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Immediate loading of an implant with fine threaded neck – bone resorption and clinical outcome of single tooth restorations in the maxilla

Artur Blaszczyszyn[1], Friedhelm Heinemann[2], Tomasz Gedrange[1,2], Beata Kawala[3], Hanna Gerber[4] and Marzena Dominiak[1,*]

[1] Department of Dental Surgery, Wroclaw Silesian Piast Medical University, Wroclaw, Poland
[2] Department of Orthodontics, Pediatric Dentistry and Preventative Dentistry, Ernst-Moritz-Arndt Medical University, Greifswald, Germany
[3] Department of Orthodontics, Wroclaw Silesian Piast Medical University, Wroclaw, Poland
[4] Department of Maxillo-Facial Surgery, Wroclaw Silesian Piast Medical University, Wroclaw, Poland

Abstract

One of the conditions for ensuring success in implant surgery with an immediate loading (IL) protocol is to achieve maximum primary stability (PS) through the use of dental implants with the appropriate design and surface and a properly prepared osseous bed. The aim of this study was to assess the stability, degree of osseointegration, and success rate after inserting an implant with IL in an osseous bed prepared with burs or an ultrasonic device. Twenty-five patients requiring single tooth replacement (tioLogic; Dentaurum, Ispringen, Germany) in the aesthetic zone were divided randomly into the test (K0) and control (K1) groups. The following factors were investigated: primary (PS-ISQ) and secondary (SS-ISQ) stability- implant stability quotient (ISQ value) by Ostell Mentor, initial width of the alveolar ridge, marginal bone loss (MBL), and buccal bone thickness. The effectiveness of the implant treatment 1 year after the surgery was 100% for group K0 and 93.3% for group K1. A significant correlation was observed between PS and MBL after 1 month. No statistically significant differences were noted between the groups with regard to MBL after 6 months (K0 0.5±0.4 mm vs. K1 0.8±1.3 mm), PS-ISQ (K0 70±4 vs. K1 71±4), and SS-ISQ (K0 70±2 vs. K1 72±3). The average ISQ value of 70±4 is sufficient to allow for IL. A high level of PS results in lower MBL.

Keywords: immediate loading; implants; ultrasonic preparation.

* Corresponding author: Marzena Dominiak, Department of Oral Surgery, Silesian Piast Medical University, Krakowska 26, 50-424 Wroclaw, Poland
Phone: +48-71-7840251
Fax: +48-71-7874253
E-mail: marzena.dominiak@am.wroc.pl

Introduction

The growing interest in tooth restorations based on implant procedures has been paralleled not only by changes in the geometry of the implant itself but also in the surgical procedures employed, such as the use of ultrasonic preparations. Enhanced primary stability (PS) and a high degree of bone implant contact shorten the therapeutic procedure.

The concept of immediate loading (IL), defined as a prosthetic restoration carried out within 48 h of the implant procedure, has been shown to be a predictable treatment option when sufficient PS of the implants can be achieved, especially in cases of bone density characteristic for the lower jaw [14, 15]. In the case of the maxilla, lower bone density and implant stability may lead to a high degree of micromovement resulting from IL, and thus to bone resorption and implant failure [7, 8]. Thus, there is a need to improve bone density, bone implant contact, and PS. Bone condensing using piezosurgery devices is a suitable method for this purpose and is even less traumatic than conventional instruments [13, 14]. Furthermore, the implants used should be designed in such a way that they guarantee an even distribution of stress resulting from masticatory forces in the surrounding bone and that have also been proven to cause less bone resorption with the protocol of IL [10–12, 20].

The aim of this study was to assess the PS and degree of osseointegration in the anterior part of the maxilla and mandible after implant insertion with IL in an osseous bed prepared using traditional burs or ultrasonic technology.

Materials and methods

Study design and patients

Twenty-five generally healthy adults (15 males, 10 females), aged between 18 and 55 years, participated in the prospective randomized study. The inclusion criteria included the lack of a single tooth in the anterior part of the upper or lower jaw with a proper inter-arch relationship that ensures sufficient space for a non-occluding provisional crown. The width of the alveolar ridge in such patients was >5 mm at its narrowest point, the mesio-distal distance was at least 6 mm, and the minimum height of the keratinized tissue (HKT) was >2 mm. One condition that had to be fulfilled before the procedure was an approximal plaque index, according to Lange et al. [16], of <25% immediately before the operation. The exclusion criteria included severe periodontal disease, the necessity of performing a sinus lift with the open or closed method, or

the necessity to graft the alveolar ridge. Additional exclusion criteria were poor general health, e.g., severe renal or liver failure, a history of radiotherapy in the head region, uncontrolled diabetes, recent myocardial infarction, hemophilia, bleeding disorders or cumarin therapy, metabolic disorders, signs of chronic bone disease, bruxism and general contraindications, and poor bone density.

The criterion used to divide patients into two research groups was the method of osseous bed preparation. The study material was randomly allocated into the following groups:

I. K1 – osseous bed preparation using traditional burs (Dentaurum, Ispringen, Germany)
II. K0 – osseous bed preparation with ultrasonic tips using a piezosurgery device (Mectron, Carasco, Italy)

All patients were informed of the surgical treatment method when their written consent for the procedure was obtained on the basis of signed protocols ratified by the Bioethics Committee (KB no. 93/2009).

All operations were carried out by the same operator according to the adopted research protocol. As a result, a total of 15 implantation procedures were performed with an osseous bed preparation using the classical method and 10 implantation procedures were prepared using the ultrasonic method.

Surgical and prosthodontic procedure

The surgical procedure was performed under local anesthesia by using the limited flap technique (envelope flap) (Figures 1 and 2). The osseous bed was prepared using traditional burs or ultrasonic tips cooled with a saline solution (50 ml/1 min). The implants were then placed with the hand ratchet 1 mm subcrestally. In the study, tioLogic (Dentaurum) implants with a cylindrical-cone rough CBS and platform focusing were used. If a bone defect was confirmed in the marginal region of the alveolar ridge (2–3 mm), an augmentation procedure was carried out using either a xenogeneic bone substitute material (BioOss; Geistlich Pharma AG, Wolhusen, Switzerland) or a synthetic material (Nanobone; Artoss GmbH, Rostock, Germany) depending on the patient's choice. The defect was additionally covered with Resodont (Resorba, Nürnberg, Germany) collagen membrane. The PS of the implant was then checked using a dynamometric key produced by Dentaurum and through a resonance frequency analysis (RFA) device (Ostell Mentor; Integration Diagnostics AB, Gamlestadsvägen, Göteborg, Sweden). For IL to be possible, stability had first to be achieved, measured by a torque on the ratchet >35 N cm.

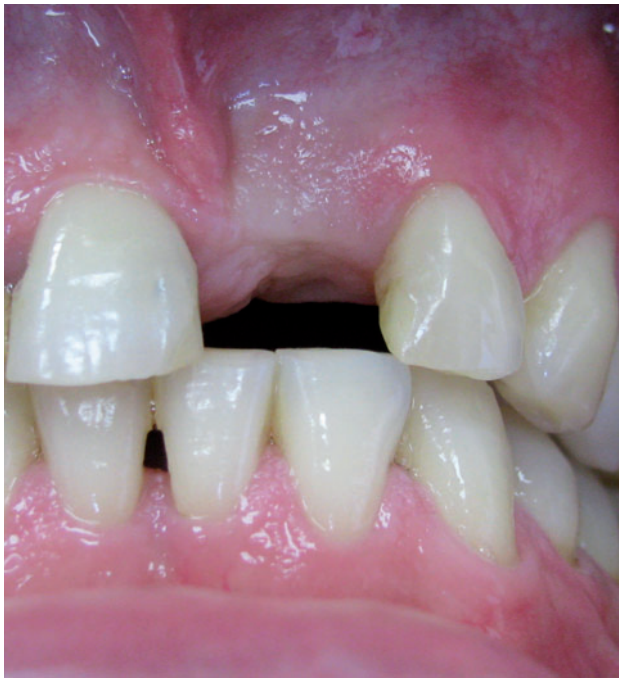

Figure 1 Preoperative photo, loss of tooth 21.

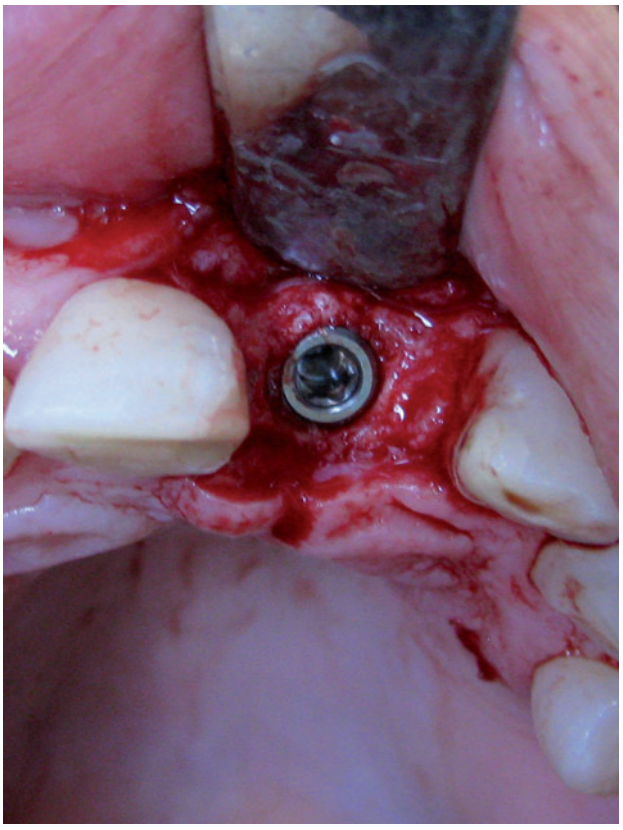

Figure 2 Clinical features after implant placement.

The provisional composite crown was placed directly after the surgical procedure, and was excluded from the occlusion and splinted with the neighboring teeth. The final metal-ceramic crowns were made and cemented on standard abutments 6 months after the implant procedure (Figure 3). Implantlink Semi (Detax GmbH, Ettllingen, Germany) was used for cementation purposes.

Clinical and radiological examination

Before the study procedures, the biotype of the periodontium (thin, thick) and the HKT, measured at the center of the

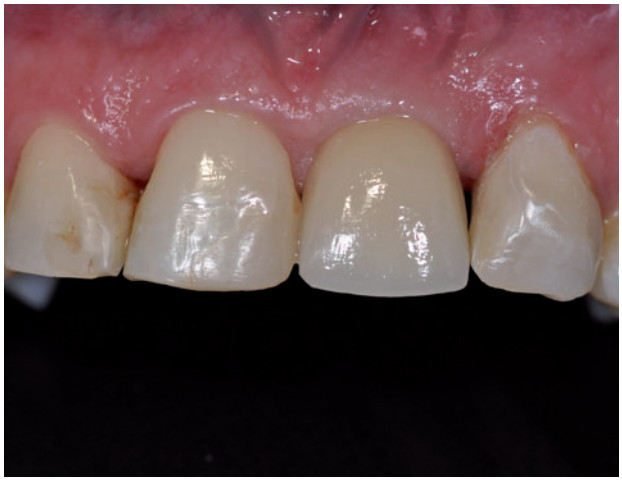

Figure 3 Clinical features after final restoration with a metal-ceramic crown.

missing tooth in a straight line from the top of the alveolar ridge up to the mucogingival junction by using a Williams periodontometer calibrated every 1 mm, were assessed. The HKT was also measured 1 and 6 months after implantation in the central part of the inserted implants.

In addition, the depth of the periodontal pocket around the implant was estimated at four measuring points (m, mesial; b, buccal; d, distal; 1, palatal or lingual) 1 and 6 months after surgery.

To assess the osseointegration of the implant, the clinical-radiological method was employed for every patient. PS was measured by insertion torque (IT) values and RFA with an Ostell Mentor. Ostell Mentor is a wireless device and makes use of an aluminum peg attached to the implant. The "smart peg" is excited, and the RFA is expressed electromagnetically in implant stability quotient (ISQ) units. RFA is extensively used in clinical research to monitor implant stability. In other words, it determines the stiffness of the bone-implant complex in the maxilla and mandible, and the ISQ values vary from 1 to 100. To assess secondary stability, ultrasonic tests were used exclusively.

Each patient underwent computed tomography (Kodak 9000 3D; Carestream Health, Toronto, Canada), and X-rays were taken using radiovisiography (RVG) to obtain extraoral images (Visualixe HD; Gendex, Danaher Corporation, Washington, DC, USA) in a system 0 (before surgery) and 1–6 months after surgery, during which the behavior of the buccal bone and the degree of implant osseointegration were assessed. RVG projections were made using a collimator narrowing the radiation beam and target rings with guides and bite blocks (right-angle digital sensor holders, Rinn XCP-DS; Dentsply Rinn Company, Elgin, IL, USA). These images were imported in the form of graphic files (in JPEG format – Joint Photographers Export Group), archived, and evaluated using Gendex software for analyzing and processing X-rays. The following were subjected to radiological assessment: 1. The initial width of the alveolar ridge in a transsectoral projection at three measuring points, i.e., a) at the crest of the ridge, b) at its midway point, and c) at its base, based on computed tomography. 2. Marginal alveolar bone loss (MBL, in mm) – measured as the distance between the implant platform and the crestal bone level by using RVG. The measurements were made on the mesial and distal side for every implant, and then the average was calculated for a given case. The buccal thickness of bone (BThB, in mm) was estimated using computed tomography on the buccal surface of the implant at three measuring points (a, top of the implant; b, the first large thread from the implant head; c, the head of the implant). The success of the implant treatment was assessed using the Albrektsson success criteria [2].

The research results were subjected to statistical analysis. The distribution type was checked for all study variables. When the distribution of the measurable parameters was normal, the Shapiro-Wilk test was used. For measurable data, the average and standard deviation were calculated (mean±SD); non-measurable data were expressed in amounts and percentages. The average (median) values for two groups of independent variables were compared using the Mann-Whitney test. The average (median) values for two groups of dependent variables were compared using the Wilcoxon test (paired samples). To assess the interdependence between two measurable variables, the Spearman coefficient was used (correlation coefficients: Spearman's ρ). Moreover, contingency tables were used to analyze the relationships between non-measurable coefficients (frequency table and χ^2-test or Fisher's exact test).

A value of $p<0.05$ was adopted as the level for statistically significant differences. For the purpose of statistical analysis, the STATISTICA 9.0 package (StatSoft, Inc., Tulsa, OK, USA) was used.

Results

A descriptive analysis of the study groups of patients and implants is included in Tables 1 and 2. The average age of the patients that underwent surgery was 36±8 years, without any significant differences between the groups. There were significantly more women in the study group (42%). The majority were non-smoking patients. TioLogic Ø 3.3 mm implants were placed in 8 patients (K0, 5 patients; K1, 3 patients), Ø 3.7 mm implants in 7 patients (K0, 4 patients; K1, 3 patients), and Ø 4.2 mm implants in 10 patients (K0, 1 patient; K1, 9 patients). In 23 cases, the implants were

Table 1 Description of the study groups of patients and implants.

Diameter of implants (mm)	K0, no. of implants	K1, no. of implants
3.3	5	3
3.7	4	3
4.2	1	9
Location of implants		
Maxilla	9	14
Mandible	1	1

K0, ultrasonic preparation; K1, classic preparation.

Table 2 Intra- and inter-group analysis of the effectiveness of the implant procedure using traditional (K1) and ultrasonic preparation observed 1 (1M) and 6 months (6M) after the insertion.

	Total (n=25)	K0 (n=10)	K1 (n=15)	Test K0 vs. K1
Age	36±8	36±11	35±5	0.831
Female	10 (42%)	7 (70%)	3 (21%)	0.050
Smoking	2 (8%)	0 (0%)	2 (14%)	0.618
B	18 (75%)	6 (60%)	12 (86%)	0.339
HKT 1M	3.5±0.5	3.8±0.6	3.2±0.3	0.014
HKT 6M	3.4±0.8	3.8±0.5	3.0±0.9	0.022
IA	7 (29%)	4 (40%)	3 (21%)	0.595
BA	7 (29%)	2 (20%)	5 (36%)	0.704
PS-ISQ	70±4	70±4	71±4	0.681
PS- IT	39±3	38±3	41±3	0.028
SS-ISQ	71±2	70±2	72±3	0.139
MBL 1M	0.1±0.2	0.1±0.3	0.0±0.0	0.412
MBL 6M	0.6±1.0	0.5±0.4	0.8±1.3	0.838
BThB a 1M	2.6±1.4	2.3±0.8	2.9±1.8	0.558
BThB b 1M	1.6±0.6	1.4±0.6	1.6±0.6	0.364
BThB c 1M	1.5±0.6	1.2±0.4	1.6±0.7	0.095
BThB a 6M	2.7±1.4	2.4±0.8	2.9±1.8	0.747
BThB b 6M	1.5±0.8	1.4±0.7	1.6±0.8	0.488
BThB c 6M	1.5±0.8	1.2±0.6	1.7±0.8	0.024

B, gingival biotype; 1, thick; 0, thin; HKT, height of keratinized tissue (measured in mm); IA, implant angulation; BA, bone augmentation; PS-ISQ, primary stability-implant stability quotient; PS-IT, primary stability-insertion torque; SS-ISQ, secondary stability-implant stability quotient; MBL, marginal bone loss; BThB, buccal thickness of bone at three measurement points (a, apex of implant; b, first thread from implant head; c, implant head) measured in millimeters (mm).

placed in the maxilla (K0, 10 patients; K1, 13 patients), and in 2 cases in the mandible (K0, 1 patient; K1, 1 patient).

A descriptive analysis of the clinical-radiological parameters based on intra- and inter-group comparisons is presented in Table 2. The average radiological width of the alveolar process in a transsectoral profile is presented in Table 3. No significant differences between the groups were identified. The highest value at all measuring points was noted in group K1. The lowest value in the region of the base of the alveolar ridge amounted to 7.8±1.9 mm, and in the region of the ridge crest it was 5.1±1.1 mm. Augmentation of the marginal bone was performed in seven cases, i.e., in 29% of the study group. Augmentation of the marginal bone was performed more frequently on patients in group K1 than on patients in group K0.

Table 3 Descriptive analysis of the initial width of the alveolar ridge in a transverse section, with a division into two groups depending on the bed preparation method.

	Total (n=24)	K0 (n=10)	K1 (n=14)	Test K0 vs. K1
BV a (mm)	8.7±2.4	7.8±1.9	9.3±2.7	0.161
BV b (mm)	7.3±1.9	6.6±1.5	7.8±2.2	0.167
BV c (mm)	5.3±1.5	5.1±1.1	5.5±1.8	0.545

K0, ultrasonic method; K1, classic method; BV, initial width of alveolar ridge in a transverse section at three measuring points.

The average MBL in the study group as a whole amounted to 0.1±0.2 mm at 1 month after the procedure and to 0.6±1.0 mm after 6 months. When the groups were compared, the MBL 6 months after the procedure was 0.8±1.3 mm for group K1 and 0.5±0.4 mm for group K0. No significant differences were noted between the groups, with slightly greater MBL noted after 6 months in the K1 group when using dental burs. Moreover, the angularity of the abutment had no effect on the marginal bone around the implant.

A significantly thicker bone plate was noted in the transsectoral cross section 6 months after the operation in the area around the implant head in the group for which the osseous bed was prepared in the traditional way (Table 3). Moreover, a positive correlation was observed between BThB at the height of the implant top and MBL when observed after 6 months (Table 4, Figure 4).

The average primary ISQ value was 70±4 for all the study patients, 70±4 for group K0, and 71±4 for group K1. The average secondary ISQ value amounted to 71±2 for all groups 6 months after the operation, including 70±2 for group K0 and 72±3 for group K1. The average PS measured by the IT value was 39±3 for all the study patients and was significantly higher in the control group (K1), i.e., 41±3. A significant correlation was demonstrated between the PS of the implant measured by the IT value and the MBL around the implant 1 month after the operation (Table 5, Figure 5).

No significant correlation was noted between the thickness of the buccal bone after 1 and 6 months and the secondary ISQ value (Table 4). The procedure was 100% effective in group K0 according to the Albrektsson [2] criteria 1 year after the implant procedure, while one implant was lost in group K1 (implantation success, 93.3%).

Discussion

The high average success rate of 96% achieved after immediate implantation for all patients 1 year after the operation (K0, 100%; K1, 93.3%) is comparable with the results of other authors, e.g., den Hartog et al. [4, 5], who reported a similar success rate of 96.8% in a 1-year observation period. It appears that the key to success in implantation procedures in the aesthetic zone is to ensure that the right patients are selected for the procedure, that the PS is good, and that provisional crowns are excluded from occlusion. Augmentation of the bone at a height of 2–3 mm from the implant neck was carried out in only 29% of cases. These factors had a decisive impact on increasing the PS of the implants, which is especially important in cases of IL. To provide an objective assessment of PS, RFA [24] is especially recommended. The success of an implant procedure with IL with an ISQ Ostell value of 70±4, as presented in the present work, confirms the recommendations of other authors regarding the use of this loading method in cases where the measuring value is >60 [18]. Ensuring the proper implant structure by using a small cervical thread and the correct geometry of the implant

Table 4 Matrix of coefficients of the correlations between MBL and BThB, SSO and BThB after 1 and 6 months.

	BThB a 1M (mm)	BThB b 1M (mm)	BThB c 1M (mm)
MBL 1M (mm)	r=0.064	r=0.049	r=-0.240
	p=0.766	p=0.818	p=0.260
	BThB a 6M (mm)	BThB b 6M (mm)	BThB c 6M (mm)
MBL 6M (mm)	r=0.681*	r=0.332	r=0.295
	p=0.0003*	p=0.121	p=0.162
	BThB a 1M (mm)	BThB b 1M (mm)	BThB c 1M (mm)
SS-ISQ	r=0.294	r=0.233	r=0.171
	p=0.163	p=0.274	p=0.424
	BThB a 6M (mm)	BThB b 6M (mm)	BThB c 6M (mm)
SS-ISQ	r=0.305	r=0.231	r=0.149
	p=0.147	p=0.289	p=0.486

*Statistically significant. MBL, marginal bone loss; BThB, buccal thickness of bone; SS-ISQ, secondary stability-implant stability quotient.

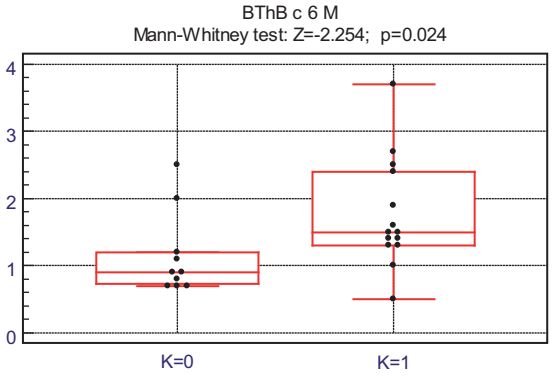

Figure 4 Graphic presentation of bone plate thickness values on the buccal side in the region of the implant head observed after 6 months, based on a division into two study groups.

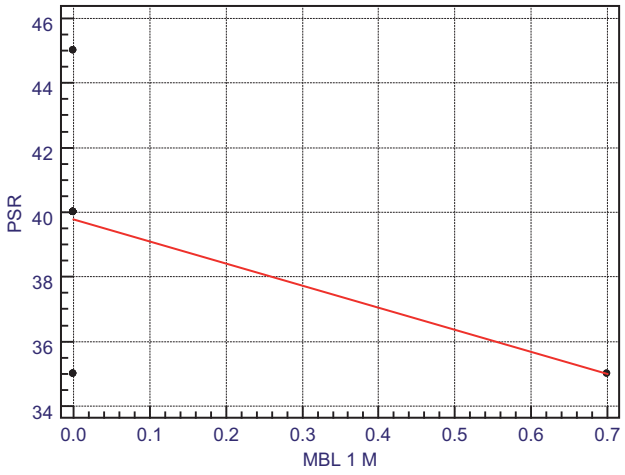

Figure 5 Graphic presentation of the correlation between the primary stability of implant measured on a ratchet (PSR) and marginal bone loss (MBL) observed after 1 month.

allows for a more physiological distribution of forces during the healing process and bone remodeling, which results in reduced MBL. The tioLogic implants used in this study, which possess a thick and small cervical thread and a rounded apex, and which had been designed with the help of the mechanical event simulation (MES) analysis (finite elements method), meet these requirements and make an even distribution of forces without harmful overloading possible [23]. The average MBL of 0.6±1.0 mm noted in the present study for all groups after 6 months is comparable with the study results of other authors that used implants with appropriate micro- and macrostructures [9, 23]. When older implant systems were used in a two-stage procedure, the average MBL ranged between 1.5 and 2 mm [14, 22]. Moreover, the positive correlation noted in the present study between the MBL around the implant 1 month after the procedure and a high PS value is confirmed by a study carried out by Blanco et al. [3] with an animal model. These studies showed that low PS resulted in a lower level of osseointegration up to 4 weeks after the implant procedure. Moreover, a good PS may be achieved not only through the correct micro- and macrostructures of the implant [1] but also through proper procedures of implant bed preparation. Ultrasonic preparation is a delicate, atraumatic method that makes it possible to achieve high PS, which is especially important for

Table 5 Matrix of coefficients of the correlations between MBL and BThB, SSO and BThB after 1 and 6 months.

	MBL 1M			MBL 6M		
	K0 (n=10)	K1 (n=14)	Total (n=24)	K0 (n=10)	K1 (n=14)	Total (n=24)
PS-ISQ	r=0.570	r=0.000	r=0.312	r=0.335	r=0.280	r=0.268
	p=0.085	p=1.000	p=0.138	p=0.344	p=0.332	p=0.205
PS-IT	r=-0.500	r=0.000	r=-0.440	r=0.057	r=-0.162	r=-0.013
	p=0.141	p=1.000	p=0.031	p=0.876	p=0.580	p=0.950
SS-ISQ	r=0.315	r=0.000	r=0.026	r=0.221	r=0.075	r=0.131
	p=0.375	p=1.000	p=0.904	p=0.539	p=0.800	p=0.540

K0, ultrasonic preparation; K1, classic preparation; PS-ISQ, primary stability-implant stability quotient; PS-IT, primary stability-insertion torque; SS-ISQ, secondary stability-implant stability quotient; MBL, marginal bone loss.

the implant procedure in the case of "soft" bone (types III and IV according to Lekholmet al. [17]) combined with IL. Histomorphological tests on an animal model [3] confirmed that the degree of early osseointegration (2 weeks after the procedure) is closely correlated with PS during the procedure and is slower in the case of low PS. Simultaneously, piezoelectric technology, when applied properly, results in a higher level of osseogenesis in patients compared with the classic preparation method using burs [6]. It is especially important to observe a preparation protocol that ensures a high level of cooling (the critical value is 20 ml/min), owing to the higher risk of the bone overheating compared with the classic method [21]. It was thus shown that ultrasonic preparation using implants with a porous surface results in faster osseointegration combined with a higher number of osteoblasts, and at the same time reduced inflammation in comparison with the classic preparation method [19]. This appears to be confirmed by the present study, which indicated similar levels of effectiveness for an implant procedure using both bed preparation methods, but with a fractionally lower level of MBL after 6 months in the case of the ultrasonic method (K0 0.5±0.4 mm vs. K1 0.8±1.3 mm).

Moreover, the platform processing employed in tioLogic implants, which takes into account the biological width and features a small cervical thread, reduces possible complications in the form of gingival recession around the implants by maintaining a high level of marginal bone around the neighboring teeth, a fact that has also been confirmed by the present study. Achieving a positive aesthetic effect, with regard to the level of the gingival papilla, also depends on using the correct type and shape of the temporary crown supporting the architecture of the soft tissue during the healing process [19].

Conclusions

Inserting implants with the correct geometry and appropriate micro- and macrostructures results in reduced MBL, and a high PS helps reduce MBL. The procedure can be highly effective both when using ultrasonic technology and in the case of conventional methods, when all procedures are properly performed. Simultaneously, it is important that the operator has the appropriate theoretical knowledge and extensive experience with regard to the complex surgical-prosthetic procedure involved, which could give rise to errors during the course of the operation.

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