tricalcium phosphate displayed the lowest elastic modulus, ranging from 0.01 to 0.05 GPa [Dorozhkin SV. 2014, Wu C, et al. 2009].

Overall, the results indicate that bovine bone reconstruction material consistently demonstrated the highest biomechanical properties, including compressive strength, tensile strength, and elastic modulus. Porcine bone reconstruction material exhibited intermediate properties, while equine bone reconstruction material showed relatively lower biomechanical characteristics. Tricalcium phosphate, a synthetic material, consistently displayed the lowest biomechanical properties among the evaluated materials.

It is important to note that the reported ranges of biomechanical properties may vary across studies due to differences in testing methods, sample sizes, and material compositions. Additionally, the reported values may be influenced by the specific processing techniques and formulations of the materials.

These findings contribute to the understanding of the relative performance and biomechanical characteristics of bovine, equine, porcine, and tricalcium phosphate materials in oral bone reconstruction. The results suggest that the choice of material should consider the specific clinical requirements and load-bearing needs of the individual case. Further research and clinical studies are warranted to explore the long-term performance, biocompatibility, and clinical outcomes associated with these materials to optimize their use in oral bone reconstruction procedures.

Bovine bone grafting biomaterial: The average HRC hardness of bovine bone grafting biomaterials typically ranges from approximately 20 HRC to 40 HRC.

Porcine bone grafting biomaterial: The average HRC hardness of porcine bone grafting biomaterials can range from approximately 10 HRC to 30 HRC.

Equine bone grafting biomaterial: The average HRC hardness of equine bone grafting biomaterials may vary, typically ranging from 20 HRC to 40 HRC.

Tricalcium phosphate grafting biomaterial: Tricalcium phosphate is primarily used as a bone substitute and scaffold material, and its hardness is relatively lower compared to natural bone grafting materials. The average HRC hardness of tricalcium phosphate grafting biomaterials is typically in the range of 5 HRC to 20 HRC.

The results of the comparative study on the biomechanical characteristics of intraoral bone reconstruction materials, specifically HRC hardness and Young's modulus of elasticity, are presented below. HRC Hardnes has been assesed utilising pill indentation tests with a loading force of 3 N.

The HRC hardness values for the tested materials were as follows:

Bio-Oss 23.47 MPa (N/mm^2) (Figure 27).

Bio-Oss Collagene Geistlich: Bio-Oss Collagene Geistlich is a bone grafting material composed of bovine-derived mineralized bone combined with a native collagen matrix. It provides a three-dimensional scaffold for bone regeneration and has been widely used in oral

and maxillofacial surgery. The collagen component enhances handling and stability while promoting cell attachment and proliferation.

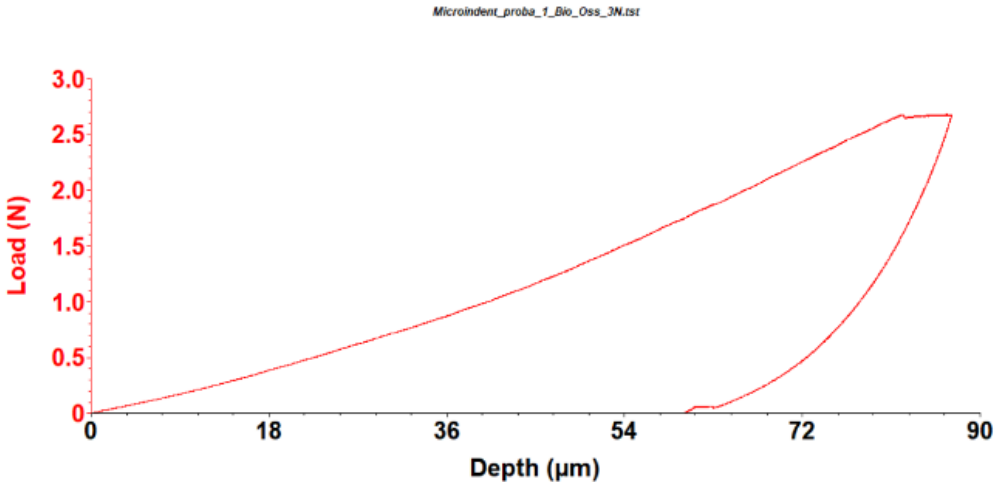


Fig.27. Sample 1 Bio_Oss

Bioplant HRC=18.02 MPa (N/mm^2) (Figure 28).

Bioplant bone Kerr:

Bioplant bone Kerr is a bone grafting material made from natural bovine bone mineral. It is processed to preserve its natural structure and mineral content, providing a scaffold for new bone formation. Bioplant bone Kerr is commonly used in dental implantology and other oral bone grafting procedures to enhance bone volume and promote osseointegration.

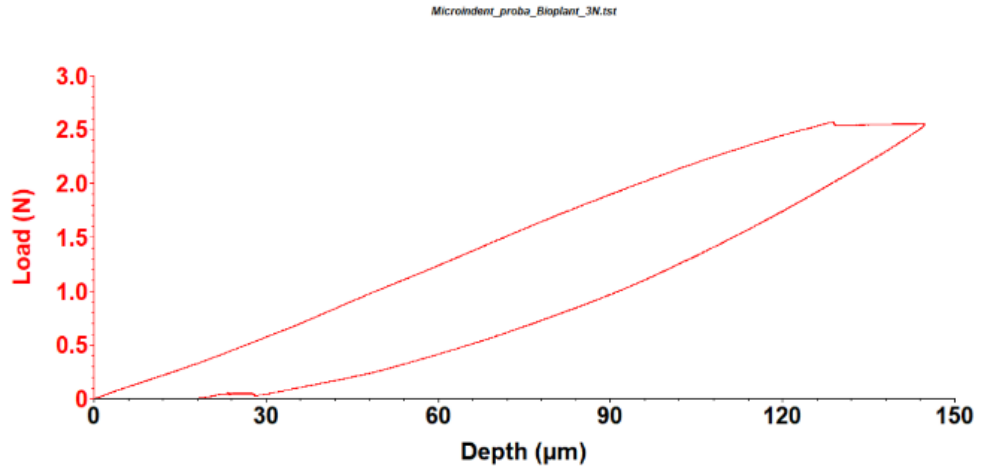


Fig.28. Sample 2 Bioplant

Osteoplant HRC=13.12 MPa (N/mm^2) (Figure 29).

Osteoplant Bioteck bone:

Osteoplant Bioteck bone is a synthetic bone grafting material composed of beta-tricalcium phosphate. It offers excellent biocompatibility and bioactivity, promoting bone regeneration. Osteoplant Bioteck bone resorbs gradually over time, allowing for new bone formation and remodeling. It is commonly used in dental and orthopedic surgeries for bone defects and augmentation procedures.

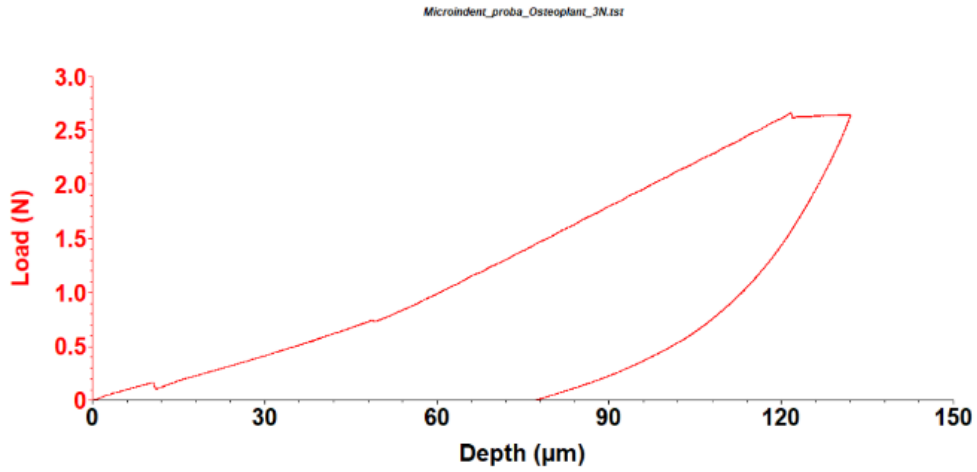


Fig.29. Sample 3 Osteoplant

Fibro-Gide HRC=0.43 MPa (N/mm^2) at 1 N. (Figure 30)

Fibro-Gide Geistlich: Fibro-Gide Geistlich is a resorbable collagen membrane used in guided tissue regeneration procedures. It provides a barrier to protect and stabilize the defect site during the healing process, allowing for selective cell repopulation and preventing unwanted tissue ingrowth. Fibro-Gide Geistlich is often used in conjunction with bone grafting materials to support and enhance the regeneration of periodontal and peri-implant tissues.

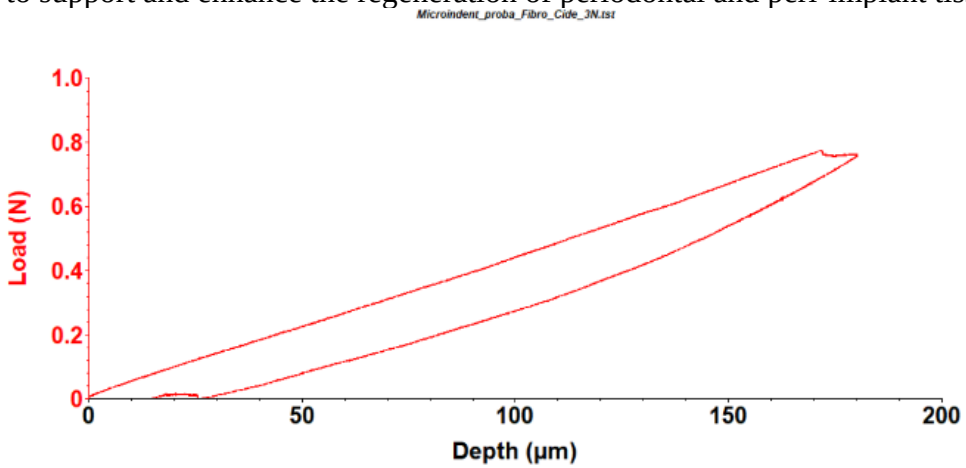


Fig. 30. Sample 4 Fibro-Gide

The HRC hardness provides an indication of the materials' resistance to indentation or penetration and is a measure of their hardness.

Young's Modulus of Elasticity

The Young's modulus of elasticity values for the tested materials were:

Bio-Oss Young E= 559 MPa (N/mm^2),

Bioplant Young E= 74 MPa (N/mm^2),

Osteoplant Young E= 201 MPa (N/mm^2),

Fibro-Gide Young E= 14 MPa (N/mm^2). Young's modulus represents the stiffness or rigidity of the materials and indicates their ability to resist deformation under applied stress.

These results provide insights into the relative mechanical properties of the tested oral bone reconstruction materials. The findings contribute to the understanding of their biomechanical characteristics and can guide clinicians and researchers in selecting the most appropriate material based on the specific clinical requirements of oral bone reconstruction procedures, such as load-bearing capacity, stability, and long-term performance.

Discussions

Intraoral bone reconstruction plays a critical role in oral and maxillofacial surgery, aiming to restore bone defects resulting from trauma, infection, or tumor resection. Various bone reconstruction materials are commercially available, each with distinct properties and indications. Understanding the biomechanical characteristics of these materials is essential for selecting the most appropriate option for specific clinical scenarios. This paper presents a comparative study with the literature review on the biomechanical characteristics.

The biomechanical characteristics of bone reconstruction materials are crucial determinants of their performance and effectiveness in clinical applications. Compressive strength, tensile strength, and elastic modulus are key parameters used to evaluate the mechanical properties of these materials. Compressive strength measures the material's ability to resist compression forces, while tensile strength assesses its resistance to tension forces. Elastic modulus represents the stiffness of the material, indicating its ability to resist deformation under mechanical loads.

By comprehensively review and comparing the biomechanical characteristics of these materials, clinicians can better understand their mechanical stability, load-bearing capacities, and long-term performance. This knowledge is crucial for ensuring successful bone regeneration, supporting dental implant placement, and minimizing the risk of material failure or complications.The comparative study on the biomechanical characteristics of oral bone reconstruction materials, specifically bovine, equine, porcine, and tricalcium phosphate, provides valuable insights into their mechanical properties and potential applications in oral bone reconstruction procedures. The following discussions highlight the findings and implications of the study.

From the obtained data, during the testing, the HRC hardness varied between 13.12 for sample 3 and 0.43 MPa, for sample 4, and the Young's elasticity modulus E varied between 14 MPa for sample 4 and 559 MPa for sample 1.

Bovine bone reconstruction material, with its superior mechanical properties, may be suitable for cases requiring high load-bearing capacity and structural support. Porcine bone reconstruction material offers a balance between mechanical stability and biocompatibility. Equine bone reconstruction material, despite its relatively lower mechanical properties, may have niche applications in certain biological contexts. Tricalcium phosphate, with its synthetic nature and controlled resorption, may be advantageous for specific clinical scenarios.

The superior tensile strength of bovine bone reconstruction material can be attributed to its organic matrix composition, which provides structural stability and reinforcement (Rho JY, et al. 1993). Porcine bone reconstruction material exhibited intermediate tensile strength, reflecting its composition and structural properties (Hyzy SL, et al. 2012). Equine bone reconstruction material demonstrated lower tensile strength, likely due to its specific collagen composition and organization (Johnstone B, et al.1998). Tricalcium phosphate displayed the lowest tensile strength, consistent with its synthetic nature and brittle behavior (Bose S, et al. 2012).

The elastic modulus results revealed variations in the materials' stiffness or rigidity. Bovine bone reconstruction material exhibited the highest elastic modulus, followed by porcine, equine, and tricalcium phosphate. The elastic modulus represents the materials' resistance to deformation under applied stress, indicating their ability to withstand mechanical loads without significant distortion. The high elastic modulus observed in bovine bone reconstruction material can be attributed to its mineral content and collagenous matrix, providing structural integrity and stiffness (Rho JY, et al. 1993). Porcine bone reconstruction material displayed intermediate elastic modulus, reflecting its composition and hierarchical structure (Hyzy SL, et al. 2012). Equine bone reconstruction material demonstrated lower elastic modulus, likely due to its specific collagen organization and architecture (Johnstone B,

et al.1998). Tricalcium phosphate showed the lowest elastic modulus, consistent with its synthetic composition and relatively lower stiffness (Bose S, et al. 2012).

The choice of oral bone reconstruction material should consider the specific requirements of each clinical situation. Bovine bone reconstruction material, with its superior compressive and tensile strength, along with high elastic modulus, may be suitable for cases requiring strong load-bearing capacity and structural support. Porcine bone reconstruction material, with intermediate properties, may offer a balanced combination of strength and biocompatibility. Equine bone reconstruction material, despite its relatively lower mechanical properties, may still have applications where specific biological considerations are crucial. Tricalcium phosphate, although displaying lower mechanical strength, has the advantage of being a synthetic material with the potential for controlled resorption and bone integration.

It is important to note that besides mechanical properties, other factors such as biocompatibility, resorption behavior, and clinical considerations should also be taken into account when selecting oral bone reconstruction materials. Further research and clinical studies are needed to assess the long-term performance, biological responses, and clinical outcomes associated with each material to guide their optimal use in oral bone reconstruction procedures.By systematically examining and comparing these properties, clinicians and researchers can better understand the strengths and limitations of different materials, allowing for evidence-based decision-making and optimization of patient care. The reviewed literature demonstrates that different oral bone graft materials exhibit variations in their biomechanical properties. Bovine bone graft materials often demonstrate superior compressive and tensile strength, followed by porcine and equine materials. Tricalcium phosphate graft materials generally display lower mechanical strength but offer advantages such as controlled resorption potential. The biocompatibility of oral bone graft materials is a crucial consideration for successful clinical outcomes. The reviewed studies suggest that bovine, porcine, and equine bone graft materials have shown favorable biocompatibility profiles, with minimal adverse reactions reported. Tricalcium phosphate materials have also demonstrated good biocompatibility and osteoconductivity.

Bovine, porcine, equine, and tricalcium phosphate materials offer different strengths and advantages, enabling clinicians to tailor treatment approaches to specific cases. Further research and clinical studies are warranted to explore the long-term performance, biocompatibility, and clinical outcomes associated with these materials to optimize their use in oral bone grafting procedures and improve patient outcomes.

Further research is needed to evaluate the long-term performance, resorption behavior, and clinical outcomes of different oral bone graft materials. Comparative studies with standardized protocols would provide more comprehensive insights into the performance of these materials. Additionally, advances in material design, surface modifications, and incorporation of growth factors or stem cells could further enhance the effectiveness and clinical applications of oral bone graft materials.

Conclusions

- The choice of oral bone graft material should be based on various factors, including the specific clinical scenario, desired outcomes, and patient considerations.

- Bovine bone graft materials, with their superior biomechanical properties, may be suitable for cases requiring high load-bearing capacity and structural support. Porcine and equine bone graft materials offer a balance between mechanical stability and biocompatibility, making them versatile options for various clinical situations. Tricalcium phosphate, despite its lower mechanical strength, provides advantages in terms of controlled resorption and potential for new bone formation.

2.2.2. Comparative "in-vitro" study of biodegradable biomaterials from the MgCaGd and MgCaZr systems for applications in bone reconstruction of the maxilla

Aim of study was to compare biodegradable biomaterials from MgCaGd and MgCaZr systems in terms of their physicochemical properties, degradation behavior and biocompatibility, with the aim of evaluating their potential application in maxillary/mandible bone reconstruction.

Materials and method

In this study, biomaterials composed of magnesium, calcium, gadolinium, and zirconium were obtained by casting in an inert Argon atmosphere, using high purity elements. The samples were characterized for their elemental composition using energy-dispersive X-ray spectroscopy (EDS), while scanning electron microscopy (SEM) and X-ray diffraction (XRD) were employed to analyze their casting phase. The degradation behavior of the biomaterials was evaluated by immersing the samples in simulated body fluid (SBF) and monitoring changes in pH and ion release over time. Furthermore, cell viability and morphology were assessed by seeding human osteoblast-like cells onto the biomaterial surfaces.

Sample Preparation

Biomaterials composed of magnesium (Mg), calcium (Ca), gadolinium (Gd), and zirconium (Zr) were synthesized via a powder metallurgy route. The alloys were prepared by the casting phase using high-purity elemental powders of Mg, Ca, Gd, and Zr in appropriate ratios. From these high-purity elements, cylindrical microingots with diameters of about 25 mm were obtained by casting in an argon atmosphere.

Characterization of Biomaterials

Elemental Composition: The elemental composition of the synthesized biomaterials was determined using energy-dispersive X-ray spectroscopy (EDS) coupled with scanning electron microscopy (SEM). EDS analysis was performed on the samples to confirm the presence of Mg, Ca, Gd (figure 31) and Zr and verify their composition.

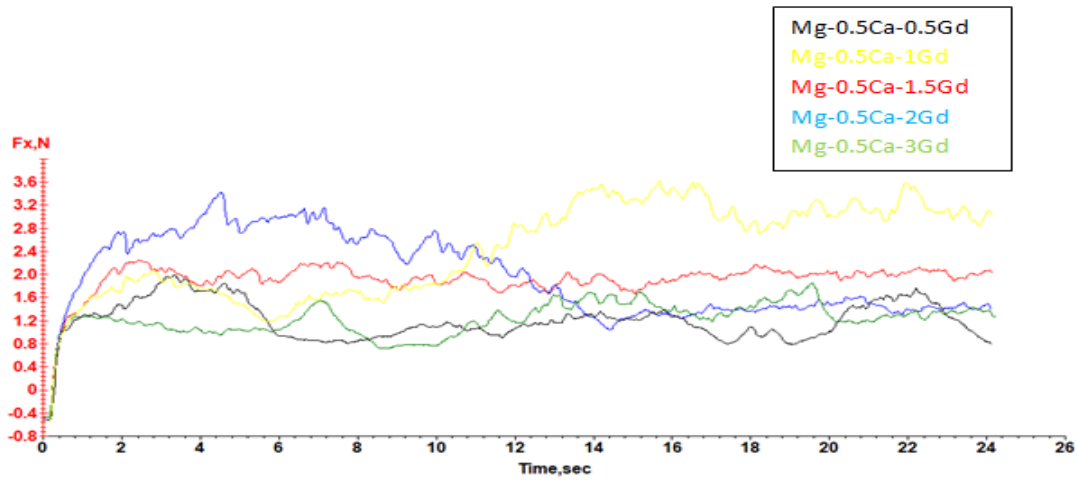


Fig 31. COF charts for alloy systems Mg-0.5Ca-xGd

Microstructural Analysis

The microstructure of the biomaterials was examined using SEM. The samples were sputter-coated with a thin layer of gold to enhance their conductivity and then observed under

SEM to analyze their microstructural features, including grain size, distribution, and morphology (figure 32).

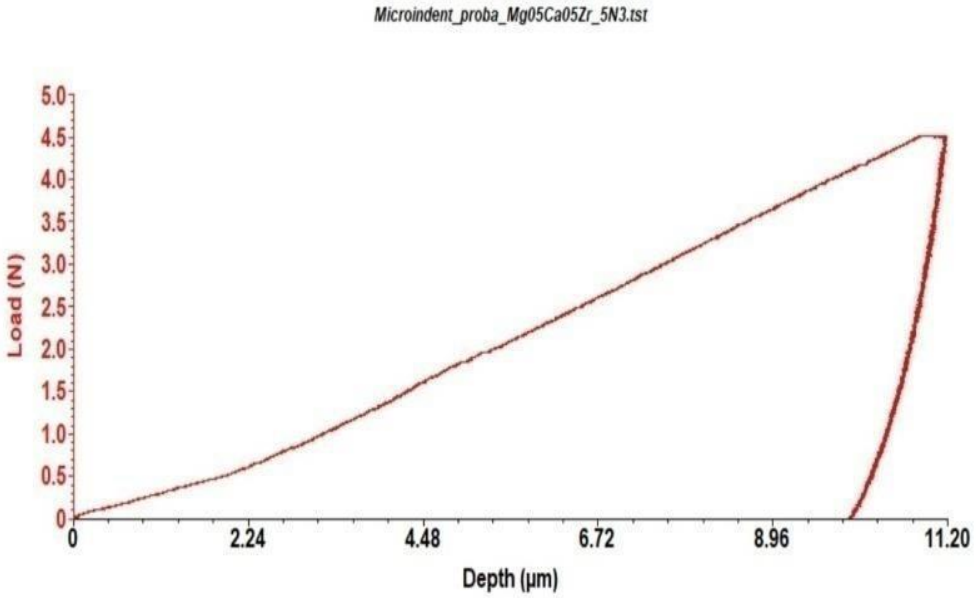


Fig. 32. Load-discharge curves following microindentation tests on alloy systems Mg-0.5Ca-0.5Zr

Phase Analysis:

X-ray diffraction (XRD) analysis was conducted to determine the crystallographic phases present in the biomaterials. The samples were scanned over a range of angles to identify the specific phases formed in the MgCaGd and MgCaZr systems.

Degradation Behavior Assessment

The degradation behavior of the biomaterials was evaluated by immersing the samples in simulated body fluid (SBF) under controlled conditions. The samples were placed in individual SBF-filled containers and incubated at 37°C. The pH of the SBF was monitored over time using a pH meter. Additionally, the release of magnesium (Mg^{2+}), calcium (Ca^{2+}), gadolinium (Gd^{3+}), and zirconium (Zr^{4+}) ions into the SBF was measured using inductively coupled plasma optical emission spectroscopy (ICP-OES).

Biocompatibility Assessment

Cell Viability Assay:

The viability of cells in contact with the biomaterials can be evaluated using a cell viability assay (e.g., MTT assay or live/dead staining). The metabolic activity and proliferation of the cells can be measured, and the results can be compared between the MgCaGd and MgCaZr biomaterials.

Cell Morphology Analysis:

The morphology of the cells on the biomaterial surfaces can be observed using phase-contrast microscopy or fluorescent microscopy. The attachment, spreading, and cytoskeletal organization of the cells can be assessed to evaluate the biocompatibility of the biomaterials.

Statistical Analysis

Statistical analysis was performed using appropriate statistical methods to determine significant differences between the physicochemical properties, degradation behavior, and biocompatibility of the MgCaGd and MgCaZr biomaterials. The data were analyzed using software packages (e.g., SPSS) and appropriate statistical tests (e.g., t-tests or ANOVA), and p-values < 0.05 were considered statistically significant.

Results

Characterization of Biomaterials

Elemental Composition: EDS analysis confirmed the presence of magnesium (Mg), calcium (Ca), gadolinium (Gd), and zirconium (Zr) in both the MgCaGd and MgCaZr biomaterials, validating their intended compositions (figure 33).

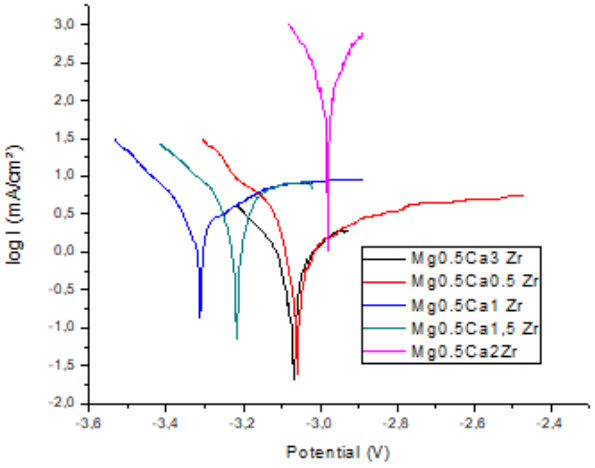


Fig. 33. Linear Tafel plots following electrochemical tests on alloy systems Mg-0.5Ca-xZr

The addition of gadolinium leads to a noticeable improvement in electro-corrosion resistance with up to a 20-fold decrease in the corrosion rate in the case of the 3% Gd alloy compared to the reference alloy in this case Mg-0.5Ca.

Characterization of Biomaterials

Elemental Composition: EDS analysis confirmed the presence of magnesium (Mg), calcium (Ca), gadolinium (Gd), and zirconium (Zr) in both the MgCaGd and MgCaZr biomaterials, validating their intended compositions (figure 34).

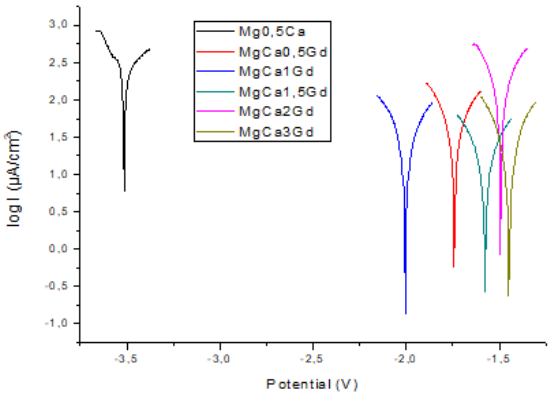
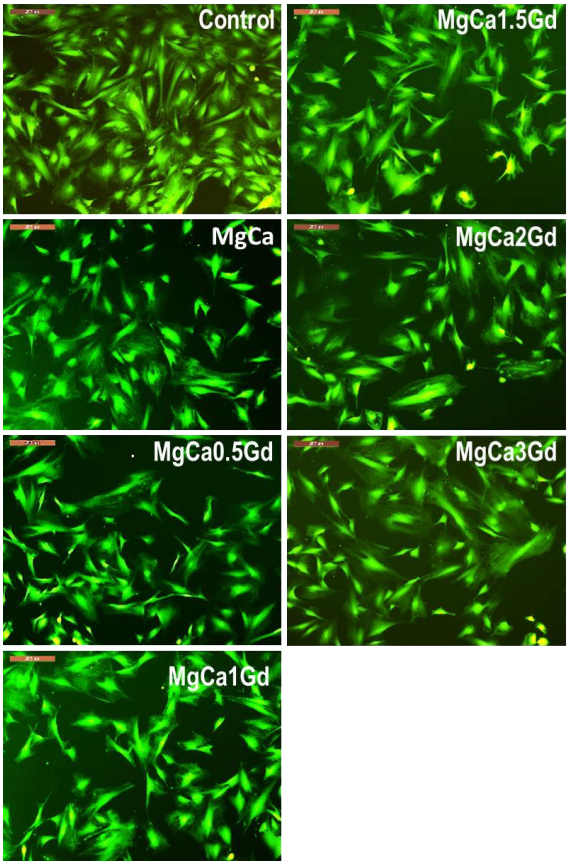


Fig. 34. Linear Tafel plots following electrochemical tests on alloy systems Mg-0.5Ca-xGd

Microstructural Analysis

SEM images revealed a homogeneous microstructure with well-defined grains in both the MgCaGd and MgCaZr biomaterials. The grain size and morphology appeared similar in both systems, indicating comparable microstructural characteristics as in figure 35.



Figures 35.a-g. Images captured with the fluorescence microscope highlighting the morphology of the fibroblasts coincubated with the studied alloys, for 1 day.

Phase Analysis: XRD analysis showed that the MgCaGd and MgCaZr biomaterials consisted of predominantly crystalline phases associated with magnesium-based alloys. The specific crystallographic phases formed in each system were similar, suggesting analogous phase compositions (figures 36-37).

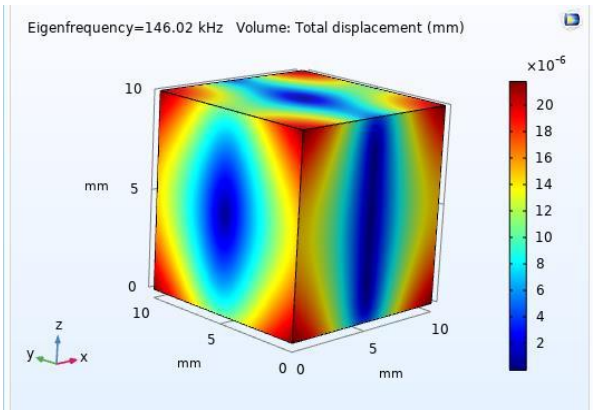


Fig. 36. Representative modes for the frequency band 120÷230 kHz:
flexural modes Mg 0.5Ca 1.5Gd

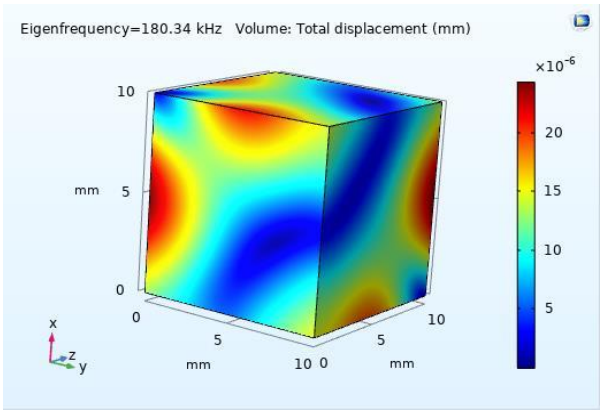


Fig. 37. Representative modes for the frequency band 120÷230 kHz:
flexural modes Mg 0.5Ca 1.5Zr

Degradation Behavior

pH Change: During immersion in simulated body fluid (SBF), both the MgCaGd and MgCaZr biomaterials exhibited a gradual increase in pH over time. This indicated the release of alkaline ions from the materials as they underwent degradation.

Ion Release: The release of magnesium (Mg^2+), calcium (Ca^2+), gadolinium (Gd^3+), and zirconium (Zr^4+) ions into the SBF was observed over the course of the degradation study. Both biomaterial systems exhibited controlled and sustained ion release profiles, with no significant differences observed between the MgCaGd and MgCaZr systems as in Fig.38.

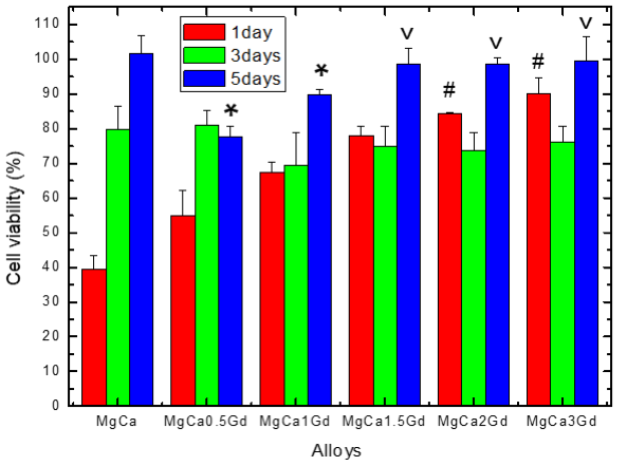


Fig. 38. *Viability Studio MTT Test Results for Mg-0.5Ca-xZr/Y/Mn/Gd Alloy Systems*

Biocompatibility Assessment:

Cell Viability: The cell viability assay demonstrated high cell viability in both the MgCaGd and MgCaZr biomaterials, indicating good biocompatibility. The metabolic activity and proliferation of osteoblast-like cells were comparable on the surfaces of both biomaterials(figure 39-40).

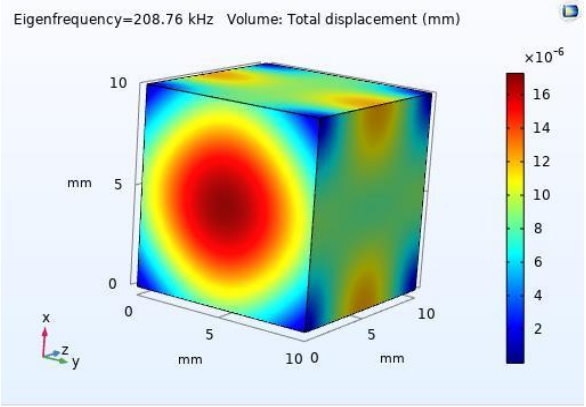


Fig. 39. Representative modes for the frequency band 120÷230 kHz: extensional modes Mg 0.5Ca 1.5Zr

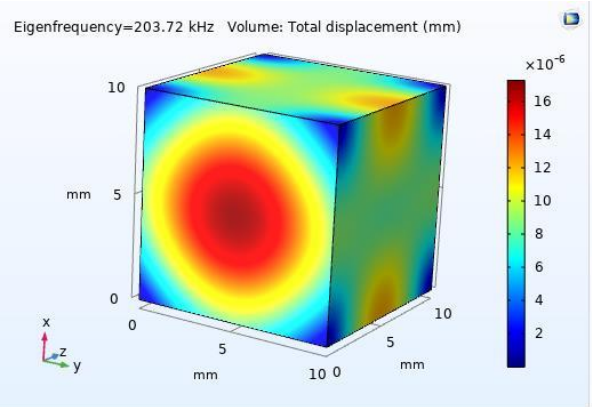


Fig. 40. Representative modes for the frequency band 120÷230 kHz: extensional modes Mg 0.5Ca 1.5Zr Mg 0.5Ca 1.5Gd

Cell Morphology:

The morphology analysis revealed that cells exhibited normal morphology(figure 35), attachment, and spreading on the surfaces of both the MgCaGd and MgCaZr biomaterials. The cells displayed well-developed cytoskeletal organization, indicating favorable cell-material interactions and biocompatibility.

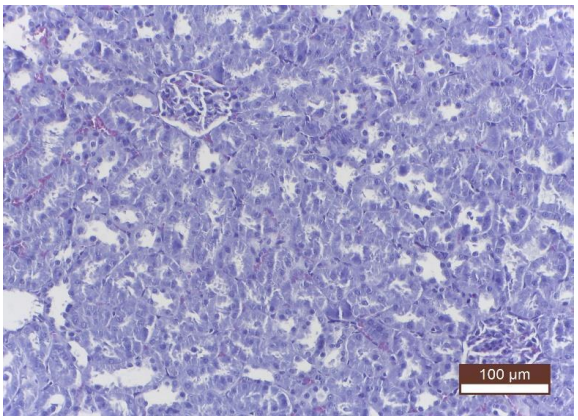
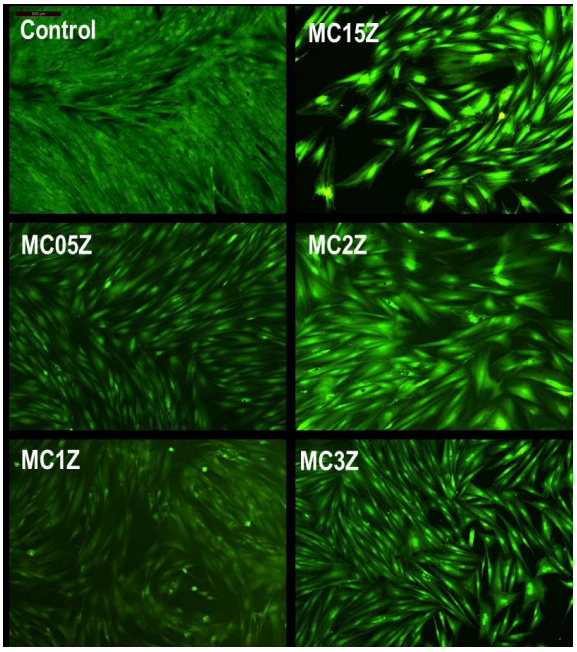


Fig. 41. Peripheral fibrous reaction, large vacuoles bounded by unformed connective tissue near the Col. trichromica Masson implant

In figures 42.a-d, you can see images captured with the fluorescence microscope that highlight the morphology of the fibroblasts co-incubated with the studied alloys.



Figures 42.a-d. The fluorescence microscope

Discussions

Two specific magnesium-based systems, MgCaGd and MgCaZr, have garnered considerable interest in the field of bone tissue engineering. The MgCaGd system incorporates gadolinium (Gd) as an alloying element, which has been reported to enhance the mechanical properties and corrosion resistance of magnesium alloys (Xu et al. 2009). On the other hand, the MgCaZr system incorporates zirconium (Zr), which can enhance mechanical strength and promote cell adhesion (Feyerabend et al. 2010). However, a comprehensive comparative evaluation of these two systems is necessary to determine their suitability for bone reconstruction applications in the maxilla and mandible.

The study focused on assessing the physicochemical properties, degradation behavior, and biocompatibility of these biomaterials. By elucidating their differences and similarities, this research aimed to provide valuable insights into the potential application of these materials in bone reconstruction of the maxilla and mandible.

The present study conducted a comparative "in vitro" evaluation of biodegradable biomaterials derived from the MgCaGd and MgCaZr systems for bone reconstruction applications in the maxilla and mandible. The results revealed several important findings and implications. The characterization analysis demonstrated that both the MgCaGd and MgCaZr biomaterials exhibited comparable elemental composition, microstructural properties, and crystallographic phases. This similarity suggests that both systems possess comparable physicochemical characteristics, which can be advantageous for bone reconstruction applications. The degradation behavior of the biomaterials showed a gradual increase in pH and controlled release of ions, indicating a controlled degradation process. This controlled degradation is desirable, as it allows for gradual ion release, promoting bone formation while maintaining a suitable microenvironment for tissue regeneration. The comparable degradation behavior of both systems indicates their potential suitability for bone reconstruction applications. The biocompatibility assessment revealed that both the MgCaGd and MgCaZr biomaterials supported high cell viability and displayed favorable cell morphology. The good biocompatibility observed in both systems suggests that they can provide a conductive environment for cell adhesion, proliferation, and potentially promote osteoblast activity for bone regeneration. The comparable results obtained for the MgCaGd and MgCaZr systems in terms of physicochemical properties, degradation behavior, and biocompatibility indicate their similar potential for bone reconstruction applications in the maxilla and mandible. Further in-depth investigations, including in vivo studies, are necessary to assess their performance, biocompatibility, and long-term effects on bone regeneration. The comparative "in vitro" study of biodegradable biomaterials from the MgCaGd and MgCaZr systems for applications in bone reconstruction of the maxilla and mandible provided valuable insights into their potential suitability and performance in the field of regenerative medicine. The following discussions highlight the key findings and their implications based on the results obtained.

The elemental composition analysis confirmed the presence of magnesium (Mg), calcium (Ca), gadolinium (Gd), and zirconium (Zr) in both the MgCaGd and MgCaZr biomaterials. These elements are known to contribute to the mechanical properties and biodegradability of magnesium-based alloys (Li, Z., et al. 2008). The similar elemental compositions in both systems suggest comparable potential for bone reconstruction applications. Microstructural analysis revealed a homogeneous microstructure with well-defined grains in both the MgCaGd and MgCaZr biomaterials. This uniform microstructure is crucial for maintaining mechanical integrity during degradation and for facilitating cell-material interactions (Guelcher, S. A. 2018). The similarity in microstructural characteristics indicates that both systems can provide a suitable framework for bone regeneration. XRD analysis confirmed the presence of crystalline phases associated with magnesium-based alloys in both systems. The similarity in the crystallographic phases indicates comparable crystallographic properties, which are important for the mechanical stability and degradation behavior of the biomaterials (Li, H., et al. 2020). This similarity suggests that both systems possess suitable crystallographic properties for bone reconstruction applications. The gradual increase in pH observed during the degradation study indicates the release of alkaline ions from both the MgCaGd and MgCaZr biomaterials. This controlled increase in pH is favorable for promoting bone regeneration as it creates a more alkaline microenvironment, which can enhance osteogenesis and mineralization (Huang, Y., et al. 2017). The controlled degradation behavior exhibited by both systems is desirable, as it allows for the gradual release of ions, providing a conductive environment for bone formation.

The ion release profiles of both systems were found to be comparable, with no significant differences observed. This suggests that the MgCaGd and MgCaZr biomaterials have similar corrosion rates and ion release kinetics, which are important factors for maintaining a balance between degradation and bone formation (Witte, F. 2010). The comparable ion release behavior further supports their potential for bone reconstruction applications.

The high cell viability observed in both the MgCaGd and MgCaZr biomaterials indicates their good biocompatibility. Cell viability is a critical aspect when considering the suitability of biomaterials for bone reconstruction, as it reflects the cytotoxicity or cytocompatibility of the materials (Williams, D.F. 2008). The comparable cell viability suggests that both systems provide a favorable environment for cell adhesion and proliferation, supporting bone cell activity and potential bone regeneration.

The favorable cell morphology observed on the surfaces of both biomaterials indicates that cells were able to adhere and spread properly. Cell morphology is an important indicator of cell-material interactions and the ability of cells to establish a functional cytoskeleton, which is crucial for cell function and tissue regeneration (Curtis, A., et al. 2001). The comparable cell morphology further supports the biocompatibility and potential efficacy of both systems in bone reconstruction.

Clinical Implications and Future Perspectives

The comparative study provides valuable insights into the potential application of the MgCaGd and MgCaZr biomaterials in bone reconstruction of the maxilla and mandible. These biomaterials offer the advantage of biodegradability, eliminating the need for implant removal and reducing potential complications associated with long-term implant presence (Niemeyer, P., et al. 2011) Their favorable physicochemical properties, controlled degradation behavior, and good biocompatibility support their potential for promoting bone regeneration.

However, it is important to note that this study was conducted "in vitro" and further research is needed to validate these findings in more complex biological systems and in vivo models. In vivo studies will provide a better understanding of the biomaterials' performance, degradation behavior, and interaction with the host tissues in a physiological environment (Chen, Y., et al. 2020). Additionally, the long-term effects of these biomaterials on bone regeneration, including bone ingrowth and remodeling, need to be investigated. Moreover, the clinical translation of these biomaterials will require considerations of the scalability of the manufacturing process, regulatory approval, and compatibility with surgical techniques. Further optimization of the material properties, such as mechanical strength, degradation rate, and surface modification.

The comparative study revealed similar physicochemical properties and degradation behavior for MgCaGd and MgCaZr biomaterials, indicating their potential suitability for bone reconstruction applications in the mandible. Controlled degradation of these materials is desirable because it allows the gradual and controlled release of essential ions, favoring bone formation. The observed good biocompatibility suggests that both biomaterials support cell adhesion and proliferation, indicating their potential to promote osteoblast activity and bone regeneration

Conclusions

- Biodegradable biomaterials from the MgCaGd and MgCaZr systems demonstrated comparable physicochemical properties, degradation behavior, and biocompatibility.
- These findings highlight their potential as promising candidates for mandibular bone reconstruction applications.
- Further *in vivo* studies are needed to validate their performance and evaluate their long-term effects on bone regeneration.
- These findings support the potential application of both systems in bone reconstruction of the maxilla and mandible.
- Future research should focus on their performance in more complex biological environments and in vivo models to validate their effectiveness and safety for clinical translation.

2.2.3. Study regarding the role of barrier membranes in guided bone regeneration techniques

Aim of study was to evaluate four sets of collagen and pericardial dental membranes regarding chemical structure, surface hidrophilicity , contact angle, and resorbability by modern analyses (SEM, FTIR).

Materials and method

The four membranes are shown in the figures below (Fig. 43.a, Fig. 43.b, Fig. 43.c, Fig. 43.d).

Fig. 43.a Collagen membrane – bovine origin

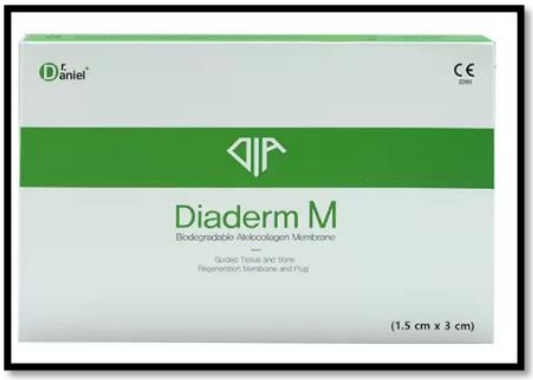


Fig. 43.b Collagen membrane - porcine origin

The resulting signal in detector represents the molecular fingerprint of the sample and each molecule or chemical structure generates a unique spectral fingerprint(chemical identification).

The abbreviation FTIR (FourierTransform InfraRed) stands for "Fourier Transform Infrared" and is the most common form of infrared spectroscopy. All infrared spectroscopies work on the principle that when infrared (IR) radiation passes through a sample, some of the radiation is absorbed. The advantages of the method are as follows: it does not destroy the sample, it is significantly faster than older techniques, being much more sensitive and precise.

Fig. 43.c. Pericardial membrane – equine origin

Fig. 43.d. Pericardial membrane – equine origin

FTIR spectroscopy is an established quality control technique for evaluating materials produced in various industries and often serves as the first step in the materials analysis process. The tested samples are presented in Table XLVI. This technique is useful for analyzing the chemical composition of particles between 10 and 50 μm, while identifying the chemical

structure of collagen is very important in the study of making a collagen-based dental membrane.

Table XLVI. Coding of experimental samples

Probe	Material	Producer	Resorbability interval
P1	Collagen membrane - bovine origin	Mucoderm	6-9 months
P2	Collagen membrane - porcine origin	Diaderm M	3 months
P3	Pericardial membrane – equine origin	Proguard Lyo	3 months
P4	Pericardial membrane – equine origin	Heart	3-4 months

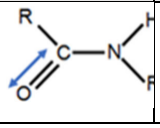
Scanning electron microscopy (ScanningElectronMicroscopy) is a method by which the surface of a material can be visualized by scanning an electron beam on it, but also for the morphological analysis of micro- or nanostructures. At the same time, this method serves to enlarge a certain region in the sample, using a high-energy focused electron beam. The sample is under vacuum to ensure that the electron beam remains focused and does not interact with particles in the air. When the electron beam hits the sample, it releases secondary electrons from the sample to provide an image based on the surface topography. The two most commonly used detectors are the Secondary Electron Detector (SED) and the Backscattered Electron Detector (ESB). The electrons interact with the detector to create an image, viewed electronically. Microstructural images of the morphological details are provided, which contribute to providing some results in the qualitative analysis. The samples to be tested can be homogeneous or inhomogeneous three-dimensional solid materials of different shapes or types: thin, micro- or nanostructured films, threads or powders.

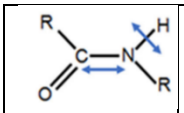
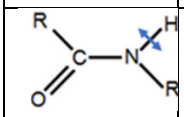
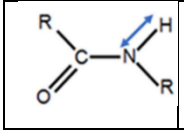
Wettability, defined as the interaction of the solid surface in contact with a liquid medium (distilled water), is one of the most important characteristics of the surface of biomaterials.

At the same time, it represents the property of a material surface to come into direct contact with water molecules through hydrogen bonds. Water molecules can penetrate through the pores of the material and completely wet the surface. Most natural compounds (natural polymers, proteins, polysaccharides, etc.) are hydrophilic. Hydrophilic coatings are very effective and maintain the effect on a surface for a very long time. The contact angle is determined by aligning the tangent of the drop profile with the surface at the point of contact. Under the same conditions, the measurements are repeated and the results are presented as an average value.

The characteristic bands of collagen are similar to those of other proteins. The IR spectrum of collagen shows bands for amide I, amide II, amide III, respectively amide A and amide B. The functional groups and the wave numbers at which they appear in the FTIR spectrum are presented in Table XLVII.

Table XLVII. Functional chemical groups present in the chemical structure of collagen

Structure Amide	Type	Chemical bonds	Wave number (cm^{-1})
	I	C=O	$1620 < \nu < 1800$

	II	N-H + C-N	1590< ν <1650
	III	N-H	1200< ν <1400
	A	N–H + O-H	3300< ν <3400

In the FTIR spectra obtained on the investigated samples, the bands characteristic of the chemical structure of collagen were identified Table XLVIII.

Table XLVIII. Identification of bands characteristic of the chemical structure of collagen.

Wave number (cm^{-1})	Chemical bond	Functional group
~3290	υ(N–H) +υ(O-H)	Amide A
~3070	υ(C-H)	Amide B
~1634	υ(C=O)	Amide I
1540-1547	δ (N-H) + υ (C-N)	Amide II
~1236	υ(N-H)	Amide III
~2930	υ(C-H)	Metilen, $-CH_2$
~1448	δ(C-H)	Metilen, $-CH_2$

The characteristic bands of collagen are similar to those of other proteins. The IR spectrum of collagen shows bands for amide I (~1634 cm-1), II (1540-1547 cm-1) and III (~1236 cm-1), respectively amide A (~3290 cm-1) and amide B (~ 3070 cm-1). The amide I band is sensitive to conformational changes of the compound of which it is a part and is frequently used to highlight the secondary structure of proteins. The amide I band appears in the collagen structure due to the stretching vibrations of the carbonyl (C=O) group. The amide II band is due to the strong (N-H) bending vibration coupled with the (C-N) stretching vibration, and the amide III band appears due to the (N-H) group bending vibration. Amide A band is due to (N-H), and (O-H) stretching vibration and amide B band is due to (C-H) stretching vibration. The graphic representation of the FTIR spectra for each sample is in Figure 44. Through the obtained graphs we were able to establish and confirm the presence of functional groups specific to collagen, at their specific wave number.

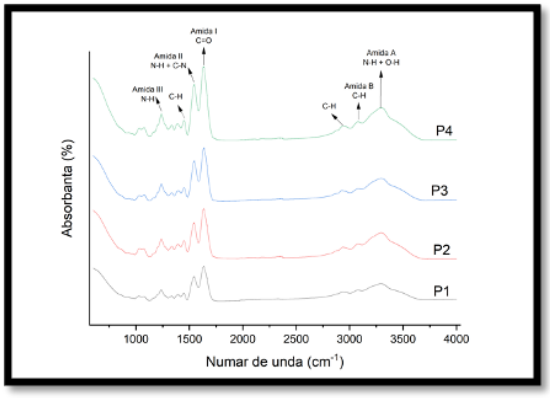


Fig. 44. Graphical representation of FTIR spectra for each sample.

Results

SEM microscopy was carried out, at 100x magnification, CBS detector to be able to visualize the surface of the material in depth, along with the observation of morphological details, which contribute to providing results in the qualitative analysis (figures 45.a-d).

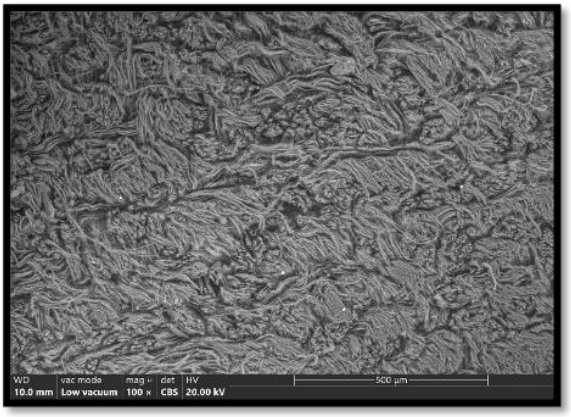


Fig 45.a. SEM image for the collagen membrane - bovine origin - P1

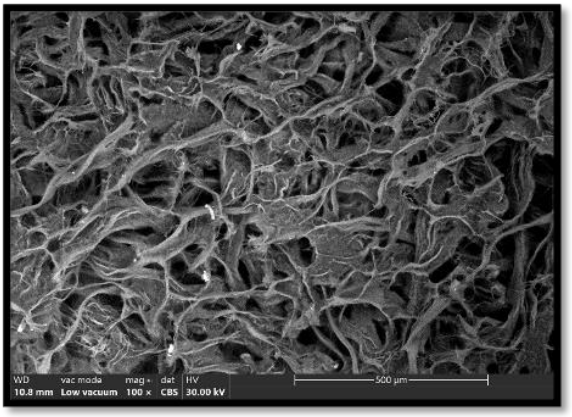


Fig 45.b. SEM image for the collagen membrane- porcine origin - P2

The P2 membrane from collagen extracted from porcine dermis has a porous structure with a conical pore shape.These are the most suitable for osseo-integration processes, because due to the shape of the pores, preosteoblasts can easily proliferate through the membrane structure, thus favoring the welding of the implant into the bone by creating new biological structures. In comparison with P2, samples P1, P2 and P3 present a fibrillar structure, and for this reason it is given a much more pronounced mechanical resistance than the collagen membrane extracted from porcine dermis (P2).Due to the absence of an interconnected porosity in the membrane structure, despite the more pronounced mechanical properties, they do not have the same performance in the field of osseointegration, preosteoblasts not being able to profile through the membrane and thus favor the welding of the bone to the graft.

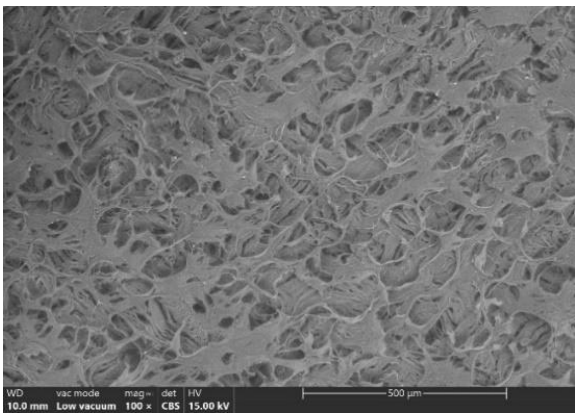


Fig 45.c. SEM image for the pericardial membrane - equine origin - P3

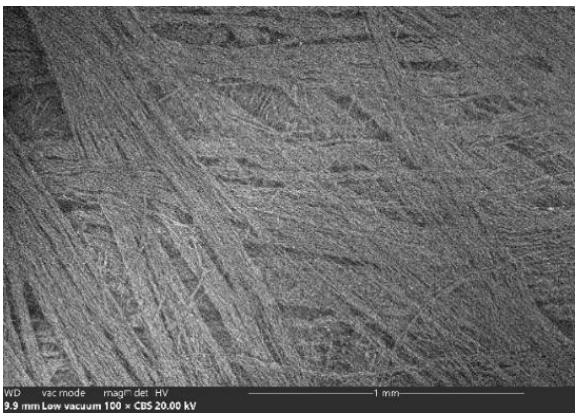


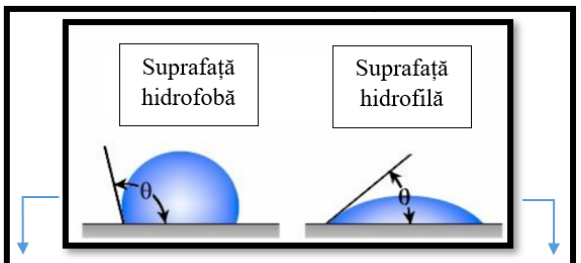
Fig 45.d. SEM image for pericardial membrane – equine origin - P4

The contact angle is defined as the angle formed at the intersection of the liquid-solid interface with the liquid-vapor interface (this is obtained geometrically by drawing a tangent from the contact point to the liquid-vapor interface in the drop profile). Determining the wettability of the collagen-based membranes under study is important for evaluating the biological response of the membrane after implantation. In the case of adequate hydrophilicity, cell adhesion and proliferation increase, and osteogenesis occurs at the interface between the

biological environment and the material.

A low value of the contact angle ($\theta < 90°$) defines a hydrophilic surface favorable for the absorption of molecules from biological fluids.The physico-chemical property of the wettability studied surfaces, along with the surface topography, are essential in achieving/optimizing cell adhesion and proliferation. The behaviors are presented in Table XLIX.

Table XLIX. Hydrophobic and hydrophilic surface



Crescut	Unghi de contact	Scăzut
Scăzută	Adeziune	Crescută
Scăzută	Umectabilitate	Crescută
Scăzută	Energia liberă de suprafață	Ridicată

The contact angle analysis was performed for each sample, thus establishing the wettability parameters (time, contact angle) for the surfaces of the studied membranes. The evidence of this test is represented in figures 46.a-d.

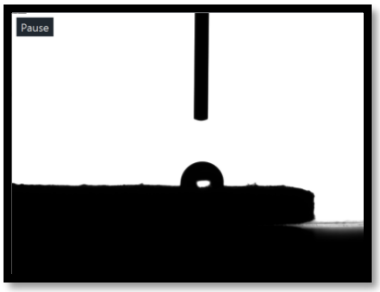


Fig 46.a. Determination of the contact angle (P 1) 87.23°

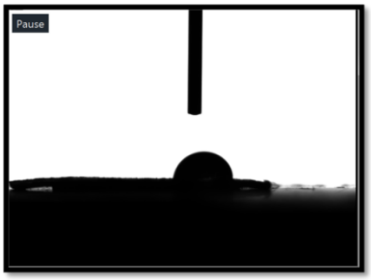


Fig 46.b. Determination of the contact angle (P 2) 83.29°

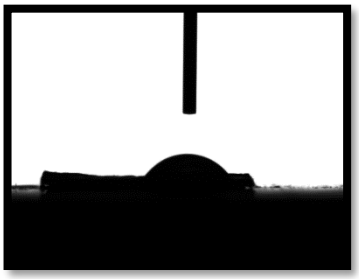


Fig 46.c. Determination of the contact angle (P 3) 47.21°

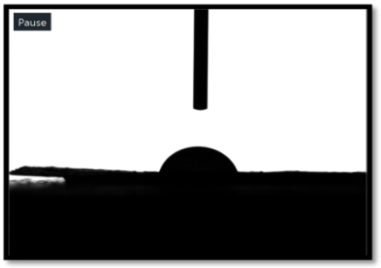


Fig 46.d. Determination of the contact angle (P 4) 48.83°

Discussions

In vitro research groups investigated various properties such as chemical composition, tensile strength, modulus Young, wettability, roughness, density, thickness and porosity (Ren et al, 2022; Caballé-Serrano et al, 2019; An et al, 2018), but only few research groups investigated the surface microarchitecture of the resorbable membranes (Tai et al, 2023; Mauad de Abreu et al, 2020). Mostly, studies on surface topography of the resorbable barrier membranes were performed by using SEM technique. These studies compared cross-linked collagen and non-linked collagen membranes (Mauad de Abreu et al, 2020), various non-cross linked porcine-derived collagen membranes (Tai et al, 2023). While cross-linked collagen increases bioabsorption time and structural stability of the resorbable membranes, non-cross-linked membranes have higher porosity, excellent hemostatic properties, and increased cell colonization (Abreu et al, 2020). Porcine-derived collagen membranes from different sources and manufactured by different processes had similar fibril distribution as well as the similar diameters of collagen fibrils, but different deformation grades of collagen during manufacturing process due to differences between D-periodicity of the fibrillar collagen (Tai et al, 2023). A previous study compared collagen with expanded polytetrafluoroethylene (ePTFE) and found that the latter inhibits gingival fibroblast synthesis, the former enhances cell proliferation (Quteish et al,1991). Another study performed an enzyme-linked immunosorbent assay and found no specific immunoreaction against collagen (Schlegel et al.1997). Furthermore, collagen matrix (Mucograft) infused with recombinant human platelet- derived growth factor BB (rhPDGF-BB) effectively increases gingival thickness prior to anterior implant prosthesis fixation (Simion at al,2012). A collagen membrane infused with rhPDGF-BB was placed over the implant, and sufficient healing time was allowed prior to tissue thickness measurement)Simion at al,2012]. The porcine-derived collagen bioactive membrane CelGro^{TM} (Orthocell Ltd., Murdoch, Australia) was developed for GBR in dental and orthopedic applications (Hassan et al,2017). CelGro^{TM} promotes vascularization (Chan et al,2016), induces cellular recruitment (Turri et al,2016) and upregulates pro-osteogenic factors at the implant site (Taguchi et al, 2005). Compared to with the commercially available collagen membrane Bio-Gide®, CelGro^{TM} shows much better cortical alignment and lower porosity at the defect interface. Celgro^{TM} can restore bone defects without complications or adverse events. Collagen membranes can modulate the osteoimmune response of macrophages. Chen et al. modified a collagen membrane by coating it with a nanometer bioactive glass (hardysonite) through pulsed laser deposition for GBR and evaluated its ability to enhance osteogenesis through osteoimmunomodulation (Chen et al, 2018). They found that the modified collagen membrane can enhance the osteogenic differentiation of bone-marrow-derived mesenchy- mal stem cells, suggesting that collagen membranes with nanometer-sized hardysonite coating are promising for GBR applications. A study on a collagen membrane with prolonged resorption time, found significantly higher membrane exposure in the new collagen membrane than in the native collagen membrane (Annen et al, 2001). The magnesium membrane has been proven to have all of the necessary requirements for an optimal regenerative outcome from both a mechanical and biological perspective. The *in vivo* performance study demonstrated that the

magnesium membrane has a comparable healing response and tissue regeneration to that of a resorbable collagen membrane. (Rider et al,2022). In our study, the influence of the material from which the resorbable membranes are made on the contact angle was highlighted, even if they have the same duration of resorbability (P2, P3, P4). Due to the difference between the porous structure and the fibrillar structure it has been shown that the design and processing of biomaterials influence resorbability.

Conclusions

- The influence of the material from which the resorbable membranes are made on the contact angle was highlighted, even if they have the same duration of resorbability.
- Due to the difference between the porous structure (P2 membrane) and the fibrillar structure (P1 membrane), it has been shown that the design and processing of biomaterials influence resorbability.
- Resorbable barrier membranes serve as physical barriers, preventing soft tissue ingrowth while allowing the migration of osteogenic cells from adjacent bone into the defect area.
- The membranes help to stabilize the blood clot, maintain a space for undisturbed bone regeneration, and facilitate the recruitment of mesenchymal stem cells and progenitor cells.
- Factors such as membrane degradation rate, exposure to bacterial contamination, and immune responses may affect the regenerative outcomes.

SECTION II.

FUTURE PLANS OF DEVELOPMENT ON SCIENTIFIC AND ACADEMIC CAREER

II.1. FUTURE DIRECTIONS IN RESEARCH ACTIVITY

My career is based on two directions, dental practice and didactic activity, which are permanently combined ensuring a foundation for daily activity in medical practice as well as teaching-learning.

In my future work, I want to concentrate on expanding into new study topics while also continually developing the current research methodologies. I'll keep steadily advancing my knowledge in the professional, academic, and scientific fields while maintaining a cautious balance throughout all my activities. To conduct joint research projects, I will continue to form research teams with experts from the same industry as well as from various specialties. Another goal for developing joint initiatives and research networks is to develop collaboration with maxillofacial departments at other institutions. I'll continue to discuss the findings of current research in papers I submit to national and international scientific conferences, as well as publish articles in journals with ISI ratings and BDI indexes.

My research career's specific goals for the future will be guided towards:

- Achieving valuable original results to be presented in national and international scientific events, as well as published in highly accessed ISI and BDI journals, or monographs;
- Determination of the main future research directions in accordance with the latest topics of interest in the field of oral surgery and lasers;
- Focusing efforts only on research directions whose results can have applicability in medical practice;
- Development of interdisciplinary collaborations on research projects for interdisciplinary and interuniversity studies in the field of oral surgery and lasers;
- Collaborating with other interdisciplinary research groups to advance current knowledge regarding diagnosis and treatment;
- Organizing and participating in national and international scientific events;
- Development of applications for winning grants and multidisciplinary research projects;
- Encouraging residents and students to join mixed research teams and disseminating research results through dissertations or scientific events;
- Choosing the best candidates for doctoral studies from those deemed most suitable who demonstrate a passion for academic research and an interest in pursuing particular areas of research;
- And looking for ways to upgrade the current infrastructure.

Future academic work by me will focus primarily on areas and research areas that are already active, including tasks that have been the focus of my attention for the past five years, such as complex periodontal disease diagnosis and treatment, as well as new research directions, such as:

- **Expanding research on systems of computerised planning of the preimplant and implant surgical preparation using laser technology**

Due to the variety of wavelengths and the potential for transmission to oral tissues, laser therapy has permeated several dental medical specialties including periodontology, implantology, the treatment of dental cavities, endodontics, aesthetic procedures, and pedodontics. The trauma, haemorrhage, and postoperative problems that are distinctive characteristics of laser treatment are decreased by the selective and precise contact with the mouth cavity tissue.

A full understanding of the fundamental concepts and operating parameters of laser devices, as well as the findings of research that look into the effectiveness and success rate of laser treatments in dental care, are necessary to assure the efficiency and safety of laser therapies.

The continuation of the research aims to deepen the knowledge regarding the use of laser technology for the pro-prosthetic preparation of the protective space, the pre-implant stage and implant stage to encourage minimally invasive approach and greater accuracy of implant therapy.

The original research demonstrated the superiority of laser techniques by comparing them with classical surgical techniques used in the proprosthetic stage. In the same way, previous research has evaluated the possibility of using laser biostimulation in the proprosthetic stage of patients with soft tissue injuries but the efficiency of ablation of various types of oral tissues.

Through future research, I want to establish clear protocols regarding the techniques and indications for the use of laser technologies in surgical practice in particular, but also in general dentistry.These protocols will provide clear details regarding the characteristics of working techniques to obtain high quality clinical results.

In order to create specific fix or mobile prosthetic restorations that guarantee a high-quality esthetic outcome, ideal occlusal connections, and that do not harm the health of periodontal tissues, laser devices can be utilized as an adjuvant approach. The gingival sulcus, junction epithelium, and attachment tissue make up a 3 mm broad region known as the biological width, which laser treatment supports. Diode lasers, CO2 lasers, and lasers from the Er family can all be used for therapeutic operations involving soft tissues. Er lasers are the only ones that can be used effectively to reshape bone tissue.

The following benefits come from using lasers in the pro-prosthetic stage: surgical accuracy; hemostasis; speeding up the healing process for the gingiva. A significant reduction of intra-operatory bleeding, of the postoperative pain and an acceleration of the healing time in relation to the conventional surgical methods are some of the characteristics of laser-assisted pro-prosthetic surgical interventions (gingivectomy, frenectomy, vestibuloplasty)

- **Study regarding the role of barrier membranes in guided bone regeneration techniques**

Barrier membranes are crucial to guided bone regeneration because they prevent the invasion of soft tissues into bone defects and provide the space necessary to support the formation of new bone within normal limits.

In the repair of the muco-osseous support in oral complex rehabilitation, guided tissue regeneration procedures are frequently employed. To ensure optimal implant location and a successful long-term result of the implant-prosthetic treatment, it is necessary to rebuild the alveolar bone that has undergone extensive resorption. Barrier membranes and various types of bone grafts (autogenous bone, xenografts, and alloplastic grafts) are employed as biomaterials in these procedures.

The fundamental idea behind guided bone regeneration technique is the application of a barrier membrane to prevent non-osteogenic components (epithelial and connective tissue cells) from penetrating the bone compartment and interfering with bone regeneration processes.

The resorbable membranes used in the guided bone regeneration techniques are natural and artificial polymer membranes.These membranes are divided, related to their origin, as follows:• natural polymers, represented by collagen;• synthetic polymers represented by

aliphatic polyesters (eg poly (lactic acid) (PLA), poly (polyglycolic acid) (PGA), poly (ε-caprolactone) (PCL).

Due to their improved mechanical strength and degradation cycle, crosslinked collagen membranes can produce superior outcomes in the regeneration of soft tissues and bones. Despite having good biocompatibility, the collagen membranes' unexpected rate of breakdown can compromise the efficacy of guided bone regeneration procedures. To improve clinical tissue regeneration, collagen membranes must be modified, often by cross-linking and the transfer of bioactive compounds. The primary goal of the cross-linking method is to increase the mechanical durability and slow down the collagen membranes' natural decomposition cycle, which should have an impact on the therapeutic result of collagen membranes.

The mechanical and physicochemical properties of the resorbable membranes varies widely between commercial products. The importance of in vitro studies is highlighted by the influence of these properties on the clinical handling and long-term implant survival and success. In vitro research groups investigated various properties such as chemical composition, tensile strength, modulus Young, wettability, roughness, density, thickness and porosity. Resorbable barrier membranes serve as physical barriers, preventing soft tissue ingrowth while allowing the migration of osteogenic cells from adjacent bone into the defect area.

The membranes help to stabilize the blood clot, maintain a space for undisturbed bone regeneration, and facilitate the recruitment of mesenchymal stem cells and progenitor cells. Factors such as membrane degradation rate, exposure to bacterial contamination, and immune responses may affect the regenerative outcomes. The resorbable barrier membranes play a crucial role in guided bone regeneration by creating a protected environment, facilitating osteogenic cell migration, and promoting bone formation.

- **Bone regeneration influence in the success of implant surgery**

Dental implants have a very high success rate, but there will always be some instances of early or late implant failure. It's important to keep in mind that the amount and quality of bone in the region immediately around the implant play a significant role in determining the effectiveness of dental implants. Bone grafts are frequently used to guide the bone regeneration around dental implants, either immediately after implant placement or as part of a periimplantitis therapy strategy. Deproteinized bovine bone mineral implants have demonstrated long-term viability and significant therapeutic benefits.

Treatment options for the condition show a lot of promise, including bone grafts, bio membranes, concentrated microspheres, and topical ointments that deliver antibiotics locally. By preserving connective tissue loss with the use of bone grafts and the local antibacterial action of antibiotics, successful management of peri-implantitis and directed bone regeneration following expedited insertion of dental implants can lower the likelihood of implant failure.

The amount and quality of alveolar bone in the implant site affects implant position, primary stability, soft tissue shape recovery, and other elements essential to a successful implantation restoration in oral implantology. Following tooth loss, secondary bone resorption and atrophy lead the alveolar ridge's breadth and height to gradually decrease, making the ridge ultimately unsuitable for implant insertion.

For this reason, effective alveolar bone healing is crucial to oral implantology. Numerous treatment techniques, including guided bone regeneration (GBR), onlay bone grafting, bone extrusion, bone splitting, and distraction osteogenesis, are available to treat alveolar bone abnormalities. Because of its simplicity, low technical sensitivity, osteogenic stability, and potential for multidirectional osteogenesis, GBR is currently among the most widely used procedures for treating alveolar bone abnormalities.

GBR technology selectively blocks epithelial cells and connective tissue cells from entering the bone defect area through a barrier membrane based on the hypothesis that different cell types have different migration rates, allowing osteoblasts to enter the area preferentially to complete bone induction and regeneration. Bone graft materials are put in the area of the bone

deficiency to function as scaffolds while the new bone is being created by the osteoblasts and osteocytes.

Pluripotent and osteogenic cells, such osteoblasts from the periosteum and/or adjacent bone and/or bone marrow, must move to the site of the bone defect for GBR to be effective, while cells that prevent bone formation, including epithelial cells and fibroblasts, must be excluded.

Most bone graft and replacement materials used in dentistry to replace lost hard tissue components are either particles or blocks. Dental grafting materials are in high demand and are in high demand right now. Current bone graft and replacement materials' main purpose is to act as a framework for osteo-regenerative processes, which only need to adhere to the osteoconductivity standards.

However, as tissue engineering research develops, new developments have been made, including a variety of ceramic and polymeric-based bone substitutes supplemented with live osteogenic progenitor cells or growth hormones.

II.2. FUTURE DIRECTIONS IN ACADEMIC ACTIVITY

II.2.1. Academic activities regarding students and residents

Any university professor's teaching activities include engaging in instructional activities. Our primary responsibility is to instruct our students, but how we accomplish this is of utmost significance. In addition, because future researchers or at the very least the greatest residents who will be able to have an outstanding clinical evolution can be chosen from this stage of evolution.

As the future dentists, teaching the students and residents about lasers and oral surgery is a significant part of my everyday work. Among the guidelines I adhere to are enhancing my expertise, giving them thorough explanations, encouraging them to conduct independent research, attend as many scientific meetings, seminars, and courses as possible, encouraging them to write scientific articles, and including them in research initiatives.

Implementing research findings in medical practice and educational processes, coordinating research topics at student scientific meetings, moving forward in the teaching stages in accordance with the acquired skills and the available opportunities, as well as boosting the department's, faculty's, and university's scientific reputation, are all requirements for linking research to educational and medical activities.

All these activities helped me get valuable experience interacting with children and gave me a greater knowledge of their true needs and viewpoint. I was able to build a solid foundation for my academic work with pupils in this way. To achieve this goal, it is important to continue to update the course presentations' material to improve learning and capture students' interest. To do this, do the following actions:

- Expanding the use of interactive presentation techniques and improving course delivery and design.
- Adding newly developed information with a focus on practical aspects.
- The most capable students who are interested in research activities must be chosen to participate in research studies and join research teams.
- Student scientific circles must be established to pique the interest of students in scientific research and in the surgical disciplines.
- The student evaluation system must be updated frequently.
- Interesting bachelor's thesis topics must be created to pique the interest of students in oral surgery.

- Encourage students to take the initiative to pursue specific research topics within the field of oral surgery.
- Presenting eloquent teaching materials from clinical practice in accordance with the curriculum and in compliance with the requirements for personal data protection by archiving the clinical information of patients who have been diagnosed and treated in the oral surgery clinic
- Plan workshops and symposiums tailored to the student's area of interest;
- Offer optional courses in accordance with the existing demands;
- Active participation in scientific events on a national and international scale;
- Diversification of assessment techniques based on student performance and skills, periodic evaluation of the student tasks to become familiar with the methods of final examination and evaluation.
- Collaboration with other national centers to facilitate student mobility.
- Building a strong teamwork environment within the oral surgery discipline for interested and skilled students.

II.2.2. Academic activities regarding doctoral students

A doctoral student represents a separate category of student because he constantly needs guidance and support to achieve the proposed objectives.

I also benefited from this special guidance when I completed my doctoral studies under the guidance of Prof. Univ. Dr. Eugenia Popescu, the studies carried out under her guidance materializing in ISI and BDI articles published in prestigious magazines as well as in conferences, courses and oral presentations held at national and international scientific events.

The key future development directions for the academic activities involving PhD students are as follows:

- Establishing specific areas of recent interest and development in the field of oral and maxillofacial surgery that would be suitable for doctoral studies, in relation to the existing and ongoing research subjects;
- Teaching doctorate students the most recent information regarding the research topic and the practical methods;
- Selected the most capable students and resident doctors showing interest in learning and performing scientific research, for doctoral studies fellowship.
- Encourage doctoral students to join multidisciplinary teams to broaden the scope of ideas and discover new technological solutions;
- Pursue opportunities for interdisciplinary and inter-university collaborations to facilitate access to information, technology, and experience exchange;
- Encourage doctoral students to publish articles, present their work as oral presentations or posters at various conferences to make their work visible.

II.3. DIRECTIONS FOR FUTURE PROFFESIONAL ACTIVITY

My whole career preparation is influenced by the characters I interacted with and the teaching staff, and it all stems from my ambition to push myself beyond my comfort zone in order to advance professionally.

I want to maintain this activity right now and get to a crucial strength point for me that will provide the groundwork for a predictable but positive advancement in my profession after the studies I completed for my PhD and in numerous professional institutions in various job

directions. My experience has enabled me to coordinate the group's efforts in a way that will enable us to handle any obstacles that may occur successfully.

The following are some potential possibilities for my professional career going forward:

- Improving medical treatment through the application of new technologies and enhanced protocols:
- Applying new materials and surgical techniques in the Oral surgery in order to treat the current pathology;
- Improving access to laser technology to improve the biological parameters of the implanto - prosthetic field.
- The use of digital means in the surgical treatment of oral diseases with the aim of increasing the precision of the actual surgery and thus improving results.
- Promoting interdisciplinary collaborations for the management of complex cases.
- The introduction and diversification of practical training programs for residents regarding the application of new software for planning and predictability of somato-facial aesthetics through the lens of rehabilitation of the elements of the impaired stomatognathic system.

In collaboration with the *Tissue Engineering Center*, I propose the creation of new biodegradable materials for the bone regeneration of patients with severe resorptions, an application that can be carried out together with residents, students and doctoral students.

Tissue engineering has evolved from the use of biomaterials in the plasty of tissue defects to the use of three-dimensional matrices in which cells are positioned prior to implantation

This living construct is mechanically, functionally and structurally equivalent to the tissue it replaces. The major advantage of this technique is the possibility of obtaining tissue that fits perfectly in shape, size and from an immunological point of view.

Clinical success is largely dependent on the quality of the materials used, for example the matrix, as well as the cell supply.

Another concern will consist in the coordination of students and residents on oral disease *screening* topics for the early detection of precancerous and cancerous lesions and bone resorption.

Screening for oral cancer

There are about 657,000 new cases of oral and throat cancer worldwide each year, resulting in more than 330,000 deaths, most of them are Squamous cell carcinoma. Oral cancer is largely related to lifestyle, with major risk factors being tobacco and alcohol misuse. In addition to smoking, the use of smokeless tobacco has been strongly linked to oral cancer.

Unfortunately, the diagnosis continues to rely on patient presentation and physical examination with biopsy confirmation. This may result in delay in diagnosis accounting for the fact that the majority of these cancers are diagnosed at a late stage. Studies confirm that survival does correlate with stage, making early diagnosis and treatment optimal for this disease.

Despite advances in surgical techniques, radiation therapy technology, and the addition of combined chemotherapy and radiation therapy to the treatment regimen, survival data has not shown appreciable change in decades. Five-year survival data reveal overall disease specific survival rates of less than 60% although those that do survive often endure major functional, cosmetic, and psychological burden due to dysfunction of the ability to speak, swallow, breathe, and chew. Seventy-five percent of all head and neck cancers begin in the oral cavity. According to the National Cancer Institute’s Surveillance, Epidemiology, and Ends Results (SEER) program, 30 percent of oral cancers originate in the tongue, 17 percent in the lip, and 14 percent in the floor of the mouth. Many other studies support this finding that oral cancers appear most often on the tongue, and floor of the mouth. New data related to the HPV16 virus may indicate

that these trends are changing with the poster mouth including the tonsils, tonsillar pillar and crypt, the base of the tongue, and the oropharynx increasing rapidly in incidence rates. A thorough, systematic examination of the mouth and neck need only take a few minutes and can detect these cancers at an early and curable, stage.

It is well established that virtually all oral squamous cell carcinomas are preceded by visible changes in the oral mucosa, usually by way of white (leukoplakia) and red patches (erythroplakia). In addition, there are other inflammatory disorders of the oral mucosa such as lichen planus, submucous fibrosis and perhaps oral fibrosis due to systemic sclerosis that have been associated with an increased risk of squamous cell carcinomas development. It is believed that identification and monitoring of these potentially malignant lesions and conditions allows clinicians to detect and treat early intraepithelial stages of oral carcinogenesis, for example mild, moderate or severe dysplasia and carcinoma in situ, all of which generally precede the development of invasive squamous cell carcinomas.

Currently, screening of oral cancer is largely based on visual examination.Various evidence strongly suggests the validity of visual inspection in reducing mortality in patients at risk for oral cancer. Simple visual examination is accompanied with **adjunctive techniques** for subjective interpretation of dysplastic changes. These include toluidine blue staining, brush biopsy, chemiluminescence and tissue autofluorescence.

Population screening programmes are of three main types. Mass screening describes a process whereby the whole populations are screened, but this type of programme is rarely used. Most programmes are selective and target a subset of the population who are felt to be at highest risk, the third type is opportunistic screening, where individuals are examined when they attend a healthcare professional for some other, often unrelated, purpose.

For this purpose, *I propose the conduct of some screening campaigns for the population groups at risk of oral cancer* where the criteria for subject selection should, in accordance with the risk factors for oral cancer, be:

- the institutionalized old people aged over 65
- male individuals aged between 50 and 65 who smoke and drink alcohol and have a low social-economic status.

The clinical examination and use of additional tests for the identification of malignant oral lesions might be carried out in the dental office existing in the institutions for old people, in dentists' private dental offices (in the case of rural areas) as well as in the outpatient service of the faculties of Dental Medicine. Examiners must be dentists, doctoral students, and medical residents.

In conclusion, the success of the academic profession is given by perseverance, an open mind to innovating ideas, the capacity to communicate within work teams, and the permanent improvement of teaching and professional performances.

I consider that my professional reputation and future academic career will result in the increase of visibility of the department, faculty and university where I currently work.

SECTION III

REFERENCES

1. Abdelhay N, Prasad S, Gibson MP. Failure rates associated with guided versus non-guided dental implant placement: a systematic review and meta-analysis. *BDJ Open.* 2021 Aug 18;7(1):31. doi: 10.1038/s41405-021-00086-1.
2. Academy of Osseointegration. Guidelines of the Academy of Osseointegration for the provision of dental implants and associated patient care. *Int. J. Oral Maxillofac. Implants* 2010, 25, 620–627.
3. Aghaloo, T.L. & Moy, P.K. Which hard tissue augmentation techniques are the most successful in furnishing bony support for implant placement?. *The International Journal of Oral and Maxillofacial Implants*, 2007; Vol.22, Suppl: 49-70.
4. Aghaloo, T.L.; Moy, P.K. Which hard tissue augmentation techniques are the most successful in furnishing bony support for implant placement? *Int. J. Oral Maxillofac. Implant*. 2007, 22, 49–70.
5. Agop-Forna, D.; Török, R.; Török, B.; Dragomir, R.; Ehrenfest, D.M.D.; Dascălu, C.; Stelea, C.G. Postoperative Study of Bone Gain in Mandibular Alveolar Bone Reconstructed with Screw-Guided Bone Regeneration Technique and Porcine-Derived Xenograft in 42 Edentulous Patient Candidates for Implant-Prosthetic Therapy. *Appl. Sci.* 2021, 11, 9826. https://doi.org/10.3390/app11219826.
6. Aguirre-Zorzano L.A, Estefanía-Fresco R, Telletxea O, Bravo M. Prevalence of peri-implant inflammatory disease in patients with a history of periodontal disease who receive supportive periodontal therapy. *Clin Oral Implants Res*.2015;26:1338–44.
7. Ahmed, M.A.; Jouhar, R.; Faheemuddin, M.; AlJafar, A.; Alabawi, H.; Alhumaidi, B.; Al Madeh, M. Assessment of Oral Health Knowledge, Attitude, Practice and DMFT Scores among Patients at King Faisal University, Al-Ahsa. *Medicina* 2023, 59, 688
8. Ahrberg D, Lauer HC, Ahrberg M, Weigl P. Evaluation of fit and efficiency of CAD/CAM fabricated all-ceramic restorations based on direct and indirect digitalization: a double-blinded, randomized clinical trial. *Clin Oral Investig.* 2016 Mar;20(2):291-300.
9. Ajayi, D.M., Arigbede, A.O. Barriers to oral health care utilization in Ibadan, South West Nigeria. *Afr Health Sci*. 2012;12(4):507-513.
10. Akeel, R. Usage of removable partial dentures in Saudi male patients after 1-year telephone Interview. *Saudi Dent. J.* 2010, 22, 125–128.
11. Akifusa, S.; Soh, I.; Ansai, T.; Hamasaki, T.; Takata, Y.; Yohida, A.; Fukuhara, M.; Sonoki, K.; Takehara, T. Relationship of number of remaining teeth to health-related quality of life in community dwelling elderly. *Gerodontology* 2005, 22, 91–97.
12. Al Mortadi N, Eggbeer D, Lewis J, Williams RJ. CAD/CAM/AM applications in the manufacture of dental appliances. *Am J Orthod Dentofacial Orthop*. 2012 Nov;142(5):727-33.
13. Al Quran FA, Rashdan BA, Zomar AA, Weiner S. Passive fit and accuracy of three dental implant impression techniques. *Quintessence Int* 2012;43:119-25.
14. Al-Ansari A. Awareness, utilization, and determinants of using oral diseases prevention methods among Saudi adults – A clinic-based pilot study. Int J Health Sci (Qassim) 2016; 10:77-85
15. Alauddin MS, Abdul Hayei NA, Sabarudin MA, Mat Baharin NH. Barrier Membrane in Regenerative Therapy: A Narrative Review. *Membranes (Basel).* 2022 Apr 20;12(5):444.
16. Albrektsson T, Buser D, Chen S.T, Cochran D, DeBruyn H, Jemt T, Koka S, Nevins M, Sennerby L, Simion M. et al. Statements from the Estepona Consensus Meeting on Peri-implantitis. *Clin. Implant Dent. Relat. Res*. 2012, 14:781–782.
17. Alghazzawi TF. Advancements in CAD/CAM technology: Options for practical implementation. *J Prosthodont Res.* 2016 Apr;60(2):72-84.
18. Allan, B.; Ruan, R.; Landao-Bassonga, E.; Gillman, N.; Wang, T.; Gao, J.; Ruan, Y.; Xu, Y.; Lee, C.; Goonewardene, M.; et al. Collagen Membrane for Guided Bone Regeneration in Dental and

Orthopedic Applications. *Tissue Eng. Part A* 2021, 27:372–381.
19. Almutlaqah, M.A., Baseer, M.A., Ingle, N.A., Assery, M.K., Al Khadhari, M.A.. Factors Affecting Access to Oral Health Care among Adults in Abha City, Saudi Arabia. *Journal of International Society of Preventive and Community Dentistry.* 2018; 8 (5):431-438.
20. Alshahrani, A.M., Raheel, S.A. Health care system and accessibility of dental services in kingdom of Saudi Arabia: An update. *J Int Oral Health* 2016; 8:883
21. An YZ, Kim YK, Lim SM, Heo YK, Kwon MK, Cha JK, Lee JS, Jung UW, Choi SH. Physiochemical properties and resorption progress of porcine skin-derived collagen membranes: In vitro and in vivo analysis. *Dent Mater J*. 2018 Mar 30;37(2):332-340.
22. and radiographic retrospective 1-year study. *Eur J Oral Implantol*. 2011 Autumn;4(3):257-67.
23. Angrisani, N.; Reifenrath, J.; Seitz, J.M.; Meyer-Lindenberg, A. Rare Earth Metals as Alloying Components in Magnesium Implants for Orthopaedic Applications. In New Features on Magnesium Alloys, Monteiro W.A. (ed), IntechOpen, Rijeka-Croatia, 2012. dx.doi.org/10.5772/48335
24. Annen, B.M.; Ramel, C.F.; Hämmerle, C.H.; Jung, R.E. Use of a new cross-linked collagen membrane for the treatment of peri-implant dehiscence defects: A randomised controlled double-blinded clinical trial. *Eur. J. Oral Implantol.* 2011, 4:87–100.
25. Antetomaso J, Kumar S. Survival rate of delayed implants placed in healed extraction sockets is significantly higher than that of immediate implants placed in fresh extraction sockets. *J Evid Base Dent Pract*, 2018:76-78.
26. Arisan, V.; Karabuda, C.Z.; Mumcu, E.; Ozdemir, T. Implant positioning errors in freehand and computer-aided placement methods: A single-blind clinical comparative study. *Int. J. Oral Maxillofac. Implant* 2013, 28, 190–204.
27. Armencia, A., Bobu, L., Bosînceanu, D., Bolat, M., Stupu, A., Nicolau, A., Hurjui, L., Bârlean, M., Roșu, S., Balcoș, C., Săveanu, I.C. Study on the association between caries experience and social and behavioural factors in young adults and adults in Iasi, Romania. *Romanian Journal of Medical and Dental Education* 2019;Vol. 8, No. 8:39-46.
28. Atieh M.A, Alsabeeha N.H, Faggion C.M Jr, Duncan W.J. The frequency of peri-implant diseases: a systematic review and meta-analysis. *J Periodontol*. 2013 Nov; 84(11):1586-98
29. Atrens, A.; Song, G.L.; Cao, F.; Shi, Z.; Bowen, P.K. Advances in Mg corrosion and research suggestions. *Journal of Magnesium and Alloys* 2013, 1(3), 177-200. https://doi.org/10.1016/j.jma.2013.09.003.
30. augmentation: case series study. *Maxillofac Plast Reconstr Surg*. 2019 Sep 16;41(1):36. doi:
31. Ayoub A, Pulijala Y. The application of virtual reality and augmented reality in Oral & Maxillofacial Surgery. *BMC Oral Health.* 2019 Nov 8;19(1):238.
32. Babbush CA., Hahn JA, Krauser JT, Rosenlicht JL. Dental Implants. *The Art and Science*. Saunders Elsevier. 2011.
33. Baeten, R., Spasova, S., Vnhercke, B. and Coster, S. Inequalities and access to healthcare. A study of national policies 2018. European Commission, Nov. 2018. ISBN 978-92-79-94740-7
34. Balan, A., Baciu, D., Balcos, C., Pintiliciuc Serban, V. Association of caries experience with social and behavioural factors among adults of different ages from Iasi County, Romania *International Journal Of Medical Dentistry*, 2013; 17(3): 195 – 200.
35. Bardis D, Agop-Forna D, Dascălu C, Cristea I, Forna N. Biological and mechanical-technical complications of posterior metal-ceramic implant-supported fixed partial dentures: a retrospective study. *Rom J Oral Rehab*. 2022; 14(3): 18-26.
36. Barone A, Marconcini S, Giammarinaro E, Mijiritsky E, Gelpi F, Covani U. Clinical Outcomes of Implants Placed in Extraction Sockets and Immediately Restored: A 7-Year Single-Cohort Prospective Study. *Clin Implant Dent Relat Res*. 2016 Dec;18(6):1103-1112.
37. Bart I, Dobler B, Schmidlin K, et al. Complication and failure rates of tooth-supported fixed dental prostheses after 7 to 19 years in function. *Int J Prosthodont*. 2012;25:360–367.
38. Bäumer A, Toekan S, Saure D, Körner G. Survival and success of implants in a private periodontal practice: a 10 year retrospective study. *BMC Oral Health*. 2020 Mar 30;20(1):92.
39. Beldiman MA, Diaconu-Popa D, Tatarciuc M, Nicolaiciuc O, Vasilache C, Luca O. Digital smile design in prosthodontics- an overview. *Journal of Oral Rehab*.2022;14(1):150-156.

40. Berglundh T, Armitage G, Araujo M.G, Avila-Ortiz G, Blanco J, Camargo P.M, Chen S, Cochran D, Derks J, Figuero E, Hämmerle C.H.F, Heitz-Mayfield L.J.A, Huynh-Ba G, Iacono V, Koo K.T, Lambert F, McCauley L, Quirynen M, Renvert S, Salvi G.E, Schwarz F, Tarnow D, Tomasi C, Wang H.L, Zitzmann N. Peri-implant diseases and conditions: Consensus report of workgroup 4 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. *J Clin Periodontol*. 2018 Jun;45 Suppl 20:S286-S291.
41. Berglundh T, Persson L, Klinge B. A systematic review of the incidence of biological and technical complications in implant dentistry reported in prospective longitudinal studies of at least 5 years. *J Clin Periodontol* 2002;29 Suppl 3:197-212.
42. Berglundh, T.; Armitage, G.; Araujo, M.G.; Avila-Ortiz, G.; Blanco, J.; Camargo, P.M.; Chen, S.; Cochran, D.; Derks, J.; Figuero, E.; et al. Peri-implant diseases and conditions: Consensus report of workgroup 4 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. *J. Periodontol*. 2018, 89, S313–S318.
43. Bernard, L.; Vercruyssen, M.; Duyck, J.; Jacobs, R.; Teughels, W.; Quirynen, M. A randomized controlled clinical trial comparing guided with nonguided implant placement: A 3-year follow-up of implant-centered outcomes. *J. Prosthet. Dent.* 2019, 121, 904-910
44. Beschnidt SM, Cacaci C, Dedeoglu K, Hildebrand D, Hulla H, Iglhaut G, Krennmair G, Schlee M, Sipos P, Stricker A, Ackermann KL. Implant success and survival rates in daily dental practice: 5-year results of a non-interventional study using CAMLOG SCREW-LINE implants with or without platform-switching abutments. *Int J Implant Dent*. 2018 Nov 2;4(1):33. doi: 10.1186/s40729-018-0145-3.
45. Bhandari, B.; Newton, J.T.; Bernabe, E. Income Inequality and Use of Dental Services in 66 Countries. *J. Dent. Res*. 2015, 94, 1048–1054.
46. Bibb RJ, Eggbeer D, Williams RJ, Woodward A. Trial fitting of a removable partial denture framework made using computer-aided design and rapid prototyping techniques. *Proc Inst Mech Eng H.* 2006 Jul;220(7):793-7.
47. Bidra AS, Daubert DM, Garcia LT, Gauthier MF, Kosinski TF, Nenn CA, et al. A Systematic Review of Recall Regimen and Maintenance Regimen of Patients with Dental Restorations. Part 1: Tooth-Borne Restorations. *J Prosthodont*.2016;25(suppl 1):S2–15.
48. Bose S, Roy M, Bandyopadhyay A. Recent advances in bone tissue engineering scaffolds. *Trends in Biotechnology.* 2012;30(10):546-554.
49. Böstman O, Pihlajamäki H. Clinical biocompatibility of biodegradable orthopedic implants for internal fixation: a review. *Biomaterials.* 2000;21(24):2615-2621.
50. Bozkurt A, Apel C, Sellhaus B, van Neerven S, Wessing B, Hilgers RD, Pallua N. Differences in degradation behavior of two non-cross-linked collagen barrier membranes: an in vitro and in vivo study. *Clin Oral Implants Res*. 2014 Dec;25(12):1403-11.
51. Bracey, D.N.; Seyler, T.M.; Jinnah, A.H.; Lively, M.O.; Willey, J.S.; Smith, T.L.; Van Dyke, M.E.; Whitlock, P.W. A Decellularized porcine xenograft-derived bone scaffold for clinical use as a bone graft substitute: A critical evaluation of processing and structure. *J. Funct. Biomater*. 2018, 9, 45.
52. Bredberg C, Vu C, Häggman-Henrikson B, Chrcanovic BR. Marginal bone loss around dental implants: comparison between matched groups of bruxer and non-bruxer patients: A retrospective case-control study. *Clin Implant Dent Relat Res*. 2023 Feb;25(1):124-132.
53. Broadbent JM, Thomson WM. For de-bate: Problems with the DMF index pertinent to dental caries data analysis. *Community Dent Oral Epidemiol.* 2005; 33(6):400-9.
54. Bucur A. Ghid de practică în chirurgia oro-maxilo-facială, Ed. Q Med Publishing, 2012.
55. Bunyaratavej, P.; Wang, H.-L. Collagen Membranes: A Review. J. Periodontol. 2001, 72, 215–229.
56. Buser, D.; Mericske-Stern, R.; Dula, K.; Lang, N.P. Clinical Experience with One-Stage, Non-Submerged Dental Implants. *Adv.Dent. Res*. 1999, 13, 153–161.
57. Buser, D.; Mericske-Stern, R.; Dula, K.; Lang, N.P. Clinical experience with one-stage, non-submerged dental implants. *Adv. Dent.Res*. 1999, 13, 153–161.
58. Caballé-Serrano J, Munar-Frau A, Delgado L, Pérez R, Hernández-Alfaro F. Physicochemical characterization of barrier membranes for bone regeneration. *J Mech Behav Biomed Mater*. 2019

Sep;97:13-20.
59. Calì M, Zanetti E M, Oliveri S M. Influence of thread shape and inclination on the biomechanical behaviour of plateau implant systems. *Dent Mat*, 2018;34:460–469.
60. Calin A, Agop Forna D, Forna N C. The implications of preimplantation analysis and positioning of implants in the success / failure rate of the implantation treatment. *Romanian Journal of Oral Rehabilitation*, 2016;8(3):111-119.
61. Calori GM, Mazza E, Colombo M, Ripamonti C. The use of autologous bone graft in the treatment of bone defects: new perspectives and original applications. *Journal of Orthopedic Trauma*. 2011;25(Suppl 1):S21-S25.
62. Canellas JVDS, Medeiros PJD, Figueredo CMDS, Fischer RG, Ritto FG. Which is the best choice after tooth extraction, immediate implant placement or delayed placement with alveolar ridge preservation? A systematic review and meta-analysis. *J Craniomaxillofac Surg*. 2019 Nov;47(11):1793-1802.
63. Carausu, E.M., Dascalu, C.G., Zegan, G., Burlea, L.S., Lupu, I.C., Antohe, I. (2017). The General and Oral Health Status in Older Adults from Rural Environment of Iasi County, Romania. *Revista de Cercetare si Interventie Sociala*, 59, 187-208.
64. Carra MC, Rangé H, Swerts PJ, Tuand K, Vandamme K, Bouchard P. Effectiveness of implant-supported fixed partial denture in patients with history of periodontitis: A systematic review and meta-analysis. *J Clin Periodontol*. 2022 Jun;49 Suppl 24:208-223.
65. Cattoni, F.; Chirico, L.; Merlone, A.; Manacorda, M.; Vinci, R.; Gherlone, E.F. Digital Smile Designed Computer-Aided Surgery versus Traditional Workflow in "All on Four" Rehabilitations: A Randomized Clinical Trial with 4-Years Follow-Up. *Int. J. Environ. Res. Public Health* 2021, 18, 3449.
66. Chan, A.K.Y.; Tamrakar, M.; Jiang, C.M.; Lo, E.C.M.; Leung, K.C.M.; Chu, C.H. A Systematic Review on Caries Status of Older Adults. Int. J. Environ. *Res. Public Health* 2021, 18, 10662. https:// doi.org/10.3390/ijerph182010662
67. Chan, E.C.; Kuo, S.-M.; Kong, A.M.; Morrison, W.A.; Dusting, G.J.; Mitchell, G.M.; Lim, S.Y.; Liu, G.-S. Three Dimensional Collagen Scaffold Promotes Intrinsic Vascularisation for Tissue Engineering Applications. *PLoS ONE* 2016, 11, e0149799.
68. Chang MC, et al. Comparative evaluation of biodegradable materials as bone substitutes using an osteoblastic cell line: MG63. *Journal of Oral Rehabilitation*. 2002;29(10):929-935.
69. Chatzopoulos G.S., Wolf L.F. Implant failure and history of failed endodontic treatment: A retrospective case-control study. *J Clin Exp Dent.* 2017 Nov; 9(11): e1322–e1328.
70. Chavda, S.; Levin, L. Human studies of vertical and horizontal alveolar ridge augmentation comparing different types of bone graft materials: A systematic review. *J. Oral Implant*. 2018, 44, 74–84.
71. Chen J, Cai M, Yang J, Aldhohrah T, Wang Y. Immediate versus early or conventional loading dental implants with fixed prostheses: A systematic review and meta-analysis of randomized controlled clinical trials. *J Prosthet Dent.* 2019 Dec;122(6):516-536.
72. Chen, C.-K.; Yuh, D.-Y.; Huang, R.-Y.; Fu, E.; Tsai, C.-F.; Chiang, C.-Y. Accuracy of Implant Placement with a Navigation System, a Laboratory Guide, and Freehand Drilling. *Int. J. Oral Maxillofac. Implant.* 2018, 33, 1213–1218.
73. Chen, M., Andersen, R.M., Barmes, D.E., Leclercq, M.H., Lyttle, C.S. Comparing Oral Health Care Systems: A second international collaborative study. Geneva, Switzerland: World Health Organization; 1997:350. https://apps.who.int/iris/handle/10665/41976. Accessed October 12, 2020
74. Chen, Y., et al. *Biomaterials Science* 2020, 8(3), 778-794.
75. Chen, Z.; Chen, L.; Liu, R.; Lin, Y.; Chen, S.; Lu, S.; Lin, Z.; Chen, Z.; Wu, C.; Xiao, Y. The osteoimmunomodulatory property of a barrier collagen membrane and its manipulation via coating nanometer-sized bioactive glass to improve guided bone re-generation. *Biomater. Sci.* 2018, 6:1007–1019.
76. Chiang T, et al. Equine collagen for tissue engineering applications: a systematic review. *Tissue Engineering Part B: Reviews*. 2017;23(5):474-487.
77. Chiapasco, M.; Casentini, P.; Zaniboni, M. Bone augmentation procedures in implant dentistry. *Int. J. Oral Maxillofac. Implant.* 2009, 24, 237–259.

78. Choi B, Jeong S. Digital flapless implantology. Seoul; Ji-Sung. Publishing Co.; 2015. p. 32-51.
79. Chrcanovic BR, Kisch J, Albrektsson T, Wennerberg A. Bruxism and dental implant treatment complications: a retrospective comparative study of 98 bruxer patients and a matched group. *Clin Oral Implants Res.* 2017 Jul;28(7):e1-e9.
80. Chrcanovic BR, T.Albrektsson, A.Wennerberg. Reasons for failures of oral implants. *Journal of Oral Rehabilitation*, 2014, vol. 41, no.6: 443–476.
81. Cigu, A.T.; Cigu, E. Exploring Dental Health and Its Economic Determinants in Romanian Regions. *Healthcare* 2022, 10, 2030. https://doi.org/10.3390/healthcare10102030
82. Clark D, Levin L. Dental implant management and maintenance: How to improve long-term implant success? *Quintessence Int*. 2016;47(5):417-23.
83. Coelho PG, R.Jimbo,N.Tovar,E.A.Bonfante. Osseointegration: hierarchical design in gencompassing the macrometer, micrometer, and nanometer length scales. *Dental Materials*, 2015, vol.31,no.1: 37–52.
84. Colombo M, Mangano C, Mijiritsky E, Krebs M, Hauschild U, Fortin T. Clinical applications and effectiveness of guided implant surgery: A critical review based on randomized controlled trials. *BMC Oral Health* 2017, 17, 150.
85. Colussi, C.F.; De Freitas, S.F.; Calvo, M.C. The prosthetic needs WHO index: A comparison between self-perception and professional assessment in an elderly population. *Gerodontology* 2009, 26, 187–192.
86. Corona M, Hernandez Y. Main factors provoquing dental implant failure. *MEDISAN*. 2015;19(11):1325–1329.
87. Cortellini, P.; Carnevale, G.; Sanz, M.; Tonetti, M.S. Treatment of deep and shallow intrabony defects A multicenter randomized controlled clinical trial. *J. Clin. Periodontol*. 1998, 25:981–987.
88. Cosme, D.C.; Baldisserotto, S.M.; Fernandes, E.D.L.; Rivaldo, E.G.; Rosing, C.K.; Shinkai, R.S. Functional evaluation of oral rehabilitation with removable partial dentures after five years. *J. Appl. Oral Sci*. 2006, 14, 111–116.
89. Costa F.O, Takenaka-Martinez S, Cota L.O, Ferreira S.D, Silva G.L, Costa J.E. Peri-implant disease in subjects with and without preventive maintenance: a 5-year follow-up. *J Clin Periodontol*. 2012 Feb; 39(2):173-81.
90. Cristea I, Agop-Forna D, Dascălu C, Bardis D, Topoliceanu C, Forna N. Survival and prosthetic success of fixed partial dentures supported by either abutment teeth or implants: a retrospective study. *Rom J Oral Rehab.* 2022; 14(3): 40-47.
91. Crocombe, L.A.; Broadbent, J.M., Thomson, W.M., Brennan, D.S.; Slade, G.D.; Poulton, R. Dental visiting trajectory patterns and their antecedents. J Public Health Dent 2011; 71:23- 31
92. Curtis, A., et al. *Journal of Materials Science: Materials in Medicine* 2001; 12(10-12), 989-993.
93. Cushen SE, Turkyilmaz I. Impact of operator experience on the accuracy of implant placement with stereolithographic surgical templates: an in vitro study. *J Prosthet Dent*. 2013 Apr;109(4):248-54.
D'Haese, J.; Van De Velde, T.; Elaut, L.; De Bruyn, H. A Prospective Study on the Accuracy of Mucosally Supported Stereolithographic Surgical Guides in Fully Edentulous Maxillae. *Clin. Implant. Dent. Relat. Res*. 2009, 14, 293–303.
94. Cushen SE, Turkyilmaz I. Impact of operator experience on the accuracy of implant placement with stereolithographic surgical templates: an in vitro study. *J Prosthet Dent*. 2013 Apr;109(4):248-54.
D'Haese, J.; Van De Velde, T.; Elaut, L.; De Bruyn, H. A Prospective Study on the Accuracy of Mucosally Supported Stereolithographic Surgical Guides in Fully Edentulous Maxillae. *Clin. Implant. Dent. Relat. Res*. 2009, 14, 293–303.
95. Dalago H.R, Schuldt F.G, Rodrigues M.A, Renvert S, Bianchini M.A. Risk indicators for Peri-implantitis. A cross-sectional study with 916 implants. *Clin Oral Implants Res* 2017;28:144–50.
96. Dalago HR, Schuldt Filho G, Rodrigues MA, Renvert S, Bianchini MA. Risk indicators for Peri-implantitis. A cross-sectional study with 916 implants. *Clin Oral Implants Res* 2017;28:144–50.
97. Damyanov, N.; Witter, D.; Bronkhorst, E.; Creugers, N. Dental status and associated factors in a dentate adult population in Bulgaria: A cross-sectional survey. *Int. J. Dent*. 2012, 2012, 578401.

98. Dastaran, M.; Bailey, D.; Austin, S.; Chandu, A.; Judge, R. Complications of augmentation procedures for dental implants in private practice, Victoria, Australia. *Aust. Dent. J.* 2019, 64, 223–228.
99. Daubert D.M, Weinstein B.F, Bordin S, Leroux B.G, Flemming T.F. Prevalence and predictive factors for peri-implant disease and implant failure: a cross-sectional analysis. *J Periodontol*. 2015 Mar; 86(3):337-47.
100. Davarpanah M, Szmukler-Moncler S, Davarpanah K, Rajzbaum P. Implantologie assistée par ordinateur. Éditions CdP. 2011.
101. De Almeida EO, Rocha EP, Freitas AC et al. Finite element stress analysis of edentulous mandibles with different bone types supporting multiple implant superstructures. *Int J Oral Maxillofac Implant*, 2010;25.
102. De Backer H, Van Maele G, De Moor N, Van den Berghe L, De Boever J. A 20- year retrospective survival study of fixed partial dentures. *Int J Prosthodont*. 2006;19:143–53.
103. De Boever AL, Keersmaekers K, Vanmaele G, Kerschbaum T, Theuniers G, De Boever JA. Prosthetic complications in fixed endosseous implant-borne reconstructions after an observations period of at least 40 months. *J Oral Rehabil*. 2006 Nov;33(11):833-9. Vol. 14, No.3 July-August 2022
104. De Boever AL, Quirynen M, Coucke W, Theuniers G, De Boever JA. Clinical and radiographic study of implant treatment outcome in periodontally susceptible and non-susceptible patients: a prospective long-term study. *Clin Oral Implants Res*. 2009 Dec;20(12):1341-50.
105. De Santis, D.; Gelpi, F.; Verlato, G.; Luciano, U.; Torroni, L.; Antonucci, N.; Bernardello, F.; Zarantonello, M.; Nocini, P. Digital customized titanium mesh for bone regeneration of vertical, horizontal and combined defects: A case series. *Medicine* 2021, 57, 60.
106. Del Fabbro M, Testori T, Kekovic V, Goker F, Tumedei M, Wang H.L. A Systematic Review of Survival Rates of Osseointegrated Implants in Fully and Partially Edentulous Patients Following Immediate Loading. *J Clin Med*. 2019 Dec 4;8(12):2142.
107. Derks J, Schaller D, Håkansson J, Wennström JL, Tomasi C, Berglundh T. Effectiveness of implant therapy analyzed in a Swedish population: prevalence of peri-implantitis. *J Dent Res* 2016;95:43–9
108. Derks J, Tomasi C. Peri-implant health and disease. A systematic review of current epidemiology. *J Clin Periodontol*. 2015 Apr;Suppl 16:S158-71.
109. D'haese J, Van De Velde T, Elaut L, De Bruyn H. A prospective study on the accuracy of mucosally supported stereolithographic surgical guides in fully edentulous maxillae. *Clin Implant Dent Relat Res*. 2012b;14(2), 293-303.
110. D'haese J, Van De Velde T, Komiyama A, Hultin M, De Bruyn H. Accuracy and complications using computer-designed stereolithographic surgical guides for oral rehabilitation by means of dental implants: a review of the literature. *Clin Implant Dent Relat Res*. 2012a;14(3):321-35.
111. Dioguardi, M.; Spirito, F.; Quarta, C.; Sovereto, D.; Basile, E.; Ballini, A.; Caloro, G.A.; Troiano, G.; Lo Muzio, L.; Mastrangelo, F. Guided Dental Implant Surgery: Systematic Review. *J. Clin. Med.* 2023, 12, 1490. https://doi.org/10.3390/ jcm12041490.
112. Donos, N.; Mardas, N.; Chadha, V. Clinical outcomes of implants following lateral bone augmentation: Systematic assessment of available options (barrier membranes, bone grafts, split osteotomy). *J. Clin. Periodontol*. 2008, 35, 173–202.
113. Dorozhkin SV. Calcium orthophosphate coatings on magnesium and its biodegradable alloys. *Acta Biomaterialia*. 2014;10(6):2919-2934.
114. Ducheyne P, Qiu Q. Bioactive ceramics: The effect of surface reactivity on bone formation and bone cell function. *Biomaterials*. 1999;20(23-24):2287-2303.
115. Dudovitz, R.N., Valiente, J.E., Espinosa, G., Yepes, C., Padilla, C., Puffer, M., Slavkin, H.C.,Chung, P.J. A school-based public health model to reduce oral health disparities. *Journal of Public Health Dentistry*. 2018;78: 9-16;
116. Duncan, L., Bonner A. Effects of income and dental insurance coverage on need for dental care in Canada. *J Can Dent Assoc*. 2014;80. e6.
117. Dundar S, Topkaya T, Murat Yavuz S, Ferhan Y, Atalay Y, Saybak A, Asutay F, Cakmak O. Finite element analysis of the stres distributions in peri-implant bone in modified and standard-threaded dental implants. *Biotechnology & Biotechnological Equipment*. 2016; 30(1):127-133.

118. Dutta S.R, Passi D, Singh P, Atri M, Mohan S, Sharma A. Risks and complications associated with dental implant failure: Critical update. *Natl J Maxillofac Surg*. 2020 Jan-Jun;11(1):14-19.

119. Edlibi Al Hage,W.; Dascalu, C.G.; Balcos, , C.; Agop-Forna, D.; Forna, N.C. Trends in Access to Oral Health Care among Adults from the N-E Region of Romania. *Medicina* 2023, 59, 74. https://doi.org/ 10.3390/medicina59010074
120. Eikemo, T.A., Bambra, C., Joyce, K., Dahl, E. Welfare state regimes and income-related health inequalities: a comparison of 23 European countries. Eur J Public Health. 2008;18(6):593-9.
121. Ekanayake, L.; Perera, I. The association between clinical oral health status and oral impacts experienced by older individuals in Sri Lanka. *J. Oral Rehabil*. 2004, 31, 831–836.
122. El Qaderi, S.S., Taani, D.Q. Oral health knowledge and dental health practices among schoolchildren in Jerash district/Jordan. *Int J Dent Hyg* 2004; 2:78-85.
123. Elakkiya, S.; Ramesh, A.S.; Prabhu, K. Systematic analysis on the efficacy of bone enhancement methods used for success in dental implants. J. Indian Prosthodont. Soc. 2017, 17, 219–225.
124. Elgali I, Omar O, Dahlin C, Thomsen P. Guided bone regeneration: materials and biological mechanisms revisited. *Eur J Oral Sci.* 2017 Oct;125(5):315-337.
125. Ellis, J.S., Pelekis, N.D., & Thomason, J.M. Conventional rehabilitation of edentulous patients: The impact on oral health-related quality of life and patient satisfaction. *Journal of Prosthodontics*, 2007; 16, 37–42.
126. Elnayef B, Monje A, Lin GH, Gargallo-Albiol J, Chan HL, Wang HL, Hernández-Alfaro F.Alveolar ridge split on horizontal bone augmentation: a systematic review. *Int J Oral Maxillofac Implants*. 2015 May-Jun;30(3):596-606.
127. Elnayef B, Porta C, Suárez-López Del Amo F, Mordini L, Gargallo-Albiol J, Hernández-Alfaro F. The Fate of Lateral Ridge Augmentation: A Systematic Review and Meta-Analysis. *Int J Oral Maxillofac Implants*. 2018 May/Jun;33(3):622-635.
128. Elnayef, B.; Porta, C.; Suárez-López Del Amo, F.; Mordini, L.; Gargallo-Albiol, J.; Hernández-Alfaro, F. The Fate of Lateral Ridge Augmentation: A Systematic Review and Meta-Analysis. *Int. J. Oral Maxillofac. Implant.* 2018, 33, 622–635.
129. Ersoy AE, Turkyilmaz I, Ozan O, McGlumphy EA. Reliability of implant placement with stereolithographic surgical guides generated from computed tomography: clinical data from 94 implants. *J Periodontol*. 2008 Aug;79(8):1339-45.
130. Esposito M, Dojcinovic I, Germonetal L. Safety and efficacy of a biomimetic monolayer of permanently bound multi-phosphonic acid molecules on dental implants: 1-year post-loading results from a pilot quadruple-blinded randomised controlled trial. *European Journal of Oral Implantology*, 2013, vol. 6, no. 3: 227–236.
131. Esposito M, Felice P, Worthington HV. Interventions for replacing missing teeth: augmentation procedures of the maxillary sinus. Cochrane Database Syst Rev. 2014 May 13;(5):CD008397. doi:10.1002/14651858.CD008397.pub2.
132. Esposito M, Grusovin MG, Rees J, Karasoulos D, Felice P, Alissa R, Worthington H, Coulthard P. Effectiveness of sinus lift procedures for dental implant rehabilitation: a Cochrane systematic review. *Eur J Oral Implantol*. 2010 Spring;3(1):7-26.
133. Fala V. Tratamentul complex la pacienţii cu parodontitã cronicã şi edentaţii. Chişinău, 2015.
134. Falacho, R.; Palma, P.; Marques, J.; Figueiredo, M.; Caramelo, F.; Dias, I.; Viegas, C.; Guerra, F. Collagenated porcine heterologous bone grafts: Histomorphometric evaluation of bone formation using different physical forms in a rabbit cancellous bone model. *Molecules* 2021, 26, 1339.
135. FDI, L'enjeu des maladies bucco-dentaires-L'Atlas de la santé bucco-dentaire, 2015. http://www.fdiworldental.org/media/84764/book_spreads_oh2_french.pdf
136. Fejérdy, P.; Borbély, J.; Schmidt, J.; Jánh, M.; Hermann, P. Removable partial denture design and its effect on remaining teeth, based on Hungarian national survey. Fogorv. Sz. 2008, 101, 3–11.
137. Felice P, Piana L, Checchi L, Corvino V, Nannmark U, Piattelli M. Vertical ridge augmentation of an atrophic posterior mandible with an inlay technique and cancellous equine bone block: a case report. Int *J Periodontics Restorative Dent*. 2013 Mar-Apr;33(2):159-66.

138. Ferreira C.F, Buttendorf A.R, de Souza J.G, Dalago H, Guenther S.F, Bianchini M.A. Prevalence of Peri-implant Diseases:Analyses of Associated Factors. *J Prosthodont Restor Dent.* 2015 Dec; 23(4):199-206.
139. Feyerabend F, Fischer J, Holtz J, et al. Evaluation of short-term effects of rare earth and other elements used in magnesium alloys on primary cells and cell lines. *Acta Biomaterialia*. 2010;6(5):1834-1842.
140. Filmer, D. The incidence of public expenditures on health and education: Background Note for World Development Report 2004: Making Services Work for Poor People. 2003. https://documents1.worldbank.org/curated/en/226881468779415402/310436360_20050276022932/additional/269500Benefit11e0WDR20040Background.pdf
141. Fischer K, Stenberg T. Prospective 10-year cohort study based on a randomized controlled trial (RCT) on implant supported full-arch maxillary prostheses. Part 1: sandblasted and acid-etched implants and mucosal tissue. Clinical *Implant Dentistry and Related Research*, 2012, vol.14,no.6: 808–815.
142. Forna N. Incidenta si prevalenta patologiei dentoperiodontale si a edentatiei pe teritoriul Moldovei, *Romanian Journal of Medical and Dental Education*.2013; 2: 9-25.
143. Forna D, Feier R, Topoliceanu C, Forna N, Popescu E. Study regarding the possibilities to use the application Prodent in the pro-prosthetic stage. *Romanian Journal of Oral Rehabilitation.* 2017; 9(3):97-100.
144. Forna N (coordonator), De Baat C, Bratu D, Lascu L, Mercut V, Petre Al, Popsor S, Traistaru T. Protetică Dentară, vol. II, Edit.Enciclopedică, București, 2011.
145. Forna N. Dental medicine between reality and paradigm. Ed. Demiurg, 2008.
146. Forna N. și colab. Actualități în clinica și terapia edentației parțial întinse. Tratat de protetică dentară.Iași: Editura UMF „Gr. T. Popa", 2008 : 610.
147. Forna N.; Feier R. D.; Dascalu C. G., Study regarding the possibilities to use the application of computerized score in the patient evaluation. *Romanian Journal of Oral Rehabilitation* 2018; Volume: 10 Issue: 2: 22:113-118.
148. Forna, N., Incidenta si prevalenta patologiei dentoparodontale si a edentatiei pe teritoriul Moldovei, *Romanian Journal of Medical and Dental Education*, 2013, 2, 9-25
149. Frank, R.P., Brudvik, J.S., Leroux, B., Milgrom, P., & Hawkins, N. Relationship between the standards of removable partial denture construction, clinical acceptability, and patient satisfaction. *Journal of Prosthetic Dentistry* 2000; 83, 521–527.
150. French D, Ofec R, Levin L. Long term clinical performance of 10 871 dental implants with up to 22 years of follow-up: A cohort study in 4247 patients. *Clin Implant Dent Relat Res*. 2021 Jun;23(3):289-297.
151. Fu JH, Wang HL. Horizontal bone augmentation: the decision tree. *Int J Periodontics Restorative Dent*. 2011 Jul-Aug;31(4):429-36.
152. Ganz SD. Cone beam computed tomography-assisted treatment planning concepts. *Dent Clin North Am.* 2011;55(3):515-viii.
153. Gargallo-Albiol, J.; Barootchi, S.; Salomó-Coll, O.; Wang, H.-L. Advantages and disadvantages of implant navigation surgery. A systematic review. *Ann. Anat. - Anat. Anz.* 2019, 225, 1–10.
154. Geng, J. P., Ma, Q. S., Xu, W., et al. Finite element analysis of four thread-form configurations in a stepped screw implant. *J Oral Rehab*, 2004;31:233–239.
155. Ghoddusi Johari, M.; Moftakhar, L.; Rahimikazerooni, S.; Rezaeianzadeh, R.; Hosseini, S.V.; Rezaianzadeh, A. Evaluation of Oral Health Status Based on DMF Index in Adults Aged 40-70 Years: Findings from Persian Kharameh Cohort Study in Iran. *J. Dent Shiraz. Univ. Med. Sci.* 2021, 22:206–212.
156. Gilles R, M. Belkhir, P. Compere, et al., Effect of high osmolarity acclimation on tolerance to hyperosmotic shocks in L929 cultured cells, *Tissue Cell* 1995; 27:679–687.
157. Glavina A, Vucicevic BV, Gabric D, Susic M, Granic M, Pelivan I. Plasma rich in growth factors in dentistry. AMJ 2017; 10(6): 497-501.
158. Global Burden of Disease Collaborative Network. (2020). Global Burden of Disease Study 2019 (GBD 2019). Seattle: Institute of Health Metrics and Evaluation (IHME).

159. Gomez-deDiego,M.D.R.Mang-delaRosa,M.-J.Romero Perez, A. Cutando-Soriano, A. Lopez-Valverde-Centeno. Indications and contraindications of dental implants in medically compromised patients:update. *Medicina Oral, Patologia Oral y Cirugia Bucal*, 2014, vol.19,no.5: 483–489.
160. Gorgis R, Qazo L, Bruun NH, Starch-Jensen T. Lateral Alveolar Ridge Augmentation with an Autogenous Bone Block Graft Alone with or without Barrier Membrane Coverage: a Systematic Review and Meta-Analysis. *J Oral Maxillofac Res.* 2021 Sep 30;12(3):e1.
161. Goto T. [Osseointegration and dental implants]. *Clin Calcium*. 2014 Feb;24(2):265-7.
162. Guelcher, S. A. *Acta Biomaterialia* 2018, 79, 23-30.
163. Gumeniuc A. Outcome implant treatment in complete edentulism: a retrospective 5-year follow up study. *Romanian Journal of Oral Rehabilitation*, 2013;5(1):99-103.
164. Guzman, M. Criteria of success and failure in osseo integrated dental implants. *Acta Odontologica Venezolana.* 2013;51(2).
165. Han HJ, Kim S, Han DH. Multifactorial evaluation of implant failure: a 19-year retrospective study. *Int J Oral Maxillofac Implants.* 2014;29(2):303-10.
166. Han J, Wang Y, Lü P. A preliminary report of designing removable partial denture frameworks using a specifically developed software package. *Int J Prosthodont*. 2010 Jul-Aug;23(4):370-5.
167. Hanif A, Qureshi S, Sheikh Z, Rashid H. Complications in implant dentistry. *Eur J Dent*. 2017 Jan-Mar;11(1):135-140.
1 6 8 . Hansen EJ, Schou S, Harder F, Hjorting-Hansen E. Outcome of implant therapy involving localised
169. Hassan, M.; Prakasam, S.; Bain, C.; Ghoneima, A.; Liu, S.S.-Y. A randomized split-mouth clinical trial on effectiveness of am-nion-chorion membranes in alveolar ridge preservation: A clinical, radiologic, and morphometric study. *Int. J. Oral Maxillofac. Implants* 2017, 32:1389–1398.
170. Hawthan MA, Chrcanovic BR, Larsson C. Long-term retrospective clinical study of tooth-supported fixed partial dentures: A multifactorial analysis. *J Prosthodont Res.* 2022 Aug 27. doi: 10.2186/jpr.JPR_D_21_00222.
171. Heitz-Mayfield LJA, Salvi GE. Peri-implant mucositis. *J Clin Periodontol*. 2018;45 Suppl 20: 237-245.
172. Heitz-Mayfield, L.J.A.; Heitz, F.; Lang, N.P. Implant Disease Risk Assessment IDRA–a tool for preventing peri-implant disease. *Clin. Oral Implant. Res*. 2020, 31, 397–403.
173. Heitz-Mayfield, L.J.A.; Heitz, F.; Lang, N.P. Implant Disease Risk Assessment IDRA–a tool for preventing peri-implant disease.*Clin. Oral Implant. Res*. 2020, 31:397–403.
174. Herford, A.S.; Nguyen, K. Complex bone augmentation in alveolar ridge defects. *Oral Maxillofac. Surg. Clin. North. Am.* 2015, 27,227–244.
175. Hermawan H, Alamdari H, Mantovani D, Dubé D. Iron-manganese: new class of degradable metallic biomaterials prepared by powder metallurgy. *Powder Metall* 2008;51:38–45.
176. Herrmann I, Lekholm U, Holm S, Kultje C. Evaluation of patient and implant characteristics as potential prognostic factors for oral implant failures. *Int J Oral Maxillofac Implants*. 2005; 20(2): 220–230.
177. Heydecke G, Zwahlen M, Nicol A, Nisand D, Payer M, Renouard F, Grohmann P, Mühlemann S, Joda T. What is the optimal number of implants for fixed reconstructions: a systematic review. *Clin Oral Implants Res.* 2012;23 Suppl 6:217-28.
178. Heydecke, G; Zwahlen, M; Nicol, A; Nisand, D; Payer, M; Renouard, F; Grohmann, P; Mühlemann, S; Joda, T. What is the optimal number of implants for fixed reconstructions: a systematic review. *Clin Oral Implants Res.* 2012;23 Suppl 6:217-28.
179. Hirano, S.; Suzuki, K. Exposure, Metabolism, and Toxicity of Rare Earths and Related Compounds. *Environmental Health Perspectives* 1996, 104(Suppl), 85-95. https://doi.org/10.1289/ehp.96104s185
180. Hochman N, L. Mitelman L, Hadani PE, Zalkind M. A clinical and radiographic evaluation of fixed partial dentures (FPDs) prepared by dental school students: A retrospective study. *J Oral Rehab* 2003; 30:165–170.
181. Holban C M, Agop Forna D, Forna N C. Preparations pro-implant versus pro-prosthetic. *Romanian Journal of Oral Rehabilitation*, 2016;8(3):72-79.

182. Hosseinpoor AR, Itani L, Petersen PE. Socio-economic inequality in oral healthcare coverage: results from the World Health Survey. *J Dent Res*. 2012 Mar;91(3):275-81.
183. http://bti-biotechnologyinstitute.com/us/regenerative-medicine/endoret/
184. http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/@dh/@en/documents/digita
185. https://health.ec.europa.eu/system/files/2021-12/2021_chp_romania_english.pdf
186. https://www.idsimplants.com/implant-systems/anyridge/
187. https://www.mis-implants.com
188. https://www.who.int/europe/news/item/29-08-2022-outofpocketpayments-for-health-care-in-romania undermine-progress-towards-universal-health-coverage, 21.09.2022, 07.43
189. Huang, Y., et al.*Materials Science and Engineering*: C 2017, 77, 441-448.
190. Hultin, M.; Svensson, K.G.; Trulsson, M. Clinical advantages of computer-guided implant placement: A systematic review. *Clin. Oral Implant. Res*. 2012, 23 (Suppl. 6), 124–135.
191. Hyzy SL, Hartnett BJ, Salamati M, et al. Structural and mechanical evaluation of decellularized porcine superflexor tendon for anterior cruciate ligament reconstruction. *Journal of Orthopedic Research.* 2012;30(12):1914-1922.
192. Institutul Naţional de Statisticã (2020). Proiectarea populatiei Romaniei pe regiuni de dezvoltare şi judeţe la orizontul anului 2070.
193. Ioannis Kormas, Alessandro Pedercini, Hatem Alassy, and Larry F. Wolff, The Use of Biocompatible Membranes in Oral Surgery: The Past, Present & Future Directions. A Narrative Review. *Membranes (Basel)* 2022,Volum 12, Issue 9, 841. doi: 10.3390/membranes12090841.
194. Ionescu, A.; Dodi, A.; Panagopoulos, V.; Nicolescu, M.I.; Mihai, A.T.; Tanase, G.; Vlasceanu, D. Biomechanical consequences of dental implants inserted in augmented alveolar ridges—A comparative study between tissue-level and bone-level implants: Finite elements analysis. *Rom. J. Oral Rehabil.* 2019, 11, 82–88.
195. Is¸ık, G.; Yüce, M.Ö.; Koçak-Topbas¸, N.; Günbay, T. Guided bone regeneration simultaneous with implant placement using bovine-derived xenograft with and without liquid platelet-rich fibrin: A randomized controlled clinical trial. *Clin. Oral Investig*.2021, 25, 5563–5575.
196. Istrate, B.; Munteanu, C.; Lupescu, S.; Antoniac, V.I.; Sindilar, E. Structural Characterization of Mg-0.5Ca-xY Biodegradable Alloys. *Key Engineering Materials* 2018, 782, 129-135.
197. Jacobs JJ, Gilbert JL, Urban RM. Corrosion of metal orthopaedic implants. *J Bone Joint Surg* 1998, 80:268– 82
198. Jamieson R, et al. Porcine type I atelocollagen membrane combined with collagenase shows promise for periodontal wound healing. *Journal of Periodontal Research*. 2006;41(5):363-370.
199. Javed F., Ahmed H.B., Crespi R., Romanos G.E. Role of primary stability for successful osseointegration of dental implants: Factors of influence and evaluation. Int. *Med. Appl. Sci*.2013;5:162–167.
200. Jiang W, Ma L, Zhang B, Fan Y, Qu X, Zhang X, Liao H. Evaluation of the 3D Augmented Reality-Guided Intraoperative Positioning of Dental Implants in Edentulous Mandibular Models. *Int J Oral Maxillofac Implants.* 2018 Nov/Dec;33(6):1219-1228.
201. John, M.T., Omara, M., Su, N., List, T., Sekulic, S., Häggman-Henrikson, B., Visscher, C., Bekes, K., Reissmann, D.R., Baba, K., et al. Recommendations for use and scoring of oral health impact profile versions. *Journal of Evidence-Based Dentistry* 2022, 22, 101619.
202. Johnston J.F., Phillips R.W., Dykema R.W., Modern practice in crown and bridge prosthodontics. Philadelphia: Saunders; 1971:17, 18.
203. Johnstone B, Hering TM, Caplan AI, Goldberg VM, Yoo JU. In vitro chondrogenesis of bone marrow-derived mesenchymal progenitor cells. *Experimental Cell Research*. 1998;238(1):265-272.
204. Kakatkar, G.; Bhat, N.; Nagarajappa, R.; Prasad, V.; Sharda, A.; Asawa, K.; Agrawal, A. Barriers to the Utilization of Dental Services in Udaipur, India. J. Dent. *Tehran Univ. Med. Sci.* 2011, 8, 81–89.
205. Kamberi B, Koçani F, Begzati A, Kelmendi J, Ilijazi D, Berisha N, et al. Prevalence of dental caries in Kosovar adult population. *Int J Dent.* 2016; 2016: 1-6.
206. Kang DW, Yun PY, Choi YH, Kim YK. Sinus bone graft and simultaneous vertical ridge
207. Karen W. Sanden, Achim Kohler, Nils K. Afseth, Ulrike Böcker, Sissel B. Rønning, Kristian H.

Liland Mona E. Pedersen, The use of Fourier-transform infrared spectroscopy to characterize connective tissue components in skeletal muscle of Atlantic cod (Gadus morhua L.). *J Biophotonics* 2019, Volume 12, ssue 9. doi: 10.1002/jbio.201800436.
208. Karthik K, Sivakumar, Sivaraj, Thangaswamy V. Evaluation of implant success: A review of past and present concepts. *J Pharm Bioallied Sci.* 2013;5(Suppl 1):117-9.
209. Karthik K, Sivaraj S, Thangaswamy V. Evaluation of implant success: A review of past and present concepts. *J Pharm Bioallied Sci*. 2013; 5(Suppl 1):117-9.
210. Kasaj A, Reichert C, Götz H, Röhrig B, Smeets R, Willershausen B. In vitro evaluation of various bioabsorbable and nonresorbable barrier membranes for guided tissue regeneration. *Head Face Med.* 2008 Oct 14;4:22.
211. Kassebaum N J, Bernabe E, Dahiya M,Bhandari B, Murray C J, Marcenes, W. Global burden of severe periodontitis in 1990–2010: a systematic review and metaregression. *Journal of Dental Research.*2014; 93:1045–1053.
212. Kawase T, Kamiya M, Kobayashi M, Tanaka T, Okuda K, Wolff LF, Yoshie H. The heat-compression technique for the conversion of platelet-rich fibrin preparation to a barrier membrane with a reduced rate of biodegradation. *Journal of Biomedical Materials Research B Applied Biomaterials*. 2015;103:825–31.
213. Khan, M.; Khan, A. Oral complaints and level of satisfaction among the removable denture wearers. *Pak. Oral Dent. J*. 2015, 35, 162–166.
214. Khojasteh A, Kheiri L, Motamedian SR, Khoshkam V. Guided Bone Regeneration for the
215. Khoury F, Hanser T. Three-Dimensional Vertical Alveolar Ridge Augmentation in the Posterior Maxilla: A 10-year Clinical Study. *Int J Oral Maxillofac Implants*. 2019 Mar/Apr;34(2):471-480.
216. Kim, Y.; Rodriguez, A.E.; Nowzari, H. The risk of prion infection through bovine grafting materials. *Clin. Implant Dent. Relat. Res.*2016, 18, 1095–1102.
217. Klein, J., Hofreuter-Gätgens, K., von dem Knesebeck, O. Socioeconomic Status and the
218. Konstantinidis I.K, Kotsakis G.A, Gerdes S, Walter M.H. Cross-sectional study on the prevalence and risk indicators of peri-implant diseases. *Eur J Oral Implantol*. 2015 Spring; 8(1):75-88.
219. Kraus T, Fischerauer SF, Hänzi AC, Uggowitzer PJ, Löffler JF, Weinberg AM. Magnesium alloys for temporary implants in osteosynthesis: in vivo studies of their degradation and interaction with bone. *ActaBiomater* 2012; 8:1230–1238;
220. Kreissl ME, Gerds T, Muche R, Heydecke G, Strub JR. Technical complications of implant-supported fixed partial dentures in partially edentulous cases after an average observation period of 5 years. *Clin Oral Implants Res.* 2007 Dec;18(6):720-6
221. Kubies, D.; Himmlová, L.; Riedel, T.; Chánová, E.; Balík, K.; Doudeˇrová, M.; Bártová, J.; Pesakova, V.J.P.R. The interaction of osteoblasts with bone-implant materials: The effect of physicochemical surface properties of implant materials. *Physiol. Res*. 2011,60, 95–111.
222. Kumar, S., Tadakamadla, J., Duraiswamy, P., & Kulkarni, S. (2016). Dental caries and its socio-behavioral predictors- an exploratory cross-sectional study. *J Clin Pediatr Dent*, 40(3), 186–92.
223. Lang NP, Lindhe J. Clinical Periodontology and Implant Dentistry.Blackwell Munksgaard: Copenhagen, Denmark: John Wiley and Sons; 2015.
224. Lang, N.P.; Berglundh, T.; Working Group 4 of Seventh European Workshop on Periodontology. Periimplant diseases: Where are we now?—Consensus of the Seventh European Workshop on Periodontology. *J. Clin. Periodontol*. 2011, 38 (Suppl. 11), 178–181.
225. Le, B.; Burstein, J. Esthetic grafting for small volume hard and soft tissue contour defects for implant site development. *Implant.Dent.* 2008, 17, 136–141.
226. Le, M., Papia, E., & Larsson, C. The clinical success of tooth- and implant-supported zirconia-based fixed dental prostheses. A systematic review. *Journal of Oral Rehabilitation* 2015; 42(6): 467–480.
227. Lee C.T, Huang Y.W, Zhu L, Weltman R. Prevalences of peri-implantitis and peri-implant mucositis: systematic review and meta-analysis. *J Dent.* 2017 Jul;62:1-12.
228. Lee J.S, Lim H.C, Kim M.S, Choi S.H, Jung U.W. Preferences and flexibility in decision-making among dental clinicians regarding the treatment of multirooted teeth: an interactive communication device-based survey at two academic conferences. *J Periodontal Implant Sci*. 2016 Jun;46(3):166-75.

229. Lee, D.S.; Pai, Y.; Chang, S. Physicochemical characterization of InterOss® and Bio-Oss® anorganic bovine bone grafting ma-terial for oral surgery: A comparative study. *Mater. Chem. Phys*. 2014, 146, 99–104.
230. Leite FRM, Nascimento GG, Scheutz F, López R. Effect of Smoking on Periodontitis: A Systematic Review and Meta-regression. *Am J Prev Med*. 2018;54:831–41.
231. Leroy et al., Methodological issues in epidemiological studies of periodontitis - how can it be improved? *BMC Oral Health* 2010, 10:8.
232. Leung KCM, Pow EHN. Oral rehabilitation with removable partial dentures in advanced tooth loss situations. *Hong Kong Dental Journal*. 2009; 6: 39-45.
233. Li Q, Pan S, Dangaria SJ, Gopinathan G, Kolokythas A, Chu S, et al. Platelet-rich fibrin promotes periodontal regeneration and enhances alveolar bone augmentation. *Biomedical Research International.* 2013: 638043.
234. Li Z, Gu X, Lou S, Zheng Y. The development of binary Mg-Ca alloys for use as biodegradable materials within bone. *Biomaterials*. 2008;29(10):1329-1344.
235. Li, H., et al.. *Journal of Alloys and Compounds* 2020; 835, 155340.
236. Li, J.; Xuan, F.; Choi, B.H.; Jeong, S.M. Minimally invasive ridge augmentation using xenogenous bone blocks in an atrophied posterior mandible: A clinical and histological study. *Implant Dent*. 2013, 22, 112–116.
237. Li, J.; Xuan, F.; Choi, B.H.; Jeong, S.M. Minimally invasive ridge augmentation using xenogenous bone blocks in an atrophied posterior mandible: A clinical and histological study. *Implantol. Dent*. 2013, 22, 112–116.
238. Li, Z., et al. *Biomaterials* 2008, 29(10), 1329-1344.
239. Li, Z.; Sun, S.; Chen, M.; Fahlman, B.D.; Liu, D.; Bi, H. In vitro and in vivo corrosion, mechanical properties and biocompatibility evaluation of MgF2-coated Mg-Zn-Zr alloy as cancellous screws. *Materials Science and Engineering C* 2017, 75, 1268–1280.
240. Listl, S., Galloway, J., Mossey, P.A., Marcenes, W. Global Economic Impact of Dental Diseases. *Journal of dental research*. 2015, 1-7
241. Liu J, Kerns DG.Mechanisms of guided bone regeneration:a review.*Open Dent J*.2014;8:56-65.
242. Liu, J. ; Bian, D.; Zheng, Y.; Chu, X.; Lin, Y.; Wang, M.; Lin, Z.; Li, M.; Zhang, Y.; Guan, S. Comparative in vitro study on binary Mg-RE (Sc, Y, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb and Lu) alloy systems. *Acta Biomaterialia* 2020, 102, 508–528.
243. Liu, J.; Kerns, D.G. Mechanisms of Guided Bone Regeneration: A Review. *Open Dent. J*. 2014, 8, 56–65.
244. Liu, M.; Schmutz, P.; Uggowitzer, P.; Song, G.; Atrens, A.; The influence of Y (Y) on the corrosion of Mg–Y binary alloys. *Corrosion Science* 2010, 52, 3687–3701.
245. Locker, D. Measuring oral health: A conceptual framework. *Community Dent. Health* 1988, 5, 3–18.
246. Locker, D.; Slade, G. Association between clinical and subjective indices of oral health status in an older adult population. Gerodontology 1994, 11, 108–114.
247. Lu J, Li S, Kang Y. Biomaterials for bone tissue engineering: A review. *Journal of Materials Science & Technology*. 2013;29(6):503-513.
248. Lupescu, S.; Istrate, B.; Munteanu, C.; Minciuna, M.G.; Focsaneanu, S.; Earar, K. Characterization of Some Master Mg-X System (Ca, Mn, Zr, Y) Alloys Used in Medical Applications. *Rev.Chim*. 2017, 68(6), 1408-1413.
249. Lupescu, S.; Munteanu, C.; Istrate, B.; Stanciu, S.; Cimpoesu, N.; Oprisan, B. Microstructural Investigations on Alloy Mg-2Ca-0.2Mn-0.5Zr-1Y. IOP Conf. Series: *Materials Science and Engineering* 2017, 209, 012018. https://doi.org/10.1088/1757-899X/209/1/012018
250. Lynch, C.D.; Allen, P.F. The teaching of removable partial dentures in Ireland and the United Kingdom. *Br. Dent. J.* 2007, 203, E17.
251. Ma B, Park T, Chun I, Yun K. The accuracy of a 3D printing surgical guide determined by CBCT and model analysis. *J Adv Prosthodont.* 2018 Aug;10(4):279-285.
252. MacEntee, M.I.; Mojon, P. Discrepancy between need for prosthodontic treatment and complaints in an elderly edentulous population. *Community Dent. Oral Epidemiol*. 1992, 20, 48–52.

253. Mackenbach, J.P., Stirbu, I., Roskam, A.J., Schaap, M.M., Menvielle, G., Leinsalu, M., Kunst, A.E.; European Union Working Group on Socioeconomic Inequalities in Health. Socioeconomic inequalities in health in 22 European countries. *N Engl J Med*. 2008 Jun 5;358(23):2468-81
254. Marcenes W, Kassebaum NJ, Bernabé E, et al. Global burden of oral conditions in 1990-2010: a systematic analysis. *J Dent Res*. 2013;92(7):592-597. doi:10.1177/0022034513490168.
255. Marrone A, Lasserre J, Bercy P, Brecx M.C. Prevalence and risk factors for peri-implant disease in Belgian adults. *Clin Oral Implants Res*. 2013 Aug; 24(8):934-40.
256. Marulanda A, Coral D, Sabogal D, Serrano C. Periodontal conditions of Colombian university students aged 16 to 35. *Braz Oral Res*. 2014 May;28 (5):1-7. https://doi.org/10.1590/1807-3107BOR-2014.vol28.0009
257. Mathieu V, Vayron R, Richard G, Lambert G, et al. Biomechanical determinants of the stability of dental implants: Influence of the bone–implant interface properties. *J Biomech* 2014;47:3–13.
258. Mauad De Abreu, F.A., G. Zenóbio, E., Borges Silva, G.A. and Cristina Jorge, E. (2020), Evaluation of the surface topography of the collagen membranes by scanning electron microscopy. *Clin Oral Impl Res* 2020, 31: 147-147.
259. maxilla and mandible. *POSEIDO*. 2013b;1(2): 69-83.
260. Mbele G.O, J.C. Deloulme, B.J. Gentil, C. Delphin, M. Ferro, J. Garin, et al., The zinc and calcium-binding S100B interacts and co-localizes with IQGAP1 during dynamic rearrangement of cell membranes, *J. Biol. Chem*. 2002; 277 (51):49998–50007.
261. Meijer HJ, Raghoebar GM: Quality of reporting of descriptive studies in implant dentistry. Critical aspects in design, outcome assessment and clinical relevance. *J Clin Periodontol* 2012;39(Suppl 12):108-113.
262. Mendonca G, D. B. S. Mendonca, F. J. L. Aragao, L. F. Cooper. Advancing dental implant surface technology—from micron- to nanotopography. *Biomaterials*, 2008, vol. 29, no. 28:3822–3835.
263. Mertens C, Steveling HG. Early and immediate loading of titanium implants with fluoride-modified surfaces: results of 5-year prospective study. *Clinical Oral Implants Research*, 2011, vol. 22, no.12:1354–1360.
264. Mihaela Mitrea, Edlibi Al Hage Walid, Razvan Radu Maxim, Mihaela Moscu, Irina Jemnoschi Hreniuc, Marius Constantin Moraru, Razvan Tudor Tepordei, Ovidiu Mihail Stefanescu, Oana Elena Ciurcanu, Norina Consuela Forna, Bogdan Sargu Dumachita, Simona Niculescu, Irina Luciana Gurzu, Angela Tecuceanu, Vlad Danila. Preliminary study on the success-failure balance in implant therapy. *Rom J Oral Rehab.* 2022; 14(2): 6-14.
265. Mir-Mari J, Mir-Orfila P, Figueiredo R, Valmaseda-Castellón E, Gay-Escoda C. Prevalence of peri-implant diseases. A cross-sectional study based on a private practice environment. *J Clin Periodontol*. 2012 May; 39(5):490-4.
266. Misch CE, Perel ML, Wang HL, Sammartino G, Galindo-Moreno P, Trisi P, Steigmann M, Rebaudi A, Palti A, Pikos MA,Schwartz-Arad D, Choukroun J, Gutierrez-Perez JL, Marenzi G, Valavanis DK. Implant success, survival, and failure: the International Congress of Oral Implantologists (ICOI) Pisa Consensus Conference. *Implant Dent.* 2008 Mar;17(1):5-15.
267. Misch CE. Dental implant prosthetics. Elsevier Health Sciences; MO, USA, 2014.
268. Mishra, P.; Solanki, J.; Choudhary, R.; Sharma, C.; Sharma, P.; Shah, D. Attitude towards oral hygiene among different socioeconomic groups in Jaipur city, Rajasthan. *Med. Pharm. Rep.* 2019, 92, 79–82.
269. Mitsias M, Siormpas K, Pistilli V, Trullenque-Eriksson A, Esposito M. Immediate, early (6 weeks) and delayed loading (3 months) of single, partial and full fixed implant supported prostheses: 1-year post-loading data from a multicentre randomised controlled trial. *Eur J Oral Implantol.* 2018;11(1):63-75.
270. Mittal Y, Jindal G, Garg S. Bone manipulation procedures in dental implants. *Indian J Dent.* 2016 Apr-Jun; 7(2):86–94.
271. Mittal, H., John, M.T., Sekulic´, S., Theis-Mahon, N., & Rener-Sitar, K. Patient-reported outcome measures for adult dental patients: A systematic review. *Journal of Evidence-Based Dentistry Practice* 2019; 19, 53–70.
272. Miyamoto I, Funaki K, Yamauchi K, et al. Alveolar ridge reconstruction with titanium mesh and autogenous particulate bone graft: computed tomography-based evaluations of augmented bone quality and quantity. *Clinical Implantology Dental Related Research*. 2012;14(2):304-311.

273. Moldoveanu, L.; Dima, C.; Vasile, M. A pilot study of the assessment of fixed and removable oral prosthetic needs of over 55-year-olds who attended the social centre for dentistry in Constanta, Romania. *Oral Health Dent. Manag*. 2010, 9, 199–206.
274. Mombelli A, van Oosten MA, Schurch E Jr, Land NP. The microbiota associated with successful or failing osseointegrated titanium implants. Oral Microbiol Immunol. 1987;2(4):145–51.
275. Mombelli, A.; Lang, N.P. The diagnosis and treatment of peri-implantitis. *Periodontol. 2000* 1998, 17, 63–76.
276. Mombelli, A.; van Oosten, M.A.; Schurch, E., Jr.; Land, N.P. The microbiota associated with successful or failing osseointegrated titanium implants. Oral Microbiol. Immunol. 1987, 2, 145–151.
277. Montero J. A Review of the Major Prosthetic Factors Influencing the Prognosis of Implant Prosthodontics. *J Clin Med.* 2021 Feb 17;10(4):816. doi: 10.3390/jcm10040816
278. Mora MA, Chenin DL, Arce RM. Software tools and surgical guides in dental-implant-guided surgery. *Dent Clin North Am.* 2014;58(3):597-626.
279. Moradi G, Bolbanabad AM, Moinafshar A, Adabi H, Sharafi M, ZareieB. Evaluation of Oral Health Status Based on the Decayed, Missing and Filled Teeth (DMFT) Index. *Iran J Public Health.* 2019; 48: 2050,
280. Mordenfeld, A.; Johansson, C.B.; Albrektsson, T.; Hallman, M. A randomized and controlled clinical trial of two different compositions of deproteinized bovine bone and autogenous bone used for lateral ridge augmentation. *Clin. Oral Implant. Res*.2014, 25, 310–320.
281. Moy, P.K.; Aghaloo, T. Risk factors in bone augmentation procedures. *Periodontol. 2000* 2019, 81, 76–90.
282. Muirhead, V.E., Quiñonez, C., Figueiredo, R., Locker, D. Predictors of dental care utilization among working poor Canadians. *Community Dent Oral Epidemiol*. 2009;37(3):199-208. doi:10.1111/j.1600-0528.2009.00471.x
283. Murariu A. Sănătatea orală şi calitatea vieţii populaţiei adulte, Editura Junimea, ISBN: 978-973-37-1321-0, 2008.
284. Murariu, A., Hanganu, C., Bobu, L., Vasluianu, R., Geleţu, G., Baciu, R., Stafie, C.S., Forna, N.C. Comparative study of oral health systems in Europe. *Romanian Journal of Oral Rehabilitation* 2020*;* Vol. 12, No. 4, 11-17.
285. Murphy W, Black J, Hastings GW. Handbook of biomaterial properties. 2 ed. Verlag New York: Springer; 2016.
286. Naenni, N., Bindl, A., Sax, C., Hammerle, C., & Sailer, I. A randomized controlled clinical trial of 3-unit posterior zirconia-ceramic fixed dental prostheses (FDP) with layered or pressed veneering ceramics: 3-year results. *Journal of Dentistry* 2015; 43(11): 1365–1370.
287. Naik, A., John, M.T., Kohli, N., Self, K., & Flynn, P. Validation of the English-language version of 5-item oral health impact profile. *Journal of Prosthodontics Research* 2016; 60, 85–91.
288. Nakanishi, N.; Hino, Y.; Ida, O.; Fukuda, H.; Shinsho, F.; Tatara, K. Associations between self-assessed masticatory disability and health of community-residing elderly people. *Community Dent. Oral Epidemiol*. 1999, 27, 366–371.
289. Nannmark U, Sennerby L. The bone tissue responses to prehydrated and collagenated cortico-cancellous porcine bone grafts: a study in rabbit maxillary defects. *Clin Implant Dent Relat Res*. 2008 Dec;10(4):264-70.
290. Naung NY, Shehata E, Van Sickels JE. Resorbable Versus Nonresorbable Membranes: When and Why? *Dent Clin North Am*. 2019 Jul;63(3):419-431.
291. Needleman I, Chin S, O'Brien T, et al: Systematic review of outcome measurements and reference group(s) to evaluate and compare implant success and failure. *J Clin Periodontol* 2012;39(Suppl 12):122-132.
292. Negm SAM. Implant Success versus Implant Survival. *Dentistry* 2016;6(2):1-5.
293. Niemeyer, P., et al.European Journal of Trauma and Emergency Surgery 2011; 37(1), 83-95.
294. Nistor AM. Manual de Chirurgie orală. Anatomie, Patologie și Tehnici Chirurgicale. Ed.Callisto, 2017.
295. Oancea, R., Amariei, C., Eaton, K.A., Widstrom, E. The healthcare system and the provision of oral healthcare in European Union member states Part 5: Romania. *Br Dent J*. 2016; 220:361–6.

296. Obeidat, S.R.; Alsa'di, A.G.; Taani, D.S. Factors influencing dental care access in Jordanian adults. *BMC Oral Health* 2014, 14, 127.
297. Ogunbodede E.O. Gender distribution of dentists in Nigeria, 1981 to 2000. *J Dent Educ.* 2004;68(7 Suppl):15-18. doi:10.1002/j.0022-0337.2004.68.7_suppl.tb03809.x
298. Oliveira ER, et al. Histomorphometric, radiographic, and biomechanical evaluation of the use of porcine-derived xenografts in maxillary sinus grafting: a systematic review. *Clinical Oral Implants Research*. 2019;30(11):1037-1047.
299. Olmedo DG, Tasat DR, Duffó G, Guglielmotti MB, Cabrini RL. The issue of corrosion in dental implants: a review. *Acta Odontol Latinoam*., 2009; 22(1):3-9.
300. Omar O, Elgali I, Dahlin C, Thomsen P. Barrier membranes: More than the barrier effect? *J Clin Periodontol*. 2019 Jun;46 Suppl 21(Suppl Suppl 21):103-123.
301. Oral Health WORLDWIDE A report by FDI World Dental Federation, FDI 2015. https://www.fdiworlddental.org/sites/default/files/2020-11/2015_wohd-whitepaper
302. oral_health_worldwide.pdf
303. Organisation for Economic Co-operation and Development (OECD). The territorial impact of COVID-19: Managing the crisis across levels of government. OECD, 2020, pg.1-95.
304. Organization; 1997:350. https://apps.who.int/iris/handle/10665/41976. Accessed October 12,2020
305. Ostman PO, A. Wennerberg, A. Ekestubbe, T. Albrektsson. Immediate occlusal loading of NanoTite- tapered implants: a prospective1-year clinical and radiographic study. *Clinical Implant Dentistry and Related Research*, 2013, vol. 15, no. 6:809–818.
306. Pagano, G.; Guida, M.; Tommasi, F.; Oral, R. Health effects and toxicity mechanisms of rare earth elements—Knowledge gaps and research prospects. Ecotoxicology and Environmental Safety 2015, 115, 40–48. https://doi.org/10.1016/j.ecoenv.2015.01.030
307. Palvarinne, R., Widstrom, E., Forsberg, B.C., Eaton, K.A., Birkhed, D. The healthcare system and the provision of oral healthcare in European Union member states. Part 9: Sweden. *Br Dent J*. 2018; 224:647–51.
308. Papageorgiou, S.N.; Papageorgiou, P.; Deschner, J.; Götz, W. Comparative effectiveness of natural and synthetic bone grafts in oral and maxillofacial surgery prior to insertion of dental implants: Systematic review and network meta-analysis of parallel and cluster randomized controlled trials. *J. Dent*. 2016, 48, 1–8.
309. Papakoca K. Metode şi tehnici de reconstrucţie a crestelor alveolare deficitare. Teza doctorat. U.M.F.„C.Davila", 2011.
310. Parkerson, G.R., Jr., Gehlbach, S.H., Wagner, E.H., James, S.A., Clapp, N.E., & Muhlbaier, L.H. The Duke-UNC Health Profile: An adult health status instrument for primary care. *Medical Care* 1981; 19, 806–828.
311. Patel DR, O'Brien T, Petrie A, Petridis H. A systematic review of outcome measurements and quality of studies evaluating fixed tooth-supported restorations. *J Prosthodont*. 2014 Aug;23(6):421-33.
312. Patel R., The state of oral health in Europe, 2012, www.oralhealthplatform.eu
313. Patil S, Bhandi S, Bakri MMH, Albar DH, Alzahrani KJ, Al-Ghamdi MS, Alnfiai MM, Tovani-Palone MR. Evaluation of efficacy of non-resorbable membranes compared to resorbable membranes in patients undergoing guided bone regeneration. *Heliyon.* 2023 Feb 4;9(3):e13488. doi: 10.1016/j.heliyon.2023.e13488.
314. Patrick Rider,Željka Perić Kačarević,Akiva Elad,Drazen Tadic,Daniel Rothamel,Gerrit Sauer,Fabien Bornert,Peter Windisch,Dávid Botond Hangyási,Balint Molnar,Emely Bortel,Bernhard Hesse,Frank Witte, Biodegradable magnesium barrier membrane used for guided bone regeneration in dental surgery. *Bioactive Materials*, Elsevier, 2022, 14:152-168
315. Peeran, S.A.; Al Sanabani, F.; Al-MakramanI, B.M.; Elamin, E.I. Dental prosthetic status and treatment needs of adult population in Jizan, Saudi Arabia: A survey report. *Eur. J. Dent*. 2016, 10, 459–463.
316. Peivand, B., Mohammadtaghi, M., Gholamhossein, M., Sajad, D., & Edirippulige, S. (2021). What makes inequality in the area of dental and oral health in developing countries? A scoping review. *Cost Eff Resour Alloc*, 19, 54.
317. Pellicer-Chover, H.; Peñarrocha-Oltra, D.; Bagán, L.; Fichy-Fernandez, A.J.; Canullo, L.;

Peñarrocha-Diago, M. Single-blind randomized clinical trial to evaluate clinical and radiological outcomes after one year of immediate versus delayed implant placement supporting full-arch prostheses. *Medicina Oral Patología Oral y Cirugia Bucal* 2014, 19, e295–e301.
318. Pellizzer EP, Almeida DA, Falcon Antenucci RM et al. Prevalence of removable partial dentures users treated at Aracatuba Dental School-UNESP.*Gerodontology*. 2012 Jun;29(2):140-4.
319. Peng, Q.; Huang, Y.; Zhou, L.; Hort, N.; Kainer, K.U. Preparation and properties of high purity Mg–Y biomaterials. Biomaterials 2010, 31, 398–403. https://doi.org/10.1016/j.biomaterials.2009.09.065
320. Pérez A, Pérez J, Rodriguez M. Causes and consequences of failures of the dental implantology. Matanzas. *Rev Méd Electrón*. 2018;40(4):1023–1031.
321. Petersen PE. Challenges to improvement of oral health in the 21st century—the approach of the WHO global Oral health Programme. *Int Dent J*. 2004;54(S6):329–43
322. Petersen, P.E. (2005). Sociobehavioural risk factors in dental caries—International perspectives.*Community Dent. Oral Epidemiol*, 33, 274–279.
323. Petersen, P.E., Bourgeois, D., Ogawa, H., et al. The global burden of oral diseases and risks to oral health. *Bull World Health Organ* 2005;83:661–669.
324. Pieri F, Fini M, Aldini NN, Giardino R, Marchetti C.Alveolar ridge augmentation with titanium mesh anda combination of autogenous bone and anorg anic bovine bone: a 2-year prospective study. *Journal of Periodontology*. 2008 Nov;79(11):2093-103.
325. Pjetursson B.E., Bragger U., Lang N.P., Zwahlen M. Comparison of survival and complication rates of tooth-supported fixed dental prostheses (FDPs) and implant-supported FDPs and single crowns (SCs). *Clin. Oral Impl. Res*. 2007; 18 (Suppl 3): 97–113.
326. Pjetursson BE, Heimisdottir K. Dental implants - are they better than natural teeth? *Eur J Oral Sci*. 2018 Oct;126 Suppl 1:81-87.
327. Pjetursson, B. E., Sailer, I., Makarov, N. A., Zwahlen, M., & Thoma, D. S. All-ceramic or metal-ceramic tooth-supported fixed dental prostheses (FDPs)? A systematic review of the survival and complication rates. part II: Multiple-unit FDPs. *Dental Materials* 2015; 31(6): 624–639.
328. Pjetursson, B.E., Tan, K., Lang, N.P., Bragger, U., Egger, M. & Zwahlen, M. A systematic review of the survival and complication rates of fixed partial dentures (FPDS) after an observation period of at least 5 years. *Clinical Oral Implants Research* 2004; 15: 625–642.
329. Pol C.W.P., Raghoebar G.M., Cune M.S., Meijer H.J.A. Three-unit fixed dental prostheses supported by either two abutment implants or two abutment teeth: A comparative retrospective cohort study. *Clin Exp Dent Res.* 2022 Apr;8(2):497-505.
330. Pol, C.W.P., Raghoebar, G.M., Kerdijk, W., Boven, G.C., Cune, M.S., Meijer, H.J.A. A systematic review and meta-analysis of 3-unit fixed dental prostheses: Are the results of 2 abutment implants comparable to the results of 2 abutment teeth? *Journal of Oral Rehabilitation* 2018; 45(2):147–160.
331. Pop EC. Starea de sănătate a populaţiei din România în context european. O abordare din perspectiva calităţii vieţii. *Calitatea Vieţii*.2010; 21 (3-4): 274–305.
332. Pozzi A, Tallarico M, Marchetti M, Scarfo B, Esposito M. Computer-guided versus free-hand placement of immediately loaded dental implants: 1-year post-loading results of a multicentre randomised controlled trial. *Eur J Oral Implantol*. 2014;7:229–42.
333. Pravina, P.; Sayaji, D.; Avinash, M. Calcium and its Role in Human Body. International Journal of Research in Pharmaceutical and Biomedical Sciences 2013, 4(2), 659-668.
334. Putra RH, Yoda N, Astuti ER, Sasaki K. The accuracy of implant placement with computer-guided surgery in partially edentulous patients and possible influencing factors: A systematic review and meta-analysis. *J Prosthodont Res*. 2022 Jan 11;66(1):29-39.
335. Quirynen M, De Soete M, van Steenberghe D. Infectious risks for oral implants: A review of the literature. *Clin Oral Implants Res* 2002;13:1-19.
336. Quteish, D.; Singrao, S.; Dolby, A.E. Light and electron microscopic evaluation of biocompatibility, resorption and penetration characteristics of human collagen graft material. *J. Clin. Periodontol*. 1991, 18:305–311.

337. Radhi, A.; Lynch, C.D.; Hannigan, A. Quality of written communication and master impressions for the fabrication of removable partial prostheses in the Kingdom of Bahrain. *J. Oral Rehabil*. 2007, 34, 153–157.
338. Rathnayake, N.; Trajkovski, B.; Rahman, B.; Zafiropoulos, G.G. Clinical applications and outcomes of non-resorbable polytetrafluoroethylene (PTFE) membranes in guided bone regeneration: Review. *J. Int. Dent. Med. Res.* 2019**,** 12, 1626–1635.
339. Redford, M.; Drury, T.F.; Kingman, A.; Brown, L.J. Denture use and the technical quality of dental prostheses among persons 18–74 years of age: United States, 1988–1991. *J. Dent. Res.* 1996, 75, 714–725.
340. Reich E. Trends in caries and periodontal health epidemiology in Europe. *Int Dent J*. 2001;51(6 Suppl 1):392-8.
341. Ren Y, Fan L, Alkildani S, Liu L, Emmert S, Najman S, Rimashevskiy D, Schnettler R, Jung O, Xiong X, Barbeck M. Barrier Membranes for Guided Bone Regeneration (GBR): A Focus on Recent Advances in Collagen Membranes. *Int J Mol Sci*. 2022 Nov 29;23(23):14987. doi: 10.3390/ijms232314987.
342. Renvert S, Persson GR, Pirih FQ, Camargo PM. Peri-implant health, peri-implant mucositis, and peri-implantitis: Case definitions and diagnostic considerations. *J Periodontol*. 2018 Jun;89 Suppl 1:S304-S312.
343. Review. *Int J Periodontics Restorative Dent*. 2022 May-Jun;42(3):341-349.
344. Rho JY, Ashman RB, Turner CH. Young's modulus of trabecular and cortical bone material: Ultrasonic and microtensile measurements. *Journal of Biomechanics*. 1993;26(2):111-119.
345. Riaz, Tehseen, Zeeshan, Rabia & Zarif, Faiza & Ilyas, Kanwal & Muhammad, Nawshad & Safi, Sher & Rahim, Abdur & Syed, A & Rizvi, Ihtesham & Rehman, & Rizvi, Syed & Rehman, Ihtesham. (2018). FTIR analysis of natural and synthetic collagen FTIR analysis of natural and synthetic collagen. *Applied Spectroscopy Reviews*. 53. 10.1080/05704928.2018.1426595.
346. Righolt, A.J., Jevdjevic, M., Marcenes, W., Listl, S. Global-, Regional-, and Country-Level Economic Impacts of Dental Diseases in 2015. *Journal of Dental Research*. 2018;97(5):501-507.
347. Rocchietta I., Fontana F., Simion M. Clinical outcomes of vertical bone augmentation to enable dental implant placement: A systematic review. *J. Clin. Periodontol*. 2008;35:203–215.
348. Roccuzzo M, Bonino L, Dalmasso P, Aglietta M. Long-term results of a three arms prospective cohort study on implants in periodontally compromised patients: 10-year data around sandblasted and acid-etched (SLA) surface. *Clin Oral Implants Res*.2014;25(10):1105–12
349. Rodriguez, A.E.; Nowzari, H. The long-term risks and complications of bovine-derived xenografts: A case series. *J. Indian Soc.Periodontol*. 2019, 23, 487–492.
350. Romanian Health Program for Results (P169927). (2019). Ministry of Health, Sub-Program for Health Assessment and Promotion and Health Education, 1-21.
351. Ronda, M.; Rebaudi, A.; Torelli, L.; Stacchi, C. Expanded vs. dense polytetrafluoroethylene membranes in vertical ridge augmentation around dental implants: A prospective randomized controlled clinical trial. *Clin. Oral. Implant Res* 2014, 25, 859–866.
352. Roos-Jansaker AM, Lindahl C, Renvert H, Renvert S. Nine- to fourteen-year follow-up of implant treatment. Part I: implant loss and associations to various factors. *J Clin Periodontol.* 2006;33(4):283–9.
353. Rosenstiel S.F., Land M.F., Fujimoto J., Contemporary fixed prosthodontics. St. Louis: Mosby-Year Book; 2005:51.
354. Rothamel D, Benner M, Fienitz T, et al. Biodegradation pattern and tissue integration of native and cross-linked porcine collagen soft tissue augmentation matrices—an experimental study in the rat. *Head & Face Medicine.* 2014;10(1):10-20.
355. Ruff, R.R., Niederman, R. School-based caries prevention, tooth decay, and the community environment. *JDR Clinical and Translational Research*. 2018; 3:180-187.
356. Rupp, F.; Gittens, R.A.; Scheideler, L.; Marmur, A.; Boyan, B.D.; Schwartz, Z.; Geis-Gerstorfer, J. A review on the wettability of dental implant surfaces I: Theoretical and experimental aspects. *Acta Biomater*. 2014, 10, 2894–2906.
357. Rydén L, Buhlin K, Ekstrand E, de Faire U, Gustafsson A, Holmer J, KjellströmB, Lindahl B, Norhammar A, Nygren Å, Näsman P. Periodontitis increases therisk of a first myocardial infarction: a report from the PAROKRANK study. *Circulation*. 2016;133(6):576–83)

358. Sagheb K, Schiegnitz E, Moergel M, Walter C, Al-Nawas B, Wagner W. Clinical outcome of alveolar ridge augmentation with individualized CAD-CAM-produced titanium mesh. *Internationl Journal of Implant Dentistry*. 2017 Dec;3(1):36.
359. Sailer I, Karasan D, Todorovic A, Ligoutsikou M, Pjetursson BE. Prosthetic failures in dental implant therapy. *Periodontol* 2000. 2022 Feb;88(1):130-144.
360. Sailer I, Strasding M, Valente NA, Zwahlen M, Liu S, Pjetursson BE. A systematic review of the survival and complication rates of zirconia-ceramic and metal-ceramic multiple-unit fixed dental prostheses. *Clin Oral Implants Res*. 2018 Oct;29 Suppl 16:184-198.
361. Sakka, S.; Baroudi, K.; Nassani, M.Z. Factors associated with early and late failure of dental implants. *J. Investig. Clin. Dent.* 2012,3, 258–261.
362. Salamanca, E.; Hsu, C.-C.; Huang, H.-M.; Teng, N.-C.; Lin, C.-T.; Pan, Y.-H.; Chang, W.-J. Bone regeneration using a porcine bone substitute collagen composite in vitro and in vivo. *Sci. Rep*. 2018, 8, 1–8.
363. Salamanca, E.; Lee, W.-F.; Lin, C.-Y.; Huang, H.-M.; Lin, C.-T.; Feng, S.-W.; Chang, W.-J. A novel porcine graft for regeneration of bone defects. *Materials* 2015, 8, 2523–2536.
364. Salvi GE, Brägger U. Mechanical and technical risks in implant therapy. *Int J Oral Maxillofac Implants*. 2009;24 Suppl:69-85.
365. Salvi, G.E.; Lang, N.P. Diagnostic parameters for monitoring peri-implant conditions. *Int. J. Oral Maxillofac. Implant.* 2004, 19,116–127.
366. Sambunjak D., Nickerson J.W., Poklepovic T., Johnson T.M., Imai P., Tugwell P., Worthington H.V. Flossing for the management of periodontal diseases and dental caries in adults. *Cochrane Database Syst. Rev.* 2011;7:CD008829. doi: 10.1002/14651858.CD008829.pub2.
367. Sammartino, G.; Bernard, J.P. A clinical round table about the treatment of the severely resorbed posterior mandible. Part 1: Challenges, endeavor and perspectives. *POSEIDO* 2013, 1, 65–67.
368. Sancho-Puchades, M.; Alfaro, F.H.; Naenni, N.; Jung, R.; Hammerle, C.; Schneider, D. A Randomized Controlled Clinical Trial Comparing Conventional And Computer-Assisted Implant Planning and Placement in Partially Edentulous Patients. Part 2: Patient Related Outcome Measures. *Int. J. Periodont. Restor. Dent*. 2019, 39, e99–e110.
369. Sârbu D, Topalo V, Mostovei A, Mostovei M, Sakarov A, Zingher I. Conduita în tratamentul implantologic la mandibulă în funcție de oferta osoasă. Conduita în tratamentul implantologic la mandibulă în funcție de oferta osoasă. *Anale stiintifice, Probleme clinico-chirurgicale*, 2013 ; ed.XIV, vol.4: 528-534.
370. Sârbu D, Topalo V, Chele N, Suharschi I, Mighic A, Ghetiu A., Sobetchi A, Strisca A. *Stomatologie*. 2016;1: 33-42.
371. Sasaki JI, Abe GL, Li A, Thongthai P, Tsuboi R, Kohno T, Imazato S. Barrier membranes for tissue regeneration in dentistry. *Biomater Investig Dent*. 2021 May 20;8(1):54-63.
372. Sawada K, Nakahara K, Haga-Tsujimura M, Iizuka T, Fujioka-Kobayashi M, Igarashi K, Saulacic N. Comparison of three block bone substitutes for bone regeneration: long-term observation in the beagle dog. *Odontology* 2018; 20: 10.1007/s10266-018-0352-7.
373. Sbricoli L, Guazzo R, Annunziata M, Gobbato L, Bressan E, Nastri L. Selection of Collagen Membranes for Bone Regeneration: A Literature Review. *Materials (Basel).* 2020 Feb 9;13(3):786. doi: 10.3390/ma13030786.
374. Scherer MD. Presurgical implant-site assessment and restoratively driven digital planning. *Dent Clin North Am.* 2014;58(3):561-595.
375. Schlegel, A.; Möhler, H.; Busch, F.; Mehl, A. Preclinical and clinical studies of a collagen membrane (Bio-Gide®). *Biomaterials* 1997, 18, 535–538.
376. Schnutenhaus S, Wagner M, Edelmann C, Luthardt RG, Rudolph H. Factors Influencing the Accuracy of Freehand Implant Placement: A Prospective Clinical Study. *Dent J (Basel).* 2021 May 10;9(5):54.
377. Schou S, Holmstrup P, Worthington HV, Esposito M. Outcome of implant therapy in patients with previous tooth loss due to periodontitis. Clin Oral Implants Res. 2006 Oct;17 Suppl 2:104-23.
378. Schou S. Implant treatment in periodontitis-susceptible patients: a systematic review. *J Oral Rehabil.* 2008 Jan;35 Suppl 1:9-22.

379. Schuldt F.G, Dalago H.R, Oliveira de Souza J.G, Stanley K, Jovanovic S, Bianchini M.A. Prevalence of peri-implantitis in patients with implant-supported fixed prostheses. *Quintessence Int.* 2014 Nov-Dec;45(10):861-8.
380. Schwartz Z, Goultschin J, Dean DD, Boyan BD. Mechanisms of allograft and xenograft healing. *Critical Reviews in Oral Biology & Medicine.* 1996;7(3):189-207.
381. Schwarz, F.; Giannobile, W.V.; Jung, R.E.; Groups of the 2nd Osteology Foundation Consensus Meeting. Evidence-based knowledge on the aesthetics and maintenance of peri-implant soft tissues: Osteology Foundation Consensus Report Part 2-Effects of hard tissue augmentation procedures on the maintenance of peri-implant tissues. *Clin. Oral Implant. Res*. 2018, 29 (Suppl. 15), 11–13.
382. Schwarz, W.D.; Barsby, M.J. A survey of the practice of partial denture prosthetics in the United Kingdom. *J. Dent*. 1980, 8, 95–101.
383. Schwendicke F, Dorfer CE, Schlattmann P, Foster Page L, Thomson WM, Paris S. Socioeconomic inequality and caries: a systematic review and meta-analysis. *J Dent Res.* 2015;94(1):10–8.
384. Scutariu, M.M. , Ciurcanu, OE,Forna, D.A. Forna, N.C. , Importance of dental maxillofacial aesthetics in dental therapy, Medical-Surgical Journal, Volume 120, Issue 4, 2016, 926-931
385. Shams, A.; Tavanafar, S.; Dastjerdi, M.R.; Chaijan, K.A. Patient satisfaction and complication rates after delivery of removable partial dentures: A 4-year retrospective study. *SRM J. Res. Dent. Sci*. 2015, 6, 225–229.
386. Shamsoddin E, Houshmand B, Golabgiran M. Biomaterial selection for bone augmentation in implant dentistry: a systematic review. *J Adv Pharm Technol Res*. 2019;10:46–50.
387. Sheikh Z, Sima C, Glogauer M. Bone replacement materials and techniques used for achieving vertical alveolar augmentation. *Materials* 2015; 8 (6): 2953-2993.
388. Shigli, K.; Hebbal, M.; Angadi, G.S. Prosthetic status and treatment need among patients attending the prosthodontics department in a dental institute in India.*Eur. J. Prosthodont. Restor. Dent*.2009,17:85–89.
389. Shillingburg H.T. Jr., Hobo S., Whitsett L.D., Fundamentals of fixed prosthodontics. 3rd ed. Chicago: Quintessence; 1997:85.
390. Shin YK, Han CH, Heo SJ, Kim S, Chun HJ. Radiographic evaluation of marginal bone level around implants with different neck designs after 1 year. *Int J Oral Maxillofac Implants*,2006;21:789-94.
391. Sigcho López DA, García I, Da Silva Salomao G, Cruz Laganá D. Potential Deviation Factors Affecting Stereolithographic Surgical Guides: A Systematic Review. *Implant Dent.* 2019 Feb;28(1):68-73.
392. Simion, M.; Rocchietta, I.; Fontana, F.; Dellavia, C. Evaluation of a resorbable collagen matrix infused with rhPDGF-BB in peri-implant soft tissue augmentation: A preliminary report with 3.5 years of observation. *Int. J. Periodontics Restor. Dent.* 2012, 32, 273–282.
393. Singh, A., Peres, M.A., Watt, R.G. The Relationship between Income and Oral Health: A Critical Review. *Journal of Dental Research*. 2019;98(8):853-860.doi:10.1177/0022034519849557
394. Siqueira R, Chen Z, Galli M, Saleh I, Wang HL, Chan HL. Does a fully digital workflow improve the accuracy of computer-assisted implant surgery in partially edentulous patients? A systematic review of clinical trials. *Clin Implant Dent Relat Res.* 2020 Dec;22(6):660-671.
395. Sîrbu D. Standard method of implant placement. A retrospective study of the success rate of standard mid-sized implants placed in the mandible, at a period of more than 7 years post implant placement. *Romanian Journal of Oral Rehabilitation* 2018;10(3):75-88.
396. Slade, G.D. Derivation and validation of a short-form oral health impact profile. *Community Dentistry and Oral Epidemiology*, 1997; 25, 284–290.
397. Slade, G.D., & Spencer, A.J.. Development and evaluation of the Oral Health Impact Profile. *Community Dentistry and Oral Epidemiology*, 1994; 22, 284–290.
398. Smeets R, Stadlinger B, Schwarz F, Beck-Broichsitter B, Jung O, Precht C, Kloss F, Gröbe A, Heiland M, Ebker T. Impact of Dental Implant Surface Modifications on Osseointegration. *Biomed Res Int*., 2016;2016:6285620.
399. Smeets, R.; Stadlinger, B.; Schwarz, F.; Beck-Broichsitter, B.; Jung, O.; Precht, C.; Kloss, F.; Gröbe, A.; Heiland, M.; Ebker, T. Impact of Dental Implant Surface Modifications on Osseointegration. *BioMed Res. Int.* 2016, 2016, 6285620.

400. Smith A, et al. Comparative mechanical properties of bone substitutes for use in maxillofacial surgery. *Journal of Materials Science: Materials in Medicine*. 2003;14(8):667-675.
401. Soldatos NK, Stylianou P, Koidou VP, Angelov N, Yukna R, Romanos GE. Limitations and options using resorbable versus nonresorbable membranes for successful guided bone regeneration. *Quintessence Int*. 2017;48(2):131-147.
402. Souto MLS, Rovai ES, Villar CC, Braga MM, Pannuti CM. Effect of smoking cessation on tooth loss: a systematic review with meta-analysis. *BMC Oral Health*. 2019;19:245.
403. Spies, B. C., Witkowski, S., Vach, K., & Kohal, R. J. Clinical and patient-reported outcomes of zirconia-based implant fixed dental prostheses: Results of a prospective case series 5 years after implant placement. *Clinical Oral Implants Research* 2018; 29(1): 91–99.
404. Spitznagel FA, Boldt J, Gierthmuehlen PC. CAD/CAM Ceramic Restorative Materials for Natural Teeth. *J Dent Res*. 2018 Sep;97(10):1082-1091.
405. State of Health in the EU · Romania · Country Health Profile 2021,https://health.ec.europa.eu/system/files/2021 12/2021_chp_romania_english.pdf/,
406. Streckbein P, W. Kleis, R. S. R. Buch, T. Hansen, G. Weibrich. Bone healing with or without platelet- rich plasma around four different dental implant surfaces in beagle dogs. *Clinical Implant Dentistry and Related Research*, 2014, vol. 16, no. 4:479–486.
407. Südholz, A.D.; Kirkland, N.T.; Buchheit, R.G.; Birbilis, N. Electrochemical Properties of Intermetallic Phases and Common Impurity Elements in Magnesium Alloys. Electrochem. Solid-State Lett. 2011, 14(2), C5-C7. https://doi.org/10.1149/1.3523229
408. Suppl 1):392-8. doi: 10.1111/j.1875-595x.2001.tb00585.x. PMID: 11794560.
409. Surapaneni H, Yalamanchili PS, Basha MH, Potluri S, Elisetti N, Kiran Kumar MV. Antibiotics in dental implants: A review of literature. *J Pharm Bioallied Sci*. 2016 Oct;8(Suppl 1):S28-S31.
410. *Surg Clin North Am.* 2019 May;31(2):331-338.
411. Taguchi, Y.; Amizuka, N.; Nakadate, M.; Ohnishi, H.; Fujii, N.; Oda, K.; Nomura, S.; Maeda, T. A histological evaluation for guided bone regeneration induced by a collagenous membrane. *Biomaterials* 2005, 26, 6158.
412. Tahmaseb, A.; Wismeijer, D.; Coucke, W.; Derksen, W. Computer technology applications in surgical implant dentistry: A systematic review. *Int. J. Oral Maxillofac. Implant*. 2014, 29, 25–42.
413. Tahmaseb, A.; Wu, V.; Wismeijer, D.; Coucke, W.; Evans, C. The accuracy of static computer-aided implant surgery: A systematic review and meta-analysis. *Clin. Oral Implant Res.* 2018, 29 (Suppl. 16), 416–435.
414. Tahmaseb, A.; De Clerck, R.; Eckert, S.; Wismeijer, D. Reference-based digital concept to restore partially edentulous patients following an immediate loading protocol: A pilot study. *Int. J. Oral Maxillofac. Implant*. 2011, 26, 707–717.
415. Tai A, Landao-Bassonga E, Chen Z, Tran M, Allan B, Ruan R, Calder D, Goonewardene M, Ngo H, Zheng MH. Systematic evaluation of three porcine-derived collagen membranes for guided bone regeneration. *Biomater Transl*. 2023 Mar 28;4(1):41-50.
416. Takamoli J, Pascual A, Martinez-Amargant J, Garcia-Mur B, Nart J, Valles C. Implant failure and associated risk indicators: A retrospective study. *Clin Oral Implants Res*. 2021 May;32(5):619-628.
417. Takeuchi Y, Koizumi H, Furuchi M, Sato Y, Ohkubo C, Matsumura H. Use of digital impression systems with intraoral scanners for fabricating restorations and fixed dental prostheses.*J Oral Sci.* 2018;60(1):1-7.
418. Takeuchi, R., Kawamura, K., Kawamura, S. et all. Evaluation of the child oral health promotion 'MaliMali' Programme based on schools in the Kingdom of Tonga. *Int. Dent. J.* 2017; 67:229–237
419. Tallarico M, Esposito M, Xhanari E, Caneva M, Meloni SM. Computer-guided vs freehand placement of immediately loaded dental implants: 5-year postloading results of a randomised controlled trial. *Eur J Oral Implantol*. 2018;11(2):203-213.
420. Tallarico, M et al. "Patient-centered rehabilitation of single, partial, and complete edentulism with cemented- or screw-retained fixed dental prosthesis: The First Osstem Advanced Dental Implant Research and Education Center Consensus Conference 2017." European journal of dentistry 2018; vol. 12,4: 617-626. doi:10.4103/ejd.ejd.

421. Tamez B, Neri F, Guizar J. Factors related to the success or failure of dental implants placed in the specialty of Prosthodontics and Implantology at the University of La Salle Bajío. *Rev Esp Oral Surgery Maxilofac.* 2017;39(2):63–71.
422. Tan K, Pjetursson BE, Lang NP, Chan ES. A systematic review of the survival and complication rates of fixed partial dentures (FPDs) after an observation period of at least 5 years. *Clin Oral Implants Res.* 2004 ;15(6):654-66.
423. Tandon D, Rajawat J. Present and future of artificial intelligence in dentistry. *J Oral Biol Craniofac Res*. 2020;10(4):391-396.
424. Tang, T.; Huang, Z.; Liao, L.; Gu, X.; Zhang, J.; Zhang, X. Factors that Influence Direction Deviation in Freehand Implant Placement. *J. Prosthodont*. 2019, 28, 511–518.
425. Tarawali K. Maintenance and Monitoring of Dental Implants in General Dental Practice. *Dent Update*. 2015 Jul-Aug;42(6):513-4, 517-8.
426. Terheyden H, N.P.Lang, S.Bierbaum, B.Stadlinger. Osseointegration—communication of cells. *Clinical Oral Implants Research*, 2012, vol.23,no.10: 1127–1135.
427. The World Health Organization Quality of Life assessment (WHOQOL): Position paper from the World Health Organization. Soc.Sci. Med. 1995, 41, 1403–1409
428. The World Bank; 2003. http://documents1.worldbank.org/curated/en/226881468779415402/pdf/269500Benefit11e0
429. Tibeică, Andreea, Silviu Cătălin Tibeică, Doriana Agop-Forna, Nicoleta Ioanid, Roxana Iancu, Cristian Budacu, Marcel Costuleanu, Răzvan Curcă, Cosmin Crețu, Norina Forna. "Bone regeneration influence in the success of periimplant surgery." *Romanian Journal of Oral Rehabilitation* 2023; 15(1): 22-35.
430. Toeroek R, Dohan Ehrenfest DM. The concept of Screw-Guided Bone Regeneration (S-GBR).Part 2: S-GBR in the severely resorbed preimplant posterior mandible using bone xenograft and Leukocyte and Platelet-Rich Fibrin (L-PRF): a 5-year follow-up. *POSEIDO*. 2013a;1(2):85-92.
431. Toeroek Roland, Mazor Ziv, Marco Del Corso, Ehrenfest David M. Dohan. The concept of Screw-Guided Bone Regeneration (S-GBR). Part 1: from sinus-lift to general applications in the resorbed maxilla and mandible. *POSEIDO*. 2013b;1(2): 69-83.
432. Tolstunov L, Hamrick JFE, Broumand V, Shilo D, Rachmiel A. Bone Augmentation Techniques for Horizontal and Vertical Alveolar Ridge Deficiency in Oral Implantology. *Oral Maxillofac Surg Clin North Am*. 2019 May;31(2):163-191.
433. Tolstunov, L.; Hamrick, J.F.E.; Broumand, V.; Shilo, D.; Rachmiel, A. Bone Augmentation Techniques for Horizontal and Vertical Alveolar Ridge Deficiency in Oral Implantology. *Oral Maxillofac. Surg. Clin. N. Am.* 2019, 31, 163–191.
434. Tomasi C, Derks J. Etiology, occurrence, and consequences of implant loss. *Periodontol 2000*. 2022 Feb;88(1):13-35.
435. Tonetti M, Palmer R. Clinical research in implant dentistry: study design, reporting and outcome measurements: consensus report of Working Group 2 of the VIII European Workshop on Periodontology. *J Clin Periodontol*. 2012;39:73-80.
436. Topalo V., Dobrovolschi O. Metodă miniinvazivă de instalare a implantelor dentare endoosoase. Buletinul Academiei de Ştiinţe a Moldovei. *Ştiinţe medicale*. 2008; 1(15): 153156.
437. Topalo, E. Dental implants exposure prevention in their osseointegration period. *Rom. J. Oral Rehabil.* 2019, 11, 43–48.
438. Török, B.; Török, R.; Dohan Ehrenfest, D.M.; Agop-Forna, D.; Dascalu, C.; Forna, N.C. Study of Immediate Implants Placed in Mandibular Alveolar Bone Reconstructed with Screw-Guided Bone Regeneration Technique: A 24-Months Follow-Up. *Appl. Sci.* 2021, 11, 6054. https://doi.org/10.3390/app11136054.
439. Török, I. Regional development in Romania: shaping European convergence and local divergence. 2013. https://doi.org/10.1080/13673882.2013.10739982
440. Torres J, Tamimi F, Alkhraisat MH, Manchon A, Linares R, Prados-Frutos JC, et al. Platelet-rich plasma may prevent titanium-mesh exposure in alveolar ridge augmentation with anorganic bovine bone. *Journal of Clinical Periodontology*.2010; 37 (10): 943-951.

441. Troeltzsch, M.; Troeltzsch, M.; Kauffmann, P.; Gruber, R.; Brockmeyer, P.; Moser, N.; Rau, A.; Schliephake, H. Clinical efficacy of grafting materials in alveolar ridge augmentation: A systematic review. *J. Cranio-Maxillofac. Surg*. 2016, 44, 1618–1629.
442. Tsuchiya H. Clinical application of allogeneic bone. *Journal of Orthopedic Science*. 2003;8(2):304-314.
443. Turri, A.; Čirgić, E.; Shah, F.A.; Hoffman, M.; Omar, O.; Dahlin, C.; Trobos, M. Early plaque formation on PTFE membranes with expanded or dense surface structures applied in the oral cavity of human volunteers. *Clin. Exp. Dent. Res.* 2021, *7*, 137–146.
444. Turri, A.; Elgali, I.; Vazirisani, F.; Johansson, A.; Emanuelsson, L.; Dahlin, C.; Thomsen, P.; Omar, O. Guided bone regeneration is promoted by the molecular events in the membrane compartment. *Biomaterials* 2016, 84, 167–183.
445. Uchida A, Kojima H, Fukui Y, Nakamura K, Matsumoto T. Porous hydroxyapatite ceramics for local antibiotic delivery. *Journal of Biomedical Materials Research*. 1998;43(4):478-484.
446. Urban IA, Monje A. Guided Bone Regeneration in Alveolar Bone Reconstruction. *Oral Maxillofac Surg Clin North Am.* 2019 May;31(2):331-338.
447. Urban, I.A.; Nagursky, H.; Lozada, J.L.; Nagy, K. Horizontal ridge augmentation with a collagen membrane and a combination of particulated autogenous bone and anorganic bovine bone-derived mineral: A prospective case series in 25 patients. *Int. J. Periodontics Restor. Dent*. 2013, 33, 299–307.
448. Uzbek, U.H.; Rahman, S.A.; Alam, M.K.; Gillani, S.W. Bone forming potential of an-organic bovine bone graft: A cone beam CT study. *J. Clin. Diagn Res.* 2014, 8, 73–76.
449. Val JE, Gómez-Moreno G, Ruiz-Linares M, Prados-Frutos JC, Gehrke SA, Calvo-Guirado JL. Effects of Surface Treatment Modification and Implant Design in Implants Placed Crestal and Subcrestally Applying Delayed Loading Protocol. *J Craniofac Surg*., 2017 Mar;28(2):552-558.
450. Van Assche, N.; Vercruyssen, M.; Coucke, W.; Teughels, W.; Jacobs, R.; Quirynen, M. Accuracy of computer-aided implant placement. *Clin. Oral Implant. Res*. 2012, 23 (Suppl. 6), 112–123.
451. Van de Velde T, Collaert B, Sennerby L, De Bruyn H. Effect of implant design on preservation of marginal bone in the mandible. *Clin Implant Dent Relat Res*., 2010;12:134-41.
452. Vasak, C.; Watzak, G.; Gahleitner, A.; Strbac, G.; Schemper, M.; Zechner, W. Computed tomography-based evaluation of template (NobelGuide™)-guided implant positions: A prospective radiological study. *Clin. Oral Implant.* Res. 2011, 22, 1157–1163.
453. Vercruyssen M, van de Wiele G, Teughels W, Naert I, Jacobs R, Quirynen M. Implant- and patient-centred outcomes of guided surgery, a 1-year follow-up: An RCT comparing guided surgery with conventional implant placement. *J Clin Periodontol*. 2014 Dec;41(12), 1154-60.
454. Verma, S.; Sharma, H. Translation and validation of Hindi version of oral health impact profile-14, a measure of oral health-related quality of life of geriatrics. Indian J. Dent. Res. 2019, 30, 180–184.
455. Vertical Alveolar Bone Augmentation. *Materials (Basel).* 2015 May 27;8(6):2953–93.
456. Vinci R, Manacorda M, Abundo R, Lucchina AG, Scarano A, Crocetta C, Muzio LL, Gherlone EF, Mastrangelo F. Accuracy of Edentulous Computer-Aided Implant Surgery as Compared to Virtual Planning: A Retrospective Multicenter Study. *J Clin Med.* 2020 Mar 12;9(3):774.
457. von Wilmowsky C, T. Moest, E. Nkenke, F. Stelzle, K. A. Schlegel. Implants in bone: part I. A current overview about tissue response, surface modifications and future perspectives. *Oral and Maxillofacial Surgery*, 2014, vol.18,no.3:243–257.
458. Wada M, Mameno T, Otsuki M, Kani M, Tsujioka Y, Ikebe K. Prevalence and risk indicators for peri-implant diseases: A literature review. *Jpn Dent Sci Rev*. 2021 Nov;57:78-84.
459. Wang J., Suenaga H., Yang L., Kobayashi E., Sakuma I. Video see-through augmented reality for oral and maxillofacial surgery. *Int J Med Robot.* 2017;13(2) doi: 10.1002/rcs.1754.
460. Wang M, Rausch-Fan X, Zhan Y, Shen H, Liu F. Comparison of Implant Placement Accuracy in Healed and Fresh Extraction Sockets between Static and Dynamic Computer-Assisted Implant Surgery Navigation Systems: A Model-Based Evaluation. *Materials (Basel).* 2022 Apr 11;15(8):2806. doi: 10.3390/ma15082806.
461. Webster, T.J.; Ergun, C.; Doremus, R.H.; Siegel, R.W.; Bizios, R. Enhanced functions of osteoblasts on nanophase ceramics. *Biomaterials* 2000, 21, 1803–1810.

462. Weida, E.B., Phojanakong, P., Patel, F., Chilton, M. Financial health as a measurable social determinant of health. *PLoSONE* (2020)15(5):e0233359 .https://doi.org/10.1371/journal.pone.0233359
463. Wennerberg A, S. Galli, T. Albrektsson. Current knowledge about the hydrophilic and nanostructured SLActive surface. *Clinical, Cosmetic and Investigational Dentistry*, 2011, vol.3: 59–67.
464. Wessing B, Lettner S, Zechner W. Guided Bone Regeneration with Collagen Membranes and Particulate Graft Materials: A Systematic Review and Meta-Analysis. *Int J Oral Maxillofac Implants*. 2018 January/February;33(1):87–100.
465. Wessing, B.; Lettner, S.; Zechner, W. Guided Bone Regeneration with Collagen Membranes and Particulate Graft Materials: A Systematic Review and Meta-Analysis. *Int. J. Oral Maxillofac. Implant.* 2018, 33, 87–100.
466. WHO https://www.who.int/news-room/fact-sheets/detail/oral-health
467. WHO. Out-of-pocket payments for health care in Romania undermine progress towards
468. Widstrom, E., Eaton, K.A. Oral healthcare systems in the extended European Union. Oral World Health Organisation. Romania: Oral cancer https://www.worldlifeexpectancy.com/ro/romania-oral-cancer, 21.09.2022, ora 05.04
469. Williams, D.F. *Biomaterials* 2008, 29(20), 2941-2953.
470. Winkelmann et al. Exploring variation of coverage and access to dental care for adults in 11 European countries: a vignette approach. *BMC Oral Health* (2022) 22:65.https://doi.org/10.1186/s12903-022-02095-4
471. Winkelmann, J., Gómez Rossi, J., & van Ginneken, E. Oral health care in Europe: Financing, access and provision. *Health Systems in Transition* 2022, 24(2), 1–169.
472. Witte, F. *Acta Biomaterialia* 2010, 6(5), 1680-1692.
473. Wittneben J.G, Millen C, Brägger U. Clinical performance of screw- versus cement-retained fixed implant-supported reconstructions--a systematic review. *Int J Oral Maxillofac Implants*. 2014;29 Suppl:84-98.
474. World Health Organization, 2010, http://www.mah.se/CAPP/Country-Oral-Health-Profiles/EURO/
475. World Development Report 2004: Making Services Work for Poor People. Washington, DC:
476. World Health Organization https://www.who.int/news/item/27-05-2021-world-health-assembly- resolution-paves-the-way-for-better-oral-health-care
477. Wu C, et al. Porous calcium phosphate ceramics scaffold reinforced by MgO for bone tissue regeneration. *Materials Science and Engineering: C*. 2009;29(7):2324-2331.
478. Xia, F.; Hughes, J.P.; Voldal, E.C.; Heagerty, P.J. Power and sample size calculation for stepped-wedge designs with discrete outcomes. *Trials* 2021, 22, 598.
479. Xu L, Yu G, Zhang E, Pan F, Yang K. In vitro and in vivo evaluation of the surface bioactivity of a calcium phosphate coated magnesium alloy. *Biomaterials*. 2009;30(8):1512-1523.
480. Yang L, N. Hort, D. Laipple, et al., Element distribution in the corrosion layer and cytotoxicity of alloy Mg– 10Dy during in vitro biodegradation. *Acta Biomater* 2013; 9:8475–8487.
481. Yanru Ren, Lu Fan, Said Alkildani, Luo Liu, Steffen Emmert, Stevo Najman, Denis Rimashevskiy, Reinhard Schnettler, Ole Jung, Xin Xiong, and Mike Barbeck, Barrier Membranes for Guided Bone Regeneration (GBR): A Focus on Recent Advances in Collagen membranes. *Int J Mol Sci* 2022, Volume 23, Issue 23, 2022, doi: 10.3390/ijms232314987.
482. Yogui, F.C.; Verri, F.R.; de Luna Gomes, J.M.; Lemos, C.A.A.; Cruz, R.S.; Pellizzer, E.P. Comparison between computer-guided and freehand dental implant placement surgery: A systematic review and meta-analysis. *Int. J. Oral Maxillofac. Surg.* 2021, 50, 242–250.
483. York, NY: Springer 2014: 117-143. doi:10.1007/978-1-4614-9191-0_8
484. Yu SH, Wang HL. An Updated Decision Tree for Horizontal Ridge Augmentation: A Narrative
485. Zaki, J.; Yusuf, N.; El-Khadem, A.; Scholten, R.J.P.M.; Jenniskens, K. Efficacy of bone-substitute materials use in immediate dental implant placement: A systematic review and meta-analysis. Clin. *Implant Dent. Relat. Res*. 2021, 23, 506–519.
486. Ze Yang, Chang Wu, Huixin Shi, Xinyu Luo, Hui Sun, Qiang Wang, and Dan Zhang, Advances in Barrier Membranes for Guided Bone Regeneration Techniques. *Front Bioeng Biotechnol* 2022,

Volum 10. doi: 10.3389/fbioe.2022.921576. eCollection 2022.
487. Zhang H, et al. Evaluation of a porcine xenograft for ridge preservation: histological and clinical analyses. *Clinical Oral Implants Research.* 2015;26(10):1206-1212.
488. Zhang M, Zhou Z, Yun J, Liu R, Li J, Chen Y, Cai H, Jiang HB, Lee ES, Han J, Sun Y. Effect of Different Membranes on Vertical Bone Regeneration: A Systematic Review and Network Meta-Analysis. *Biomed Res Int*. 2022 Jul 14;2022:7742687. doi: 10.1155/2022/7742687.
489. Zhao R, Yang R, Cooper PR, Khurshid Z, Shavandi A, Ratnayake J. Bone Grafts and Substitutes in Dentistry: A Review of Current Trends and Developments. *Molecules.* 2021 May 18;26(10):3007. doi: 10.3390/molecules26103007. PMID: 34070157; PMCID: PMC8158510.
490. Zimmermann H., Zimmermann N., Hagenfeld D., Veile A., Kim T.S., Becher H. Frequency of tooth brushing a risk factor for periodontitis? A systematic review and meta-analysis. *Community Dent. Oral Epidemiol*. 2015;43:116–127. doi: 10.1111/cdoe.12126.
491. Zitzmann NU, Krastl G, Hecker H, Walter C, Waltimo T, Weiger R. Strategic considerations in treatment planning: deciding when to treat, extract, or replace a questionable tooth. *J Prosthet Dent.* 2010 Aug;104(2):80-91.
492. Zitzmann NU, Krastl G, Hecker H, Walter C, Weiger R. Endodontics or implants? A review of decisive criteria and guidelines for single tooth restorations and full arch reconstructions. *Int Endod J*. 2009 Sep;42(9):757-74.
493. Zlataric, D.K., & Celebic, A. Treatment outcomes with removable partial dentures: A comparison between patient and prosthodontist assessments. *International Journal of Prosthodontics* 2001; 14, 423–426.