UNIVERSITY OF MEDICINE AND PHARMACY
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DOCTORAL SCHOOL
FIELD OF MEDICINE

STUDY OF THE MAIN RISK FACTORS IN DENTAL IMPLANT AND SINUS-LIFT PATIENTS METHODS AND TECHNIQUES

SUMMARY OF THE PHD THESIS

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CONTENT

Introduction

The insertion of dental implants has become increasingly common as a viable, simple and affordable treatment for the patients with reduced or enlarged edentulism. The major advantages of using implants is to save the adjacent teeth and to preserve the bone into which the implant is inserted. Edentulous alveolar ridge, not supported by implants (prostheses or bridges), over time, lead to bone atrophy due to lack of functional stimulation. This leads to resorption of the maxillary bone, accentuating the loss of function and making it more difficult to live with implants or prostheses after a long period of time after tooth loss.

The rationale for choosing this topic is based on understanding the possible physiologic, pathologic or systemic treatment conditions that may adversely influence healing, osseointegration of implants and bone addition. There are precise rules for the contraindication of oro-maxillo-facial surgery, but even if these rules are followed, complications of implant or bone graft insertion can occur. The research targets patients of all ages, with various pathologies and treatments undergoing implant-prosthetic treatment.

The theme of the research is in line with international and national concerns because of the need for similar surgical treatments in patients everywhere. The research has similarity with other studies in the international literature, in which the issue of systemic diseases or treatments on the osseointegration process of implants is raised.

The research hypothesis was based on the premise that there are multiple general factors that can lead to implant or bone graft failure. The study could link useful correlations between individual patient particularities and the risk of dental implant procedures.

The aim of the study was to analyze both the main risk factors in implant-prosthetic surgical patients and the particularities of those who developed postoperative complications.

The scientific objectives consisted in identifying the clinical and anthropometric characteristics of the patients presenting complications, pointing out the individual particularities for the type of complication occurred. It was intended to understand the mechanism of implant explantation by analyzing scanning electron microscopy and energy dispersive spectroscopy of explanted implants.

We aimed to outline a pattern of patients susceptible to develop complications after dental implant surgery.

I. GENERAL PART

2.3. Risk factors involved in failure of osseointegration of dental implants

2.3.1. Local factors influencing implant stability

2.3.1.1. Residual bone volume

The most common classification of alveolar ridge defects is the one according to Carl E. Misch. According to the degree of atrophy, the edentulous ridge is divided into: type A is represented by sufficient bone, with a height greater than 12 mm and a width greater than 6 mm, with the space for the crown being less than or equal to 15 mm. Type B characterizes borderline bone availability, which is divided into B+ (width between 4-6 mm) and B- (width between 2.5-4 mm), height greater than 12 mm, space available for the crown being smaller of 15 mm. Type C is represented by insufficient bone in the vertical plane C-h (height less than 12mm) or horizontally C-w (0-2.5mm), the space required for the crown being greater than 15 mm and the occlusal angulation greater than 30°. Type D is characterized by atrophy of the entire marginal ridge, as well as atrophy of the basilar margin, flattened maxilla, thin, lamellar mandible, with an available space for the crown greater than 20 mm [61].

2.3.1.2. The degree of mineralization of residual bone

According to other studies, the success of osseointegration of implants also depends to a large extent on bone density. The lower the bone density, the higher the risk of explantation. Implants inserted into bone tissue with good density will have good osseointegration, good stability, and reduced overstress stress concentration [36,37]. Misch classified bone density into 5 classes (D1-D5), these being based on the clinical resistance to drilling of the jawbones. According to Misch's classification, class D1 corresponds to dense cortical bone with a density of more than 1250 Hounsfield units (HU), located in the anterior mandibular region. Class D2 corresponds to dense trabecular bone and porous cortical bone (850-1250 HU), located in the anterior and posterior mandibular regions and the anterior maxillary region. D3 bone density defines thin trabecular bone and thin, porous cortical bone often localized to the mandible and anterior and posterior to the maxilla (350-850 HU). D4 bone density that defines a thin trabecular bone corresponds to the maxillary posterior region

(150-350 HU). Class D5 represents a non-mineralized bone (unsuitable for dental implants) with a density lower than 150 HU [37].

2.3.2. Systemic factors that can influence the osseointegration of dental implants

Many scientific studies highlight the fact that several systemic risk factors can act both independently and in association: smoking, systemic diseases (diabetes, cardiovascular diseases, autoimmune diseases, rheumatoid diseases, immunodeficiency diseases - HIV, infectious-contagious diseases (hepatitis), as well as the therapeutic ones (drugs): radiotherapy in the case of oro-maxillo-facial malignant tumors, bisphosphonates in the case of osteoporosis, glucocorticoids and other immunosuppressants used in the case of organ transplantation, autoimmune diseases [85-87].

Table 2.1. General risk factors involved in implant failure

Vicious habits	Comorbidities	Therapeutic factors
Smoking	Cardiovascular diseases	Selective serotonin reuptake inhibitors
	Metabolic disorders – Diabetes, osteoporosis	Proton pump inhibitors
	Infectious-contagious diseases- hepatitis	Bisphosphonates
	Autoimmune diseases - rheumatoid arthritis	Glucocorticoids
		Statins

II. THE SPECIAL PART-PERSONAL CONTRIBUTIONS

3. Working hypothesis and general objectives

There are currently definite protocols for the indications and contraindications of any type of surgical intervention in the oro-maxillo-facial region, with the mention of treating the underlying condition and later returning to the dental office. Thus, once the systemic pathology is compensated, healing and integration of the implant or grafts can proceed within normal parameters. In our study we aimed to establish links between the failure of surgical interventions, the comorbidities and medical treatment of the patients. In addition to the

underlying disease and systemic treatment, vicious habits (smoking), age, incidence and type of complications were taken into account.

The overall objectives of our study were:

1. Could we establish the clinical and anthropometric characteristics of the patients who develop complications following implant insertion procedures?
2. Could we establish the clinical and anthropometric characteristics of the patients who develop complications following sinus-lift procedures?
3. Can a particular type of intervention be associated with a higher risk of failure or complications?
4. Do failure rates and complications occur more frequently in a particular category of patients?
5. Scanning electron microscopy can analyze the bone composition on the implant surface ?
6. Are there different degrees of mineralization on the implant surface depending on the implant region?

4.1. General aspects

Regarding the work methodology, the doctoral research consisted of a retrospective, non-experimental, non-randomized, observational study, carried out between February 2018 and September 2023, with the inclusion of a number of 202 patients who underwent bone addition interventions and/or insertion of dental implants. A total of 1353 dental implants were inserted.

The lot was selected to include both healthy patients of different ages and patients with various comorbidities associating the appropriate medications. We consider that this group is representative of a group of patients investigated and treated both by dental implants and by vertical bone augmentation (sinus-lift).

The study took place in a dental clinic with private practice in Bucharest, namely the "Dental Institute" clinic.

The study was based on the analysis of the observation sheets - the clinical examinations and the imaging investigations that attest the edentulous sites and the related interventions with the clinical-biological parameters, the medical letters with the disease history and the associated treatments (related to those with systemic diseases).

The periodic evaluation was carried out through clinical examinations as well as through imaging investigations - dental X-rays such as orthopantomography and cone beam computed tomography (Cone Bean Computed Tomography - CBCT).

The patients were selected for the study in accordance with the National Legislation and the principles stated in the Helsinki Declaration of 1075, revised in 2000. The purpose and objectives of the study were explained to the patients, who signed the informed consent. The protocol of the doctoral research was approved by the Ethics Commission of the Dentistry Clinic with private practice "Dental Institute" from Bucharest and by the Ethics Commission of UMF "Carol Davila" (no. 18153/04.07.2024).

4.2. Patient selection criteria

The doctoral study comprised a retrospective, observational analysis of the observation charts of patients who underwent vertical bone augmentation (sinus-lift) and/or dental implant insertion. Anthropometric indicators were recorded in a database, namely demographic data (gender, age), clinical data, vices, personal pathological history with related medication, surgical reports, complications after surgery, prosthetic treatments. The evolution between February 2018 and September 2023 was also followed.

The patients were selected using certain criteria in order to demonstrate the overall objectives and working hypotheses:

Inclusion criteria:

- Patients with reduced or extensive edentulism, candidates for implant insertion;
- patients with reduced or extensive edentulism, candidates for vertical bone augmentation procedures - severe resorption of edentulous ridges with insufficient bone support for implant insertion in the maxillary region;
- patients at least 18 years of age;
- patients in good health;
- patients with controlled pathologies that allow surgery;
- written informed consent.

Exclusion criteria:

- patients without edentulism
- patients under 18 years of age;

- patients with pathologies that contraindicate surgery in the oro-maxillo-facial region:

- malignant tumors in the oral-maxillofacial region;

- either rhinogenous or odontogenic maxillary sinusitis;

- periapical involvement of neighboring teeth;

- oral mucosal lesions (oral candidiasis, herpetic infections, aphthous lesions);

- acute infectious processes (acute pericoronaritis, periosteal abscesses, facial space abscesses);

- radiotherapy in the oro-maxillo-facial sphere;

- absence of written informed consent;

- absence of standard medical tests;

-absence of medical letters or charts from various specialized medical departments confirming the diagnosis of the disease and background drug treatment.

4.3. Materials and method

After selecting the patients according to the inclusion criteria, the following data were taken from the observation sheet for each patient:

Analyzed parameters:

A. Anthropometric indicators:

1. Demographic data: sex, age;

2. Clinical data: personal physiological and pathological antecedents, heredo-collateral antecedents, medication, the intraoral examination.

B. Paraclinical indicators:

1. Laboratory tests:

-blood count, fibrinogen, blood glucose, creatinine, urea, AST, ALT, 25-OH-vit D calcidiol, total cholesterol, HDL cholesterol, LDL cholesterol, triglycerides, total calcium. Fasting venous blood was collected in a vacutainer type container without anticoagulant. These analyzes were done preoperatively.

2. Imaging indicators:

- imaging investigations - orthopantomography (OPG) and/or CBCT were performed both preoperatively and postoperatively by all patients.

C. Type of treatment

1. Surgical: dental implant insertion surgeries (without prior augmentation) and bone augmentation interventions with implant insertion, simultaneously or separately.

2. Symptomatic treatment: postoperative medication**:** anti-inflammatory and analgesic medication.

3. Prophylactic treatment: prophylaxis of surgical site infections through antibiotic therapy.

D. The complications of surgical treatment were evaluated both through clinical and imagistic monitoring.

E. The postoperative outcome of the surgical interventions was evaluated through paraclinical and clinical monitoring.

4.4. Data recording and statistical interpretation of results

For the first study, the data were stored in an Excel (Microsoft Office) file, subsequently processed using statistical models and Python programming language with specific data analysis libraries.

For the second study, data were entered into a Word Excell database and statistically analyzed using IBM SPSS Statistics, Version 20. A comparative analysis was then carried out using one-way ANOVA and independent samples t-test of difference.

4.5. Research directions

In order to achieve the proposed objectives, the following studies were composed:

Study 1: Study on the main risk factors with role in identifying patients susceptible to implant failure;

Study 2 : Study by scanning electron microscopy and energy dispersive spectroscopy on the degree of bone mineralization at the bone-implant interface.

5. Study 1: Study on the main risk factors with a role in identifying patients susceptible to implant failure

Specific objectives

The specific objectives of this study were:

1. Could we establish the clinical and anthropometric characteristics of the patients who develop complications following implant insertion procedures?
2. Could we establish the clinical and anthropometric characteristics of the patients who develop complications following sinus-lift procedures?
3. Can a particular type of intervention be associated with a higher risk of failure or complications?
4. Can a certain systemic conditions associate a higher risk of developing complications following implant insertion and/or sinus-lift procedures?
5. Are there differences in failure rates and complications between healthy patients and those with comorbidities?
6. Could we associate certain medications with higher risk of failure or complications?
7. Do vicious habits increase the risk of failure or complications?

5.2. Material and method

We conducted a clinical, retrospective, analytic observational study that aimed to address the specific objectives formulated above.

The research took place between February 2018 and September 2023 in a private practice clinic in Bucharest, "Dental Institute".

Following the inclusion criteria, 202 patients, 70 males and 132 females, aged between 31 and 81 years, were included in the study.

The group included both patients in good health and those with comorbidities: autoimmune diseases, neoplastic diseases, drug allergies, bronchial asthma, chronic bronchitis, type II diabetes, mixed dyslipidemia, atrial fibrillation, gastritis, hepatitis B, hepatitis C, infection HIV, hypertension, hypothyroidism, osteoporosis, chronic rhinosinusitis, schizophrenia, anxiety-depressive syndrome and gastro-duodenal ulcer.

A number of 1353 dental implants were inserted in a total of 493 sinus-lift and/or dental implant insertion surgeries over 6 years (February 2018 - September 2023).

Analyzed parameters:

A. Anthropometric indicators:

1. Demographic data: age, sex;

2. Clinical data: heredo-collateral antecedents, personal physiological and pathological antecedents, intraoral examination

B. Paraclinical indicators:

1. Laboratory tests:

-hemoleukogram, fibrinogen, creatinine, urea, blood glucose, ALT, AST, 25-OH-vit D calcidiol, total cholesterol, LDL cholesterol, HDL cholesterol, triglycerides, total calcium. The analyzes were performed preoperatively. Fasting venous blood was collected in a test tube without anticoagulant.

2. Imaging indicators:

-radiological investigations such as CBCT and/or OPG were carried out by all patients preoperatively to evaluate the dimensions of the surgical sites.

C. Type of treatment

1. Surgical: dental implant insertion surgeries (without prior augmentation) and bone augmentation interventions with implant insertion, simultaneously or separately.

2. Symptomatic treatment: postoperative treatment-anti-inflammatory and analgesic medication

3. Prophylactic treatment: prophylaxis of surgical site infections through antibiotic therapy.

D. The complications of surgical treatment were evaluated both through clinical and imagistic monitoring.

E. The postoperative outcome of the surgical interventions was evaluated through paraclinical and clinical monitoring.

5.3. Results

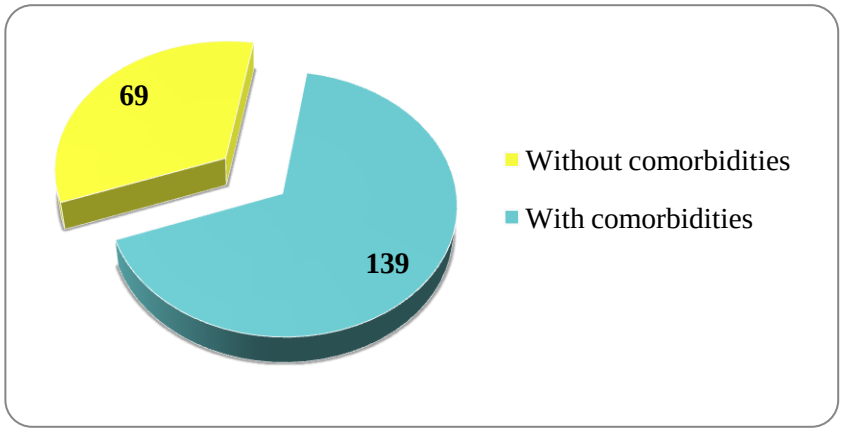

Fig. 5.4. Distribution of patients according to the presence or absence of systemic diseases

Out of the 202 patients, 139 (68.8%) had comorbidities and 31.1% had no comorbidities (representing 69 patients) (Fig. 5.4.).

Table 5.3. Table with the analysis of the logistic expression model for the "age" variable

	Coeficient	**Standard error**	**z**	**P>|z|**	**[0.025**	**0.975]**
Intercept	-4.1569	0.403	-10.30	0	-4.947	-3.366
Age	0.097	0.008	12.398	0	0.082	0.112

Using the logistic regression model we demonstrate the impact of the age at which dental implants are inserted on the development of complications. The "P-value" associated with the coefficient of the independent variable -″age″ appears in the table under the column "P>|z|". This value is very close to zero, which shows that the variable is statistically significant. (Table 5.3.)

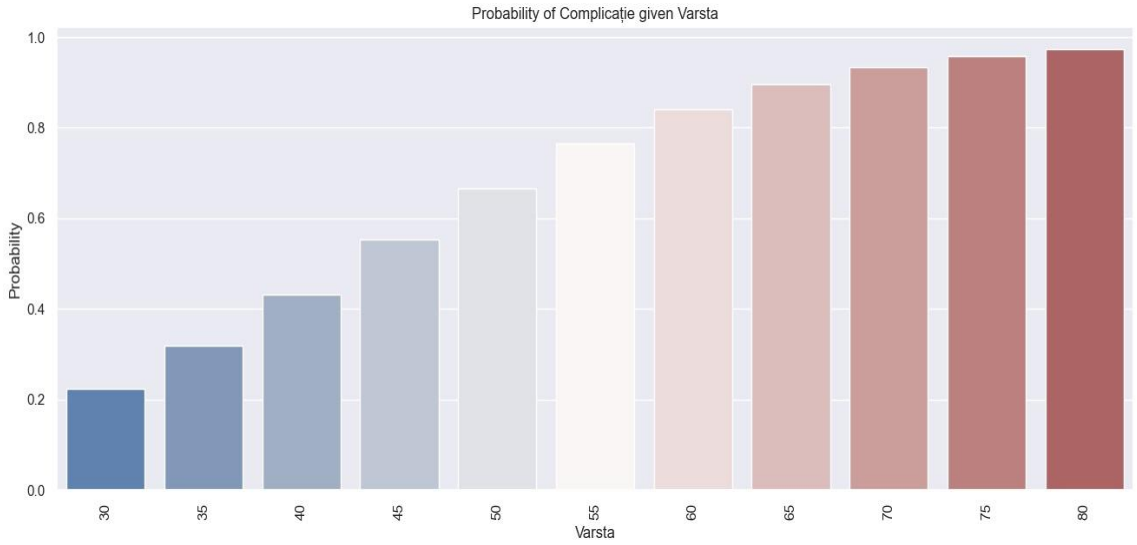

Fig. 5.17. Probability of complications in association with patient age

The probability of complications increases with age. At the age of 30 there is a 30% risk of complications, while at the age of 80 the probability approaches 100% (fig. 5.17.)

Table 5.4. Table with the analysis of the model of the logistic expression for the variable "Smoker"

	Coeficient	**Standard error**	**z**	**P>|z|**	**[0.025**	**0.975]**
Intercept	-1.351	0.078	-17.407	0	-1.503	-1.199
Smoker	1.3222	0.132	9.979	0	1.062	1.582

In Table 5.4. the impact of smoking on implant loss is demonstrated using the logistic expression model. The "P-value" associated to the coefficient of the independent variable - ″smoker″ appears in the table under the column "P>|z|". This value is very close to zero, which proves that the variable is statistically significant.

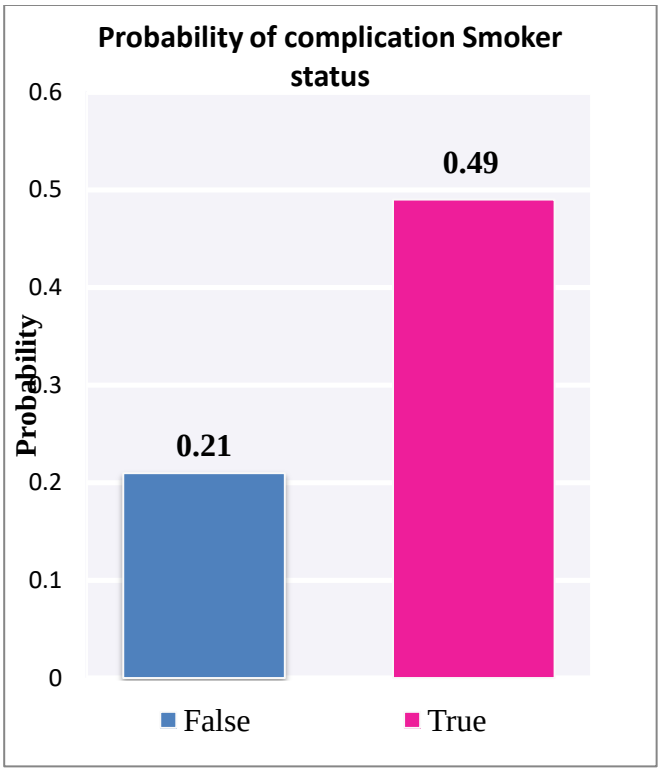

Fig.5.18. Probability of complications in association with smoking or non-smoking status

In order to have an easier interpretation of what the impact of smoking would be on the probability of developing complications, there are two scenarios: if the patient is a smoker, he has a 49% probability of developing complication, if he is not a smoker, the chance of losing the implant is 21% (fig.5.18.)

Table 5.5. Table with the analysis of the logistic expression model for the variable SSRI

	Coeficient	Standard error	z	P>|z|	[0.025	0.975]
Intercept	-1.0113	0.062	-16.22	0	-1.134	-0.889
SSRI	1.4883	0.306	4.856	0	0.888	2.089

In Table 5.5. the impact of selective serotonin reuptake inhibitors on implant loss is demonstrated using the logistic expression model. The "P-value" associated with the coefficient of the independent variable -″ISRS″ appears in the table under the column "P>|z|". This value is less than 0.05, demonstrating that the variable is statistically significant.

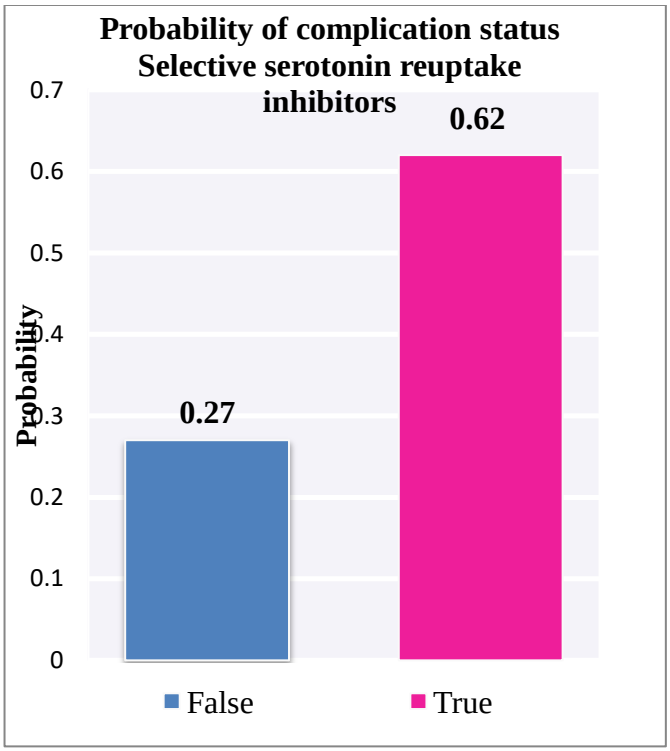

Fig. 5.19. Probability of complications in association with selective serotonin reuptake inhibitors.

In figure 5.19. the 62% probability of developing complications after dental surgeries in patients receiving SSRI medication is graphically displayed.

Table 5.6. Table with the analysis of the logistic expression model for the variable "anxious-depressive syndrome"

	Coeficient	Standard error	z	P>|z|	[0.025	0.975]
Intercept	-1.0228	0.063	-16.34	0	-1.145	-0.9
anxious-depressive syndrome	1.6289	0.3	5.437	0	1.042	2.216

Table 5.6. shows the logistic expression model for the impact of the presence of anxiety-depressive syndrome on implant loss. The "P-value" associated with the coefficient of the independent variable -″anxiety-depressive syndrome″ appears in the table under the column "P>|z|".This value is less than 0.05, which proves that the variable is statistically significant.

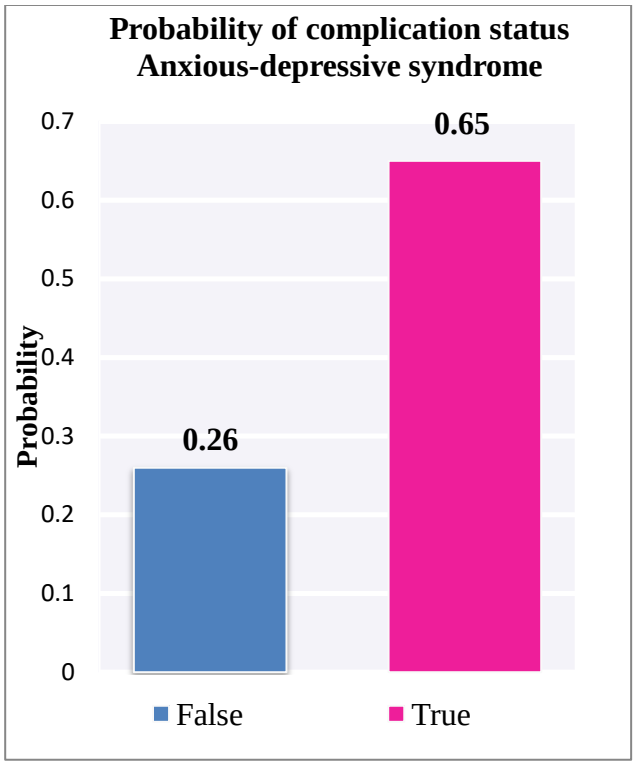

Fig. 5.20. Probability of dental implant loss in association with anxiety-depressive syndrome diagnosis

Figure 5.20 shows the 65% probability of developing complications after dental surgeries in patients with anxiety-depressive syndrome.

Table 5.7. Table with the analysis of the logistic expression model for the "gastric" variable

	Coeficient	**Standard error**	**z**	**P>|z|**	**[0.025**	**0.975]**
Intercept	-0.9846	0.061	-16.05	0	-1.105	-0.864
Gastritis	1.9009	0.487	3.904	0	0.947	2.855

Table 5.7. shows the logistic expression model for the impact of gastritis diagnosis on implant loss. The "P-value" associated with the coefficient of the independent variable -″gastritis″ appears in the table under the column "P>|z|". This value is less than 0.05 (respectively 0.012), which proves that the variable is statistically significant.

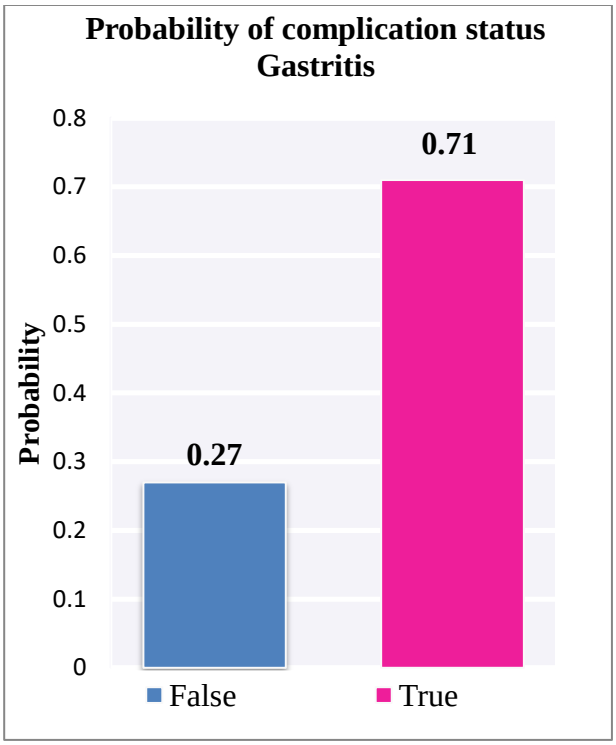

Fig. 5.21. The probability of dental implant loss in association with the diagnosis of gastritis

Figure 5.21. represents the association between developing complications and the diagnosis of gastritis, with a 71% probability for patients with gastritis to develop complications after dental implant surgeries.

Table 5.8. Logistic expression model analysis table for the variable ″Proton pump inhibitors″

	Coeficient	Standard error	z	P>|z|	[0.025	0.975]
Intercept	-0.9767	0.062	-15.79	0	-1.098	-0.855
Proton pump inhibitors	0.6765	0.301	2.244	0.025	0.086	1.267

Table 5.8. shows the logistic expression model for the impact of proton pump inhibitor treatment on the occurrence of complications in implant-prosthetic surgery. The "P-value" associated with the coefficient of the independent variable -″proton pump inhibitors″ appears in the table under the column "P>|z|". This value is less than 0.05 (respectively 0.016), which proves that the variable is statistically significant.

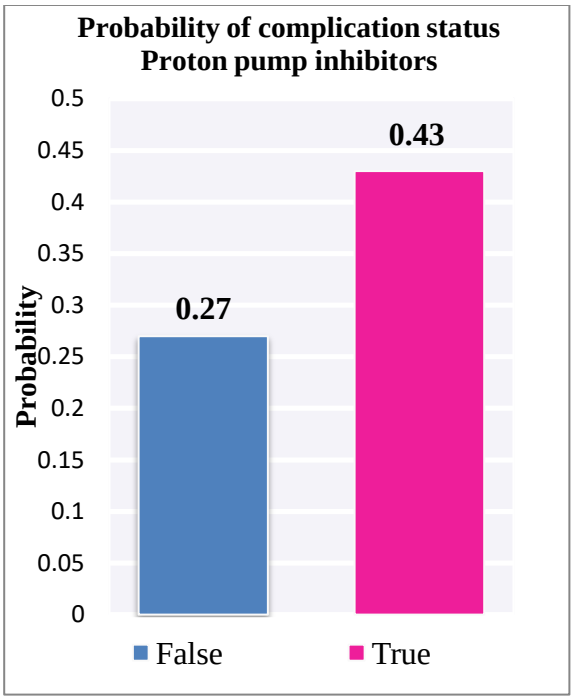

Fig. 5.22. Probability of dental implant loss in association with proton pump inhibitors

Figure 5.22. represents the association between dental implant loss and proton pump inhibitor medication, the probability being 43% for patients with this type of treatment.

6. Study 2: Scanning electron microscopy and energy dispersive spectroscopy study on the degree of bone mineralization at the bone-implant interface

Energy-dispersive X-ray spectroscopy (EDS, EDSX, EDX or XEDS) is a method of analyzing the characteristic X-ray spectrum, implemented within the SEM (scanning electron microscopy). The technique is used to determine the elemental composition or to determine the characteristic structure of a specimen. The investigation procedure is based on the principle that each element has a unique atomic structure [45, 46].

The **backround hypothesis** derived from the desire to analyze in detail the implants with an unfavorable evolution - those that are explanted, respectively, to visualize the dental implant-alveolar bone interface. Thus, a better understanding of both the osseointegration process and the explantation is desired.

The **specific objectives** of this study were:

1. Scanning electron microscopy can analyze the bone composition on the implant surface ?
2. Are there different degrees of mineralization depending on the implant region?
3. Are there mineralization differences between the median and apical regions?
4. A homogenous mineralization of the regions could be established by SEM-EDX analysis on the basis of atomic percentages and ratios?
5. Are there differences in atomic percentages between the regions?

6.2 Materials and methods

The study material was represented by 9 dental implants that were inserted in 9 patients of the dental clinic. The prosthodontics was performed with cemented fixed prosthetic restorations 3 months after implantation. The prosthodontic work was performed by the same prosthodontist and the same dental laboratory, exclusively with precautions to avoid cement back-cementing.

The 9 implants belonged to a group of patients, 5 of whom were clinically healthy at the time of explantation and 4 of whom had various compensated systemic diseases, namely osteoporosis, dyslipidemia, schizophrenia and drug allergies (to Augmentin).

Looking at the gender distribution, the group consisted of 6 male and 3 female patients. With regard to smoking habits, 8 patients were non-smokers and only one was a smoker.

The implants were explanted between 5 and 12 months after prosthesis, one implant was explanted 4 months after insertion, even in the absence of prosthesis.

Ablation of implants after therapeutic failure was achieved by manual unscrewing, as atraumatic as possible for the patients, or in the case of 4 patients with the use of a drill. After ablation, the implants were harvested in a dry environment, in sterile individual containers, and were transported to BIOMAT Research Center of the *Faculty of Materials Science and Engineering* of the National University of Science and Technology POLITEHNICA Bucharest.

At the BIOMAT Research Center, the harvested implants were analyzed using the Phenom ProX scanning electron microscope (SEM). For examination under the electron

microscope and for spectrophotometric analysis (EDX) performed with the same machine, the samples were not subjected to any special preparation.

In the study, SEM examination was performed by scanning the specimens from apical to coronal and images were taken from three areas of interest: apical, mid-region and coronal, at 500x magnification. EDX analysis was also performed for each sample at three points (apical, coronal and in the middle region of the implant), quantifying 10 chemical elements in atomic and mass percentages at each point: titanium (Ti), nitrogen (N), oxygen (O), carbon (C), calcium (Ca), boron (B), aluminum (Al), vanadium (V), fluorine (F) and phosphorus (P).

From the tables with the percentage values of the 10 chemical elements provided by the EDX analyzer, information on the amounts of Ca, N and P (from the bone structure) on the implant surfaces was taken and the ratios between them (Ca/N, Ca/P and P/N, respectively) were calculated.

We identified four bone areas according to the ratios obtained between the 3 chemical elements of interest:

1. Zone 1 - low mineralization, mostly organic content. Very low ratios between the 3 chemical elements define a very poorly mineralized bone.

2. Zone 2 - partially mineralized, which can be assimilated to zones where bone neoformation and bone remineralization occur. Here, the ratios of the 3 chemical elements have moderate values.

3. Zone 3 - higher mineralized areas with higher ratios between the 3 elements, which characterizes a bone with increased mineralization.

4. Zone 4 - highly mineralized areas, with a dense and homogeneous structure, with high Ca/N and very high P/N and Ca/P ratios, attributable to cortical bone.

For the classification of the examined bone areas, we used the same quantifications used by Prati et al. [59] for the atomic percentages of the chemical elements Ca, N and P (table 6.1.), but also for the ratios Ca/N, P/N and Ca/P (table 6.2.).

Table 6.1. - Association between the 4 types of bone and the atomic percentages of Ca, P and N in the studied samples - taken from Prati et al. [59]

Mineralization areas	**Atomic percentages of Ca**	**Atomic percentages of P**	**Atomic percentages of N**
Bone zone 1 - poorly mineralized bone (bone marrow)	Very low (<1.2)	Very low (<1.1)	High (>13)
Bone zone 2 - bone with medium mineralization (bone remodeling)	Moderate (1.21-1.75)	Moderate (1.11-1.5)	Moderate (11-12)
Bone zone 3 - highly mineralized bone (mature bone)	High (1.76-3)	High (1.51-2)	Low (<11)
Bone zone 4 - highly mineralized bone (cortical-like bone)	Very low (>3.1)	Very high (>2.1)	Moderate (11-12)

Table 6.2. - Range of atomic ratio of Ca/N, P/N and Ca/P in the analyzed bone zones - taken from Prati et al. [59]

Mineralization areas	Ca/N	P/N	Ca/P
Bone zone 1 - poorly mineralized bone (bone marrow)	Very low (<0.08)	Very low (<0.08)	Very low (<1.2)
Bone zone 2 - bone with medium mineralization (bone remodeling)	Moderate (0.081-0.16)	Moderate (0.081-0.2)	Moderate (1.21-1.5)
Bone zone 3 - highly mineralized bone (mature bone)	High (0.17-0.25)	High (0.21—0.25)	High (1.51-1.8)
Bone zone 4 - highly mineralized bone (cortical-like bone)	Very high (0.25)	Very high (>0.26)	Very high (>1.81)

Sample 3 (Tables 6.13-6.17; fig.6.7. - 6.9.) is an implant that was loaded late. The patient, a non-smoker, aged 52 years at the time of surgery, had vitamin D deficiency, drug polyallergy and osteoporosis and no antiresorptive treatment. The implant was inserted in position 2.1, in a region of the edentulous ridge with density D3 according to the Misch classification. The NOVA type implant had a diameter of 4.35 mm and a length of 13 mm, was not provisionally loaded, and was definitively loaded by cementing 35 months after insertion. It was explanted 10 months after prosthesis.

From the acquired images, the bone tissue deposition is very well represented in the middle and apex portions of the implant.

From a qualitative point of view, in the coronal area Ca and P are present in very low amounts and N is present in low amounts. The ratios between the 3 elements are very low. Poorly mineralized bone tissue is present in this area.

In the middle area of the implant, nitrogen is in low quantity, but phosphorus and calcium in very high quantity. The Ca/N and P/N ratios are very high, and the Ca/P ratio is high, being highly mineralized bone tissue.

In the apical area, nitrogen is in high quantity, and phosphorus and calcium in very low quantities. The Ca/N and P/N ratios are very low and the Ca/P ratio is moderate.

Table 6.13. Quantification of Ca, P and N by EDX analysis for sample 3 - coronal region

Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
20	Ca	Calcium	0.06	0.14
15	P	Phosphorus	0.22	0.35
7	N	Nitrogen	3.96	2.96

Table 6.14. The atomic percentages of Ca, P and N quantified by EDX for sample 3 and each zone examined

	Procente atomice Ca			Procente atomice P			Procente atomice N		
	C	**M**	**A**	**C**	**M**	**A**	**C**	**M**	**A**
Proba 3	0.06	7.5	0.78	0.22	4.95	0.57	3.96	8.12	24.67

Table 6.15. Calculated Ca/N, P/N, Ca/P ratios for sample 3 and each zone examined

	Raport atomic Ca/N			Raport atomic P/N			Raport atomic Ca/P		
	C	**M**	**A**	**C**	**M**	**A**	**C**	**M**	**A**
Proba 3	0.02	0.92	0.03	0.06	0.61	0.02	0.27	1.51	1.37

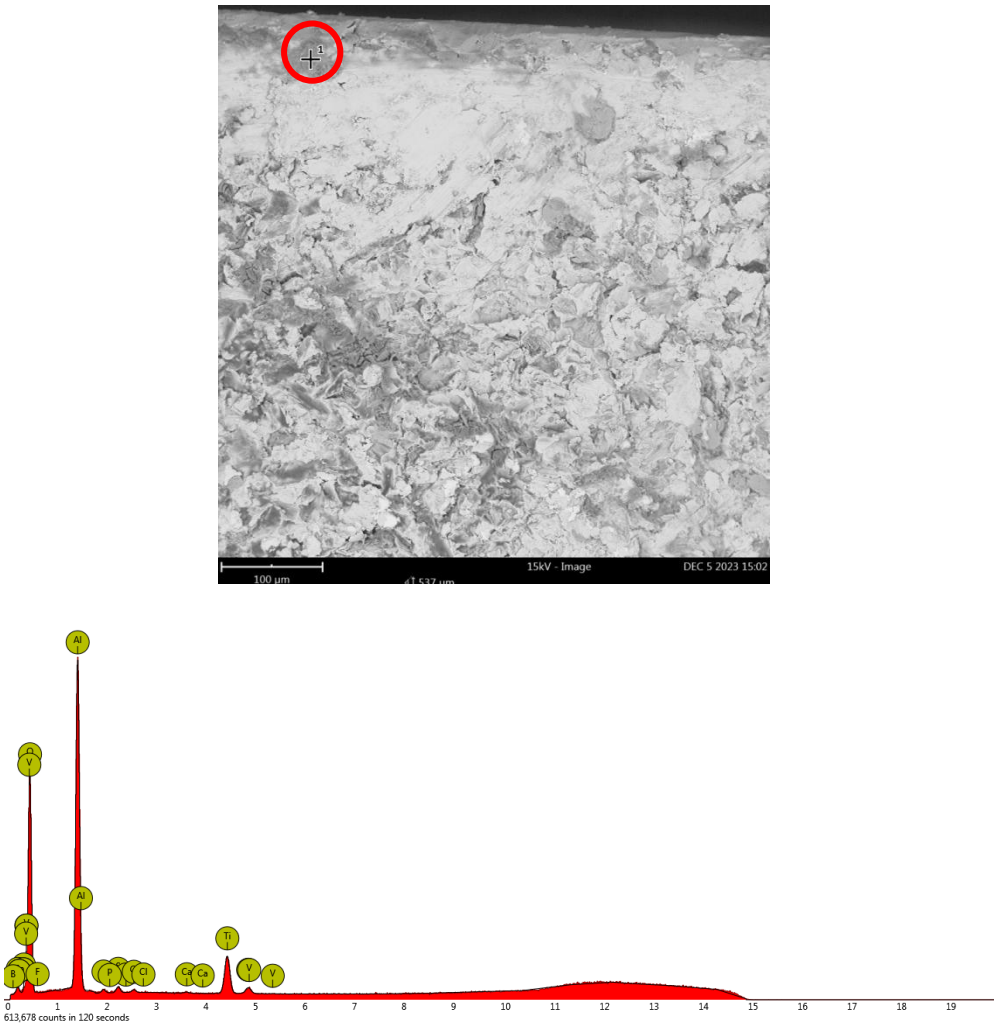

Fig. 6.7. - Scanning electron microscopy image and EDX analysis performed on a coronal spot of sample 3

Table 6.16. Quantification of Ca, P and N by EDX analysis for sample 3 - middle region

Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
20	Ca	Calcium	7.50	16.76
15	P	Phosphorus	4.95	8.55
7	N	Nitrogen	8.12	6.34

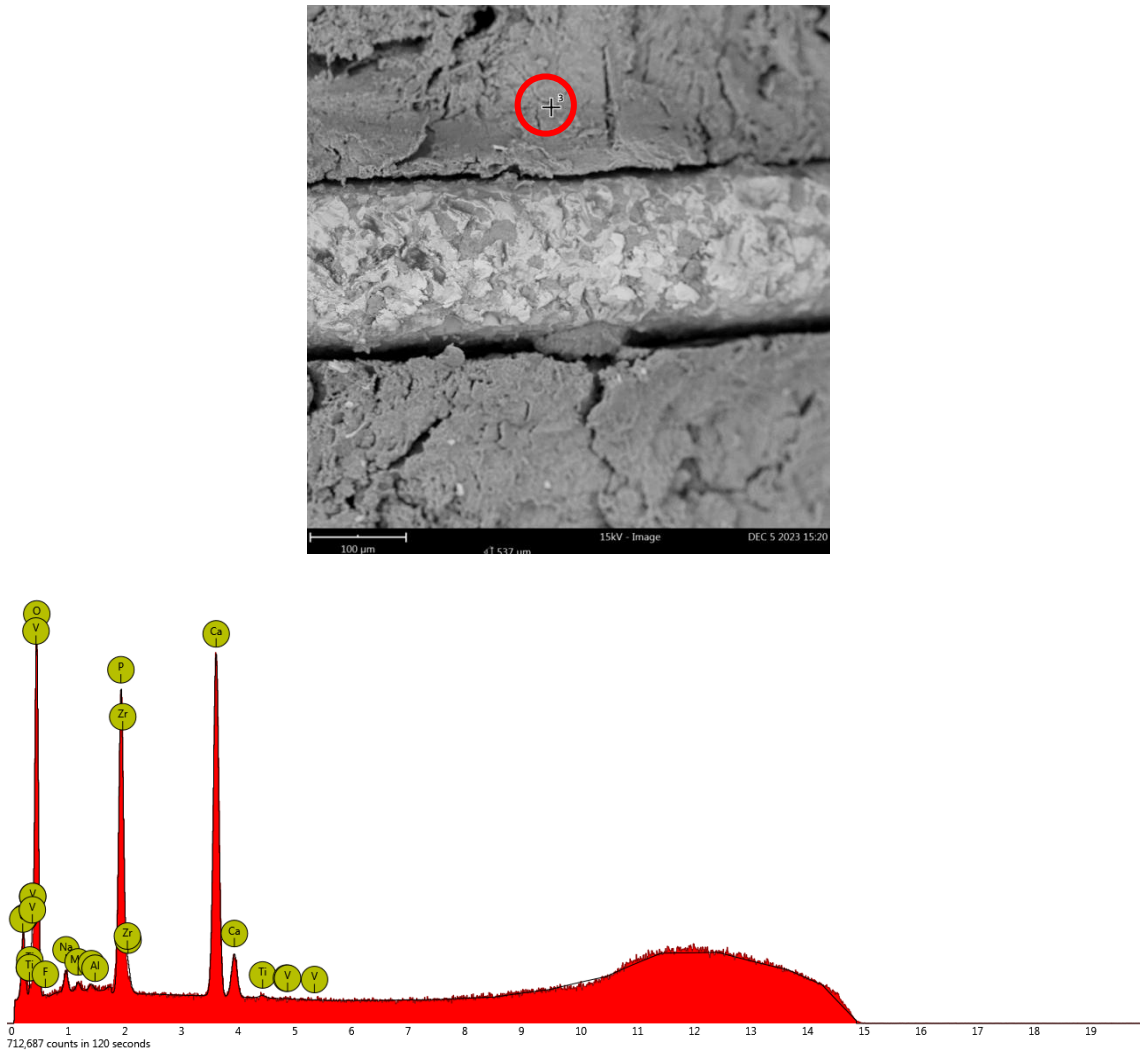

Fig. 6.8. - Scanning electron microscopy image and EDX analysis of a spot in the middle region of sample 3

Table 6.17. Quantification of Ca, P and N by EDX analysis for sample 3 - apical region

Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
20	Ca	Calcium	0.78	2.01
15	P	Phosphorus	0.57	1.13
7	N	Nitrogen	24.67	22.22

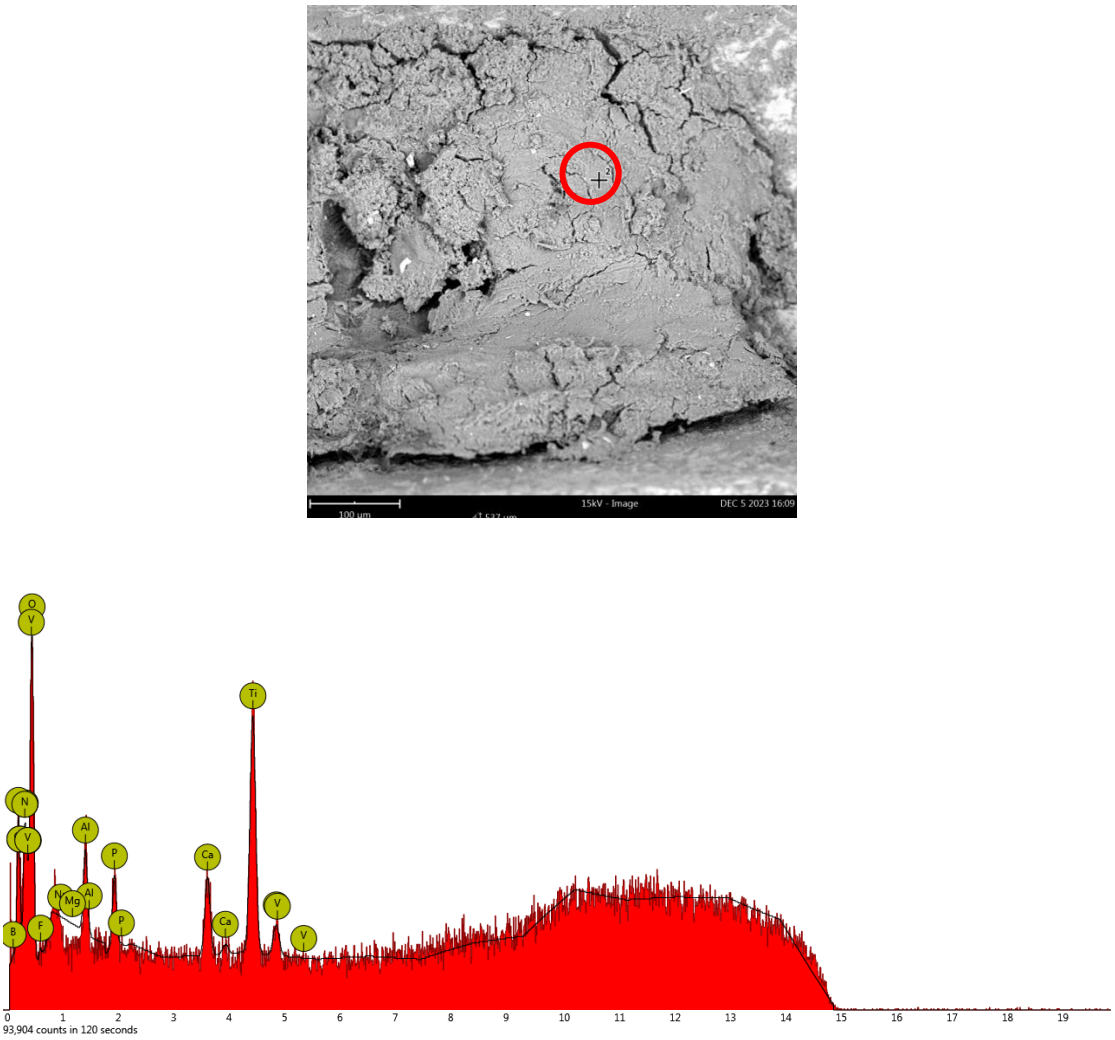

Fig. 6.9. - Scanning electron microscopy image and EDX analysis performed on an apical point of sample 3

7. Conclusions and personal contributions

Conclusions

1. Age is a statistically significant risk factor for the occurrence of complications in implant-prosthetic surgery.

2. Smoking status is a statistically significant risk factor for complications and loss of dental implants.

3. Gastritis is a statistically significant risk factor for complications and loss of dental implants.

4.Anxiety-depressive syndrome is a statistically significant risk factor for complications of implant-prosthetic surgery.

5. Patients who received selective serotonin reuptake inhibitors were at statistically significant risk for developing complications after dental surgeries.

6. Patients who received proton pump inhibitors were at statistically significant risk of developing complications following dental implant surgery.

7. There were no statistically significant differences between the diseased and healthy groups. Postoperative complications had almost equal incidence among patients with comorbidities compared to healthy patients.

8. There was an increased incidence of complications among male patients.

9. In implantology procedures, the most frequently encountered complications were implant loss first, followed by bone graft infection. The rarest complications were oro-sinus communication, intra-operative hemorrhage and acute maxillary sinusitis following implant insertion or bone augmentation procedures.

10. Scanning electron microscopy is a viable means of analyzing the mineral composition of the bone on the implant surface.

11. Divided into the three zones (coronal, middle and apical) the bone along the implant surface has different degree of mineralization depending on the location.

12. The medial and apical zones were distinguished by a higher level of mineralization in the coronal zone.

13. The apical zone was distinguished by a homogeneity of atomic percentages and atomic ratios, which may indicate a predominantly highly mineralized bone with homogeneous mineralization of that zone.

14. The atomic percentages of Ca in the medial and apical zones are much higher compared to the coronal zone.

15. The median zone is distinguished by the highest atomic percentage of P.

16. The atomic percentage of N is higher in the median zone and lower and closer in value between the coronal and apical zones.

17. The atomic ratios of Ca/N, P/N and Ca/P, on the whole lot analyzed are not representative. The exception is the average of the atomic Ca/N ratios in the coronal zone and Ca/P in the median zone, where the values are representative. The median zone is distinguished by the highest Ca/N atomic ratio.

18. The different degrees of mineralization of the implant-bone interface could not be correlated with the etiology of implant explantation.

19. Scanning electron microscopy and energy dispersive spectroscopy cannot explain the mechanism of implant explantation.

Personal contributions

In our study we analyzed in detail the implants with unfavorable evolution, i.e. implants that were explanted. By scanning electron microscopy and energy dispersive spectroscopy we visualized the dental implant - alveolar bone interface.

With this study we aimed to demonstrate and explain the explantation process of dental implants.

Our study identified the degree of mineralization of bone located along the surface of some implants (in the coronal, middle and apical region) explanted between 5-12 months after prosthetic placement.

The logistic regression statistical processing model was used to identify the main risk factors for the osseointegration of dental implants.

The impact of risk factors on the probability of patients to develop complications in implant-prosthodontic procedures was calculated on a percentage basis.

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