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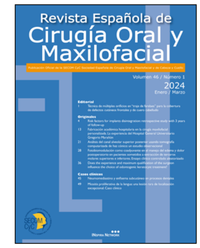

Original

Risk factors for implants disintegration: retrospective study with 3 years of follow-up

Alina Budnikova*[1], Maksym Gordiichuk[2], Oleksandr Shpachynskyi[2], Rostyslav Terletskyi[1], Yurii Chepurnyi[1], Vadym Skibitskyi[3] and Andrii Kopchak[1]

[1]Department of Maxillofacial Surgery and Innovative Dentistry. Bogomolets National Medical University. Kyiv, Ukraine. [2]Department of Oral and Maxillo-facial surgery. Bogomolets National Medical University. Kyiv, Ukraine. [3]Prosthetic Dentistry Department. Bogomolets National Medical University. Kyiv, Ukraine

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ABSTRACT

Background: The restoration of dental arch defects with partial or complete loss of masticatory efficiency is a relevant problem in modern dentistry. Often, the placement of dental implants is a challenging task for the dentist, especially in conditions of limited bone availability, requiring pre-implantation preparation. The aim of the study was to evaluate the effectiveness of placing traditional dental implants in different clinical conditions and identify risk factors associated with complications and implant disintegration.

Patients and methods: The study involved 610 patients (female-to-male ratio, average age from 18 to 81 years, median value 46 years, interquartile range 38 years – 56 years) who received 1145 conventional osseointegrated dental implant to replace dental arch defects. Of these, 420 implants (37 %) were placed in the mandible, and 725 implants (63 %) were placed in the maxilla. The main outcome variable was the disintegration of the implant in the immediate and delayed postoperative period. For further analysis, we selected potential factors that could potentially influence the risk of disintegration. The statistical analysis of relationships between variables was based on the Akaike information criterion (AIC). Subsequently, based on the identified factors, a multifactorial model of logistic regression was constructed, and their threshold/critical values for the risk of implant disintegration were determined using ROC curve analysis and the Youden index.

Results: Among the 1145 placed implants, 46 implants were lost in 23 patients (the overall frequency of implant disintegration in the study series was 4 %). The multifactorial model of mathematical regression revealed a probable correlation between the increased risk of implant loss and the presence of endocrine pathology, HR = 4.76 (95 % CI 1.78-12.8), in cases

**Correspondence:*
E-mail: alinabudnikovaa@gmail.com (Alina Budnikova).
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where tooth removal was due to cysts (compared to removal due to complicated caries, $p = 0.014$), HR = 3.0 (95 % CI 1.19-12.1), with D4 bone type (compared to D1-D2, $p < 0.001$), HR = 41.6 (95 % CI 9.6-181), and the need for pre-implantation alveolar ridge augmentation ($p < 0.001$), HR = 31.7 (95 % CI 10.9-92.3). The risk of implant loss decreased ($p < 0.05$) when the implant was placed more than 6 months after tooth removal. The size and type of the implant, as well as early or delayed loading conditions, likely did not influence the outcomes.
Conclusions: The overall level of osseointegration of traditional implants in this series was 96 %. An increased ($p < 0.05$) risk of disintegration was associated with the presence of endocrine pathology, the use of bone as the cause of tooth loss, a short period after tooth loss/removal, D4 bone type, and the need for pre-implantation alveolar ridge augmentation. The proposed five-factor model for predicting dental implant survival, based on the identified risk factors, demonstrated a high level of sensitivity at 93.6 % (95 % confidence interval 82.1-98.7 %) and specificity at 91.7 % (95 % confidence interval 90.0-93.2 %). This model can be considered when determining treatment strategies for patients in different categories.

Factores de riesgo para la desintegración de implantes: estudio retrospectivo con 3 años de seguimiento

Palabras clave:
Implante dental, preparación preimplantaria, injerto óseo, osteointegración, periimplantitis.

R E S U M E N

Antecedentes: La restauración de defectos del arco dental con pérdida parcial o completa de la eficiencia masticatoria es un problema relevante en la odontología moderna. A menudo, la colocación de implantes dentales es una tarea desafiante para el dentista, especialmente en condiciones de disponibilidad ósea limitada, lo que requiere una preparación previa a la implantación. El objetivo del estudio fue evaluar la efectividad de la colocación de implantes dentales tradicionales en diferentes condiciones clínicas e identificar factores de riesgo asociados con complicaciones y desintegración del implante.
Pacientes y métodos: El estudio involucró a 610 pacientes (proporción mujer-hombre, edad promedio de 18 a 81 años, valor mediano 46 años, rango intercuartílico 38-56 años) que recibieron 1145 implantes dentales convencionales osteointegrados para reemplazar defectos del arco dental. De estos, 420 implantes (37 %) se colocaron en la mandíbula y 725 implantes (63 %) se colocaron en el maxilar. La variable principal de resultado fue la desintegración del implante en el periodo postoperatorio inmediato y tardío. Para un análisis posterior, seleccionamos factores potenciales que podrían influir en el riesgo de desintegración. El análisis estadístico de las relaciones entre variables se basó en el criterio de información de Akaike (AIC). Posteriormente, basado en los factores identificados, se construyó un modelo multifactorial de regresión logística y se determinaron sus valores umbral/críticos para el riesgo de desintegración del implante utilizando el análisis de la curva ROC y el índice de Youden.
Resultados: Entre los 1145 implantes colocados, 46 implantes se perdieron en 23 pacientes (la frecuencia general de desintegración del implante en la serie de estudio fue del 4 %). El modelo multifactorial de regresión matemática reveló una probable correlación entre el mayor riesgo de pérdida del implante y la presencia de patología endocrina, HR = 4,76 (IC 95 % 1,78-12,8), en los casos donde la extracción del diente fue debido a quistes (en comparación con la extracción debido a caries complicadas, $p = 0{,}014$), HR = 3,0 (IC 95 % 1,19-12,1), con tipo de hueso D4 (en comparación con D1-D2, $p < 0{,}001$), HR = 41,6 (IC 95 % 9,6-181), y la necesidad de aumento del reborde alveolar previo a la implantación ($p < 0{,}001$), HR = 31,7 (IC 95 % 10,9-92,3). El riesgo de pérdida del implante disminuyó ($p < 0{,}05$) cuando el implante se colocó más de 6 meses después de la extracción del diente. El tamaño y tipo del implante, así como las condiciones de carga temprana o tardía, probablemente no influyeron en los resultados.
Conclusiones: El nivel general de osteointegración de los implantes tradicionales en esta serie fue del 96 %. Un aumento ($p < 0{,}05$) del riesgo de desintegración se asoció con la presencia de patología endocrina, el uso de hueso como causa de pérdida dental, un corto periodo después de la pérdida/extracción del diente, tipo de hueso D4 y la necesidad de aumento

del reborde alveolar previo a la implantación. El modelo propuesto de cinco factores para predecir la supervivencia del implante dental, basado en los factores de riesgo identificados, demostró un alto nivel de sensibilidad del 93,6 % (intervalo de confianza del 95 % 82,1-98,7 %) y especificidad del 91,7 % (intervalo de confianza del 95 % 90,0-93,2 %). Este modelo puede considerarse al determinar estrategias de tratamiento para pacientes en diferentes categorías.

INTRODUCTION

Replacement of dental arch defects with prosthetic constructions supported by dental implants is becoming increasingly widespread in modern dental practice. Osteointegrated dental implants are characterized by numerous advantages and high predictability of interventions compared to other methods of patient prosthetic rehabilitation[1-4].

Currently, there are hundreds of implant systems available on the market, and each year, more new systems emerge, competing with the ones already available. Dentists have to choose from more than 2000 types of dental implants and corresponding prosthetic constructions for a specific clinical case[5].

A substantial amount of research in the field of dental implantation relies on the principles of evidence-based medicine to examine both immediate and long-term outcomes. According to the authors, the success rate of implantation has significantly increased to 90-95 % today, surpassing that of previous decades. In a systematic review conducted by L. Hjalmarsson et al. (2016) on the ten-year survival of dental implants under functional loading, it was found that 95 % of the implants remained intact[6].

Similar results are presented in the systematic review by Mark-Steven Howe (2019)[2], which determined a ten-year implant survival rate of 96.4 % with a confidence interval ranging from 92 % to 99 %. These data, along with findings from other studies such as D. Buser (2000), S. Hancocks (2015), and others, may create a misleading perception that dental implantation issues are entirely resolved in today's context[2-4].

Indeed, it is widely recognized that the effectiveness of dental implantation largely depends on various factors and exhibits different efficacy indicators among patients of different groups. According to the literature, there are risk factors associated with the patient's overall health status, the condition of bone and soft tissues at the implant site, the need for alveolar ridge augmentation, and to some extent, the type of implant, its placement, and loading characteristics. With the expansion of indications for dental implants, the analysis of these risk factors and their impact on osseointegration and implant survival in the long term has become the subject of many studies, including meta-analyses. Authors have investigated whether patients' age, the presence of certain somatic diseases, implant length, and pre-implantation preparation influence implant survival. The results of existing literature publications have been found to be inconclusive and somewhat controversial[5-7].

According to Katafuchi M (2018), clinical studies of dental implants sponsored by manufacturers demonstrate a significantly lower rate of rejections (almost 4 times lower) compared to non-sponsored studies[8].

As a result, the analysis of dental implantation efficacy in various clinical cases, the assessment of risk factors, and the prediction of the probability of disintegration in prospective and retrospective multicenter studies remain essential tasks. Accumulating and analyzing clinical data in this regard serves as a basis for determining optimal treatment strategies in different clinical situations.

The aim of the study was to investigate the effectiveness of placing conventional dental implants in various clinical conditions and identify risk factors associated with complications and implant disintegration.

MATERIALS AND METHODS

Among the 610 patients included in the study, females constituted 57.6 %. The age of the patients ranged from 18 to 81 years, with a median value of 46 years and an interquartile range of 38 years to 56 years. The distribution of patients by age and gender is presented in Table I.

The implantations were conducted by experienced professionals from the Department of Maxillofacial Surgery and Modern Dental Technologies at the Institute of Postgradu-

Table I. Distribution of patients by age and gender.

Age (full years)	Males	Females	Overall
18-29	8 (2.8 %)	17 (5.3 %)	**25 (4.2 %)**
30-39	45 (15.8 %)	67 (20.5 %)	112(18.4 %)
40-49	78 (27.4 %)	64 (19.7 %)	142 (23 %)
50-59	110 (38.7 %)	137 (42 %)	247 (40.7 %)
60-69	33 (11.7 %)	36 (11 %)	69 (11.3 %)
70 and above	10 (3.6 %)	5 (1.5 %)	15 (2.4 %)
Overall	284 (46.6 %)	326 (53.4 %)	**610 (100 %)**

ate Education, Bogomolets National Medical University. The surgeries took place at the Dental Medical Center and the Clinical Dental Center of Bogomolets National Medical University between January 2018, and December 2019. The minimum postoperative follow-up period for assessing implant survival was set at 3 years.

The inclusion criteria for the study were as follows: secondary edentulism (partial or complete), suitability for dental implant placement in a position conducive to anchoring the chosen prosthetic construction (with or without pre-implantation preparation), and patient consent to participate in the research.

The exclusion criteria were as follows: patient age below 18 years, a history of radiation or chemotherapy, malignant neoplasms in the maxillofacial area, a history of myocardial infarction or acute cerebrovascular events within the past 6 months prior to the patient's referral, substance abuse, systemic decompensated or subcompensated diseases, incomplete clinical and radiological documentation of the case, psychiatric disorders, signs of acute or chronic maxillary sinusitis, non-compliance with medical recommendations, lack of interaction with the physician during the postoperative period, and patient refusal to participate in the study.

All patients who met the aforementioned criteria underwent dental implantation following the protocols and basic principles of the International Team for Implantology (ITI), under local or local potentialized anesthesia in outpatient settings. The decisions regarding the choice of implant systems, one- or two-stage protocols, the use of navigational templates, as well as the timing and conditions of loading, were left to the discretion of the dentist after discussing the treatment plan with the patient. The traditional conical osseointegrated implants from the following systems were used for the implantations: Bicon dental implants (USA), Ankylos (USA), MegaGen (South Korea), AlphaBio (Israel), B.&B. Dental s.r.l (Italy), Anthogyr (France), Straumann Roxolid, LoximISABasel (Switzerland).

All patients provided voluntary consent for the processing of personal data and for undergoing the surgical procedure. They were also informed about the possible complications of surgical treatment and received relevant recommendations. Nicotine-dependent patients were warned about the increased risk of complications such as scarring and separation of wound edges and were advised to refrain from smoking during the rehabilitation period. In all cases, patients were prescribed antibiotic prophylaxis in the form of penicillin or lincosamide group drugs in accordance with standard protocols, as well as analgesics (if necessary) and mouth rinses with a water solution of chlorhexidine in the postoperative period.

In some patients, 46 individuals (7.6 %), at 80 sites (7 %) where there was insufficient bone tissue preventing the placement of dental implants, vertical and/or horizontal augmentation of the alveolar ridge was performed. In the lateral areas of the upper jaw, sinus lifting procedures were carried out. These augmentations involved the use of autologous bone (grafts from the calvarial bone, chin, or ramus of the mandible) and/or xenogeneic bone substitute materials.

Computed tomography was performed on all patients before the surgery to assess the available bone volume and bone density, as well as the condition of the nasal sinuses, teeth, and periodontium. In the early postoperative period (up to 1 month) and in the remote period (6 months), follow-up AT scans were conducted to evaluate the morphological changes in the bone tissue and the condition of the implanted implant in dynamic progression.

Clinical and radiological data of the patients were organized into the following categories: age, gender, overall health status, presence of chronic somatic diseases, hygiene status, condition of periodontal tissues, occlusion, reason for tooth extraction, and time elapsed between tooth extraction and implant placement. The quality and volume of available bone tissue at the implantation site, the Kennedy classification of the dental arch defect, type of bone tissue, and the mucosal biotype of the oral cavity in the implantation area according to Egreja et al. (2012) were also recorded. If surgical preparation for implantation was performed, the type of bone substitute material used was noted[9].

The implantation procedure was categorized by the dental implant system used, the number and size of implants, the date of placement, the date of the second stage (if applicable), the date of loading, and the type of final prosthesis. All patients were divided based on the timing of implant placement, the presence of oral cavity contact during osseointegration, and the loading protocol.

The effectiveness of the interventions was assessed based on the Misch C.E. (1992) quality scale for implantation. During the prosthetic phase, the type of abutment, temporary, and final prosthesis was taken into consideration. The main criteria for effectiveness included the presence or absence of complications at different stages of treatment, achievement of osseointegration, and stability of the dental implant in the long-term postoperative period.

The information was collected and entered into a unified Microsoft Excel database for further analysis. To identify factors that were likely associated with the risk of implant disintegration and the development of peri-implantitis, the Akaike information criterion (AIC) was used. Subsequently, based on the identified factors, a multifactorial logistic regression model was constructed, and their threshold/critical values for the risk of implant disintegration were determined using ROC curve analysis and the Youden index. The area under the ROC curve (AUC) and its 95 % confidence interval (CI) were assessed for this purpose. Odds ratios (OR) with 95 % CIs were calculated to evaluate the impact of risk factors. A significance level of < 0.05 was considered statistically significant. The analysis was performed using the statistical package EZR v.1.54, which is a graphical user interface for R statistical software version 4.0.3, provided by the R Foundation for Statistical Computing, Vienna, Austria[10].

RESULTS

Among the 610 patients included in the study, females constituted 57.6 %. The age of the patients ranged from 18 to 81 years, with a median value of 46 years and an interquartile range of 38 years to 56 years. The distribution of patients by age and gender is presented in Table I.

In 46 patients, chronic somatic diseases were observed, predominantly endocrine pathologies, specifically type 2 diabetes, which were confirmed by an endocrinologist. Among the cases, 316 patients exhibited a thin gingival biotype around the implant, while 508 had a thick biotype, and 315 had a mixed biotype. Furthermore, 44 patients presented with periodontal tissue diseases, primarily in the form of generalized aggressive periodontitis.

The etiology of tooth loss in the implant area included caries and its complications in 1064 cases, periodontal diseases in 30 cases, jaw cysts in 36 cases, and dental-alveolar trauma in 15 cases.

The dental implant procedure followed two protocols: 76 implants (6.6 %) were placed immediately after tooth extraction (immediate implantation protocol), while 1069 implants (93.4 %) were placed in the region of a missing tooth within a time frame ranging from 4 months to 4 years (delayed implantation protocol).

In the maxilla, 725 implants (63 %) were placed, while in the mandible – 420 (37 %). The number of implants per patient ranged from 1 to 8, with an average of 2.4 ± 0.56 implants per patient. According to Misch C.E. (1992) classification, the bone density at the intervention site was categorized as follows: D1 – in 27 sites, D2 – in 274 cases, D3 – in 715 cases, and D4 – in 129 cases. The diameter and length of the dental implants varied from 3.0 to 5.5 mm and 5.0 to 12.5 mm, respectively.

Surgical templates for implant positioning were used for placing 98 implants in 23 jaws. Immediate loading protocols were applied to 19 implants (1.6 %), while 1126 implants (98 %) followed the traditional two-stage loading protocol. Fixed prostheses were utilized in 458 cases (40.4 %), partially removable prostheses in 385 cases (33.3 %), and removable prostheses in 281 cases (24.3 %). Forty-two implants (3.5 %) were not prosthetically restored due to disintegration, and four implants (0.4 %) were initially restored but subsequently removed due to disintegration.

Out of the 1145 dental implants placed in the studied patients during the observation period, 46 implants were lost in 23 patients (the overall implant disintegration rate in the study series was 4 %).

Table II presents the coefficients of the univariate logistic regression models constructed to identify factors associated with the risk of implant loss.

The analysis showed an increase ($p < 0.001$) in the risk of implant loss in patients with endocrine pathology, with an odds ratio (OR) of 6.7 (95 % confidence interval [CI]: 3.3-13.6). The presence of generalized periodontitis, specifically aggressive, also showed a significant association with a higher risk of implant loss ($p < 0.001$), with an OR of 2.11 (95 % CI: 1.56-6.2). Furthermore, cases where tooth extraction was due to cysts ($p < 0.001$) or periodontal disease exhibited a substantially higher risk of implant loss, with odds ratios of 15.4 (95 % CI: 6.97-34.2) and 9.52 (95 % CI: 3.61-25.2), respectively, compared to extractions resulting from complicated caries. The duration of time between tooth extraction and implant placement also influenced the risk of implant loss ($p < 0.001$). The risk decreased with time, with an OR of 0.06 (95 % CI: 0.02-0.14) for implants placed 6 months after extraction and an OR of 0.17 (95 % CI: 0.09-0.33) for implants placed 1 year or more after extraction, compared to immediate implantation.

The type of bone density significantly affected the implant survival ($p < 0.001$). Implants placed in type D4 bone showed a higher risk of loss, with an OR of 28.4 (95 % CI: 8.44-95.3), compared to D1-D2 bone.

Preoperative preparation also played a significant role in the risk of implant loss ($p < 0.001$). Patients who underwent alveolar ridge augmentation with xenogeneic bone materials had an OR of 27.5 (95 % CI: 13.2-57.2), while those who received free bone grafting had an OR of 22.8 (95 % CI: 7.27-71.4), and sinus lifting had an OR of 11.6 (95 % CI: 3.07-43.6), all compared to cases without preoperative preparation.

However, certain implant parameters such as length, diameter, shape, and loading protocols in the postoperative period did not significantly influence the outcome of osseointegration.

To identify a set of independent risk factors associated with implant loss, we selected independent risk factors using multivariable logistic regression models. The analysis identified five main and most significant risk factors: the presence of endocrine pathology, the reason for tooth loss, the time period after tooth loss/extraction, bone type, and the need for pre-implantation preparation/bone augmentation.

The five-factor model based on the identified factors proved to be adequate, with an area under the receiver operating characteristic curve (AUC) of 0.94 (95 % confidence interval [CI]: 0.90-0.97), indicating a very strong association between the risk of implant loss and the predetermined factors.

Table III shows detailed results of the conducted multivariate analysis.

When considering the combination of risk factors, a significant ($p < 0.05$) increase in the risk of implant loss was observed in the presence of endocrine pathology, tooth extraction due to generalized periodontitis or jaw cysts, type of bone tissue D4, and the need for alveolar ridge augmentation (see Table III). However, with an increase in the time elapsed between tooth extraction and implant placement, the risk of implant loss decreased significantly ($p < 0.05$) (see Table II).

Regarding these five risk factors, we can construct a highly predictive multivariable logistic regression model to estimate the risk of implant loss. By selecting an optimal decision threshold (see Figure 1), the constructed model exhibits a sensitivity of 93.6 % (95 % CI: 82.1-98.7 %) and a specificity of 91.7 % (95 % CI: 90.0-93.2 %). The positive predictive value (+PV) is 32.1 % (95 % CI: 27.7-36.9 %), and the negative predictive value (-PV) is 99.7 % (95 % CI: 99.1-99.9 %).

DISCUSSION

According to the literature, the replacement of dental defects with dental implants is an effective method that allows for the full restoration of lost teeth function. However, the overall success of the procedure and the risk of implant disintegration depend on various factors that can influence the process of osseointegration. This retrospective study aimed to identify the risk factors associated with dental implant loss and build regression models to predict the probability of implant rejection in different clinical scenarios.

It was found that the frequency of dental implant disintegration in the early postoperative period and during a 3-year follow-up was 4 %, which is consistent with the results reported by Mark-Steven Howe (2019)[2], who determined a ten-year

Table II. Correlation indices of factorial feature for dental implant loss.

Factorial feature		Successful implantation (number of implants)	Disintegration (number of implants)	Model coefficient value, b ± m	Significance level of the model coefficient difference from 0, p	Odds ratio, HR (95 % CI)
Age				0.012 ± 0.012	0.308	–
Gender	Females	592 (97 %)	23 (3 %)		Reference	
	Males	507 (97 %)	23 (3 %)	0.15 ± 0.3	0.61	–
Generalized aggressive periodontitis		118 (90.7 %)	12 (9.2 %)	1.13 ± 0.35	0.001	2.11 (1.56-6.2)
Gum biotype	Thick	492 (98 %)	16 (2 %)		Reference	
	Mixed	310 (96 %)	12 (4 %)	0.17 ± 0.9	0.667	–
	Thin	297 (94 %)	18 (6 %)	0.62 ± 0.35	0.077	–
Endocrine disorders		55 (82 %)	12 (18 %)	1.9 ± 0.36	<0.001	6.7 (3.3-13.6)
Reason for tooth extraction	Caries and its complications	1035 (97.2 %)	29 (2.8 %)		Reference	
	Cysts	25 (68.5 %)	11 (31.5 %)	2.74 ± 0.4	<0.001	15.4 (6.97-34.2)
	Periodontitis	24 (79.3 %)	6 (20.7 %)	2.25 ± 0.50	<0.001	9.52 (3.61-25.2)
	Trauma	15 (100)	-	12.9 ± 6.9	-	-
The term for implant placement after tooth extraction	Immediately	56 (73.6 %)	20 (26.4 %)		Reference	
	After 6 months	554 (98.7 %)	7(1.3 %)	-2.83 ± 0.45	<0.001	0.06 (0.02-0.14)
	After 1-3 years	492 (96.3 %)	19 (3.7 %)	-1.78 ± 0.34	<0.001	0.17 (0.09-0.33)
Bone tissue type	d1-d2	298 (99 %)	3 (1 %)		Reference	
	d3	700 (98 %)	15(2 %)	0.79 ± 0.64	0.218	–
	d4	101 (78.2 %)	28(21.8 %)	3.35 ± 0.62	<0.001	28.4 (8.44-95.3)
Jaw	Mandible	407 (97 %)	13 (3 %)		Reference	
	Maxilla	692 (95.4 %)	33 (4.6 %)	0.42 ± 0.33	0.205	–
Alveolar process augmentation	Absent	1045 (91.2 %)	21 (7.8 %)		Reference	
	Xenogeneic materials	31 (64.5 %)	17 (35.5 %)	3.31 ± 0.37	<0.001	27.5 (13.2-57.2)
	Free bone grafting	11 (68.7 %)	5 (31.3 %)	3.13 ± 0.58	<0.001	22.8 (7.27-71.4)
	Sinus lifting	13 (81.2 %)	3 (18.8 %)	2.45 ± 0.68	<0.001	11.6 (3.07-43.6)
Use of a surgical template		96 (98 %)	2 (2 %)	-0.74 ± 0.7	0.38	–

Table III. The coefficients of the five-factor logistic regression model for predicting the risk of implant loss.

Factorial feature		Coefficient model value, b ± m	Level of significance of the coefficient model from 0, p	Odds ratio, HR (95% CI)
Constant		-4.66 ± 1.01	<0.001	–
Endocrine disorders		1.56 ± 0.5	0.002	4.76(1.78–12.8)
Reason for tooth extraction	Caries and its complications. root fractures		Reference	
	Cysts	1.33 ± 0.59	0.024	3.0 (1.19–12.1)
	Periodontitis	0.2 ± 0.66	0.688	–
The term for implant placement after tooth extraction	Immediately		Reference	
	After 6 months	-2.2 ± 0.59	<0.001	0.12 (0.04–0.37)
	After 1-3 years	-1.22 ± 0.49	0.014	0.30 (0.11–0.78)
Bone tissue type	d1-d2		Reference	
	d3	0.99 ± 0.72	0.167	–
	d4	3.72 ± 0.75	<0.001	41.6 (9.6–181)
Preparation for implantation	Absent		Reference	
	Augmentation with xenogeneic bone materials	2.7 ± 0.9	<0.001	31.7 (10.9–92.3)
	Free bone grafting	0.70 ± 0.81	0.393	–
	Sinus lifting	1.74 ± 0.91	0.056	–

implant survival rate of 96.4 % with a confidence interval ranging from 92 % to 99 %.

The main factors influencing the survival of dental implants were the presence of endocrine disorders (such as diabetes and thyroid diseases), the presence of periodontal diseases, and the need for bone augmentation before dental implant placement (regardless of the type of bone graft or bone substitute material used for augmentation). The risk of disintegration also increased in D4 bone type and in cases of immediate implantation combined with tooth extraction.

Some authors who conducted similar studies have reported a correlation between the risk of dental implant failure and the patient's age. For example, Mark-Steven Howe (2019) also noted an increased frequency of disintegrations and unsatisfactory implant outcomes in the age group over 64 years (6.8 % compared to 3.6 % in younger patients). However, in our series, the patient's age did not have a significant influence on the implant outcomes, as evidenced by the coefficient value of the model, b ± m 0.013 ± 0.012, and the coefficient not differing significantly from 0, p = 0.306. Overall, this suggests the potential expansion of age indications for dental implant placement.

The impact of the general somatic health status was thoroughly studied in a systematic review conducted by M. Schimmel et al. (2018)[11]. The author found that in patients with cardiovascular diseases, the survival rate of implants did not differ from that of somatically healthy individuals. A high survival rate of implants was demonstrated in patients with Parkinson's disease and type II diabetes. However, negative effects on implant outcomes were observed in patients with oncological diseases who underwent radiation therapy and antiresorptive therapy[12]. In our study, the presence of diabetes and thyroid disorders likely influenced the implant outcomes, increasing the disintegration rate to 20 % compared to 4 %. It is worth noting that the number of patients with such conditions in our series was relatively small (only 46 patients).

Our data indicate the lack of a significant impact of implant type, size (length and diameter), and the manufacturer of the implant system on their survival rates. These issues have

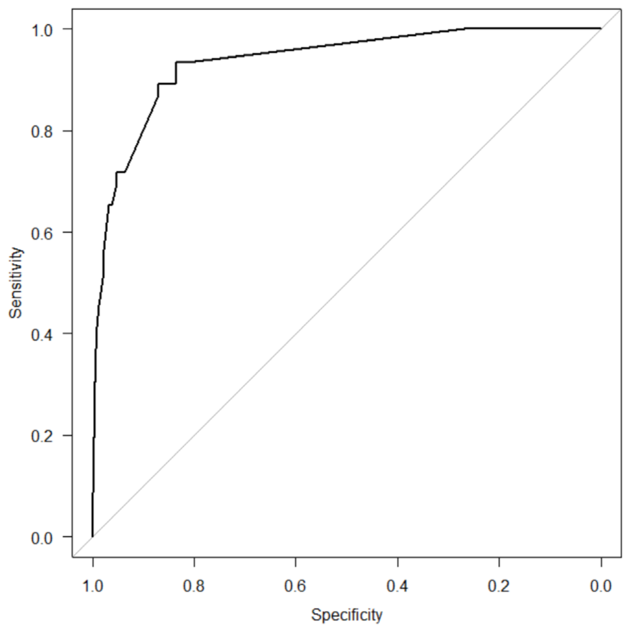

Figure 1. The receiver operating characteristic (ROC) curve of the five-factor prediction model for implant loss risk.

been extensively studied in the literature. Some studies have suggested a higher likelihood of rejection for short and ultra-short dental implants, especially when placed in the upper jaw Telleman et al.[13-14]. Nevertheless, in recent years, there have been publications presenting completely contradictory findings. Studies by Kotsovilis et al.[15], Monje et al.[16], Annibali et al.[17], Menchero-Cantalejo et al.[19], and others have accumulated data demonstrating the high efficacy of implants shorter than 6 mm, with the osseointegration rate likely not differing from implants of longer length.

This can be explained by the improvement of surgical techniques and the clear definition of indications for their placement. However, questions about long-term survival and rates of vertical bone loss around short implants under functional loading still remain open. In our study, the length of the applied implants varied from 5.0 to 12.5 mm, and no significant differences in the frequency of disintegration were noted. Similarly, in our work, the diameter of the implant within the range of 3.0 to 5.5 mm did not matter either. Some authors have investigated the influence of the implant's width on its effectiveness, but only a few studies have included results regarding narrow implants, and the highest risk is associated precisely with their use[20].

Authors[21-27] observed a large group of implants and reported rejection rates of 5.1 % for narrow implants, 3.8 % for regular implants, and 2.7 % for wide implants. The authors note that the diameter of the implant likely affects disintegration, but currently, there is insufficient research to definitively establish such a dependency Olate et al.[28].

Although this study did not find a probable effect of implant characteristics on its integration efficiency, the condition of the surrounding bone tissue played a significant role. Del Fabbro et al.[29] also investigated the impact of bone density on the course of osseointegration processes and reached similar conclusions. According to their findings, the rejection rate in D3-D4 bone type was 5-7 % higher. However, the authors pointed out the considerable variability of data in this regard and the insufficient understanding of the processes occurring in the peri-implant zone in different bone types, as well as the influence of implant parameters on them. In our study, higher risks of implant disintegration were confirmed for D4 bone type (HR = 41.6, 95 % CI 9.6-181) compared to D1-D2 bone types, after standardization for other risk factors.

Thus, the identified risk factors in this study are generally consistent with the findings of other researchers. Based on these risk factors and considering their possible combined effect, we have created and tested a regression multifactorial model that allows for a high-accuracy prediction of implant disintegration risk in patients, providing a sensitivity of 93.5 % (95 % confidence interval 82.1-98.6 %) and specificity of 91.8 % (95 % confidence interval 90.0-93.3 %) for the model.

CONCLUSION

The overall level of osseointegration of traditional osseointegrated implants in this series was 96 %. An increased ($p < 0.05$) risk of disintegration was associated with the presence of endocrine pathology, cyst as the cause of tooth loss, a short period after tooth loss/removal, D4 bone type, and the need for pre-implantation preparation (alveolar ridge augmentation). Implant size and type, as well as early or delayed loading conditions, probably did not influence the surgical outcomes. The proposed five-factor model for predicting dental implant survival, based on the identified risk factors, demonstrates a high sensitivity of 93.5 % (95 % confidence interval 82.1-98.6 %) and specificity of 91.8 % (95 % confidence interval 90.0-93.3 %) and can be considered when determining treatment strategies for patients in various categories.

ETHICAL ASPECTS

The research was submited for evaluation and received approval from the Commision on Experimental Bioethical and Ethical Issues in Scientific Research, of Bogomolets National Medical University (Protod 039).

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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