Marginal Bone Loss and Pink Esthetic Evaluation of Narrow-Diameter Dental Implants for Single Crowns: 1-Year Prospective Clinical Study

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Purpose: The aims of this study were: *(1)* to quantify the marginal bone loss (MBL) of 3.3-mm narrow-diameter, bone-level, titanium-zirconia (Ti-Zr) implants with two different surfaces in single restorations after a 1-year follow-up; *(2)* to analyze the combinations of different variables that may influence MBL; and *(3)* to record the Pink Esthetic Score (PES) value and its correlation with MBL. ***Materials and Methods:*** This is a prospective longitudinal clinical study with a 1-year follow-up after crown placement. Two different implant surfaces (sandblasted acid-etched and modified sandblasted acid-etched) were used. All bone-level and bone level–tapered implants had a diameter of 3.3 mm. Different healing and prosthetic abutments were used. Clinical, radiographic, and photographic records were taken 6 months and 1 year after placement of the restorations, and the survival rate, MBL, PES, clinical parameters, and biologic and/or mechanical complications were assessed. The correlations between the variables and MBL were verified. ***Results:*** A total of 30 narrow-diameter implants were placed in 30 patients; 18 implants had a sandblasted acid-etched surface, and 12 implants had a modified sandblasted acid-etched surface. The measured MBL at 1 year after implant function had a mean value of –0.36 mm, ranging from 0 mm to –1.77 mm. There was no implant loss. A statistically significant relationship was observed between implant shape (design and length), implant placement level, healing abutment, prosthetic abutment size, gingival thickness, and MBL. The mean PES values recorded at the beginning and end of the study were 7.58 and 11.37, respectively. ***Conclusion:*** Narrow-diameter implants showed reduced MBL values, with the surrounding tissues remaining stable after 1 year of follow-up. The MBL did not show different values on two implant surfaces. MBL does not seem to influence esthetic outcome. *Int J Oral Maxillofac Implants 2022;37:515–524.* doi: 10.11607/jomi.9051

Keywords: dental implants, marginal bone loss, narrow-diameter implants, pink esthetic score

The availability of bone in edentulous areas, both in quantity and quality, is a very important factor for the stability of implant treatments, as it has a direct influence on the treatment plan, namely on the choice of implant.[1]

The stability of the marginal, or crestal, bone around an implant plays a major role in its longevity and the esthetic results of treatment. The marginal bone forms the basis for the supracrestal soft tissues around implants, influencing the final position of the papilla and the harmony among the new restoration, the remaining teeth, and the surrounding soft tissues. Marginal bone loss (MBL) around implants is one of the most important success criteria and has been reported to be influenced by implant diameter and implant design.[2]

The use of regular-diameter implants may be hindered in situations where the spaces between adjacent teeth and implants are very small, justifying the use of narrow-diameter implants (NDIs).[3] According to the 2018 ITI Consensus Group 1, NDIs are defined as having a diameter of 3.5 mm or less.[4] Some authors have described that NDIs are indicated for: narrow bone ridges; cases with a reduced amount of interradicular bone; rehabilitation of teeth with reduced mesiodistal prosthetic space; and rehabilitation of teeth with a small cervical diameter with an ideally narrow emergence profile, such as incisors.[5] Some studies have shown that these implants have the potential to preserve peri-implant tissues in the long term and to decrease the need for more invasive surgery, improving the

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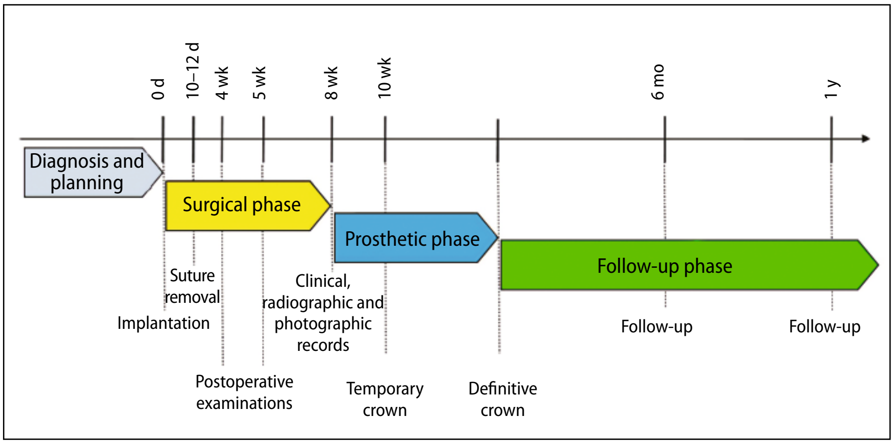

Fig 1 Timeline of interventions and follow-up visits.

prognosis, decreasing the time of surgical intervention and associated costs, and decreasing the morbidity or risk of complications.[6–9]

In vitro studies and finite element analyses have shown that stress values affecting the crestal bone are inversely proportional to the implant diameter, meaning that smaller NDIs result in a disadvantage in load distribution at the bone-implant interface.[10,11] The forces resulting from occlusal activity may lead to mechanical complications, such as fracture of the implants or their components and their restorations.[8,12] According to some authors, NDIs made of pure titanium (Ti) are more subject to fatigue fracture as a result of the smaller diameter.[13] New Ti alloys have been developed to improve the mechanical properties of implants not only in order to decrease the risk of fracture, but also to increase the indications, especially for NDIs, in sites with limited bone volume.[8] In the last decade, an alloy consisting of 83% to 87% Ti and 13% to 17% zirconium (Ti-Zr) has appeared that shows an increase in fatigue resistance by about 40% and better biocompatibility compared to pure Ti implants.[14,15]

It is important to promote studies that analyze and combine the different variables that may influence MBL and other success criteria around NDIs, especially prospective studies with long follow-up times. It is also important to clarify whether satisfactory esthetic results and soft tissue stability around NDIs can be achieved.

Therefore, the main aim of this study was to quantify MBL in narrow-diameter (3.3 mm), bone-level, and bone level–tapered Ti-Zr implants with sandblasted acid-etched and modified sandblasted acid-etched surfaces in single restorations after a 1-year follow-up and to identity possible biologic and/or mechanical complications. Secondary aims were to analyze the combinations of different variables that may influence MBL, to assess the survival and success rates of NDIs, and to assess the Pink Esthetic Score (PES)[16] as well as to verify whether it is influenced by MBL.

MATERIALS AND METHODS

Study Design

This was a prospective longitudinal clinical study with a 1-year follow-up after loading.

A sample of participants from the study center (Braga, Portugal) was selected for this study, which ran from July 1, 2017, to July 31, 2019. Patients were informed about all steps of the study and signed an informed consent according to the Helsinki Declaration developed by the World Medical Association. This research was approved by the Bioethics Committee of the University of Santiago de Compostela.

For each participant, the treatment sequence was divided into four phases: *(1)* diagnosis and planning phase; *(2)* surgical phase; *(3)* prosthetic phase; and *(4)* follow-up phase. Figure 1 shows the schedule of interventions and follow-up appointments.

Study Participants

The targeted population of the study included patients with single edentulous spaces with an indication for rehabilitation by a dental implant and screw-retained crown. Sample selection took into consideration the following inclusion criteria: age 18 years or older; no active periodontal disease[17]; presence of a natural tooth mesial and distal to the edentulous area; adequate amount of bone to receive an NDI; type II or III bone according to the Lekholm & Zarb classification[18]; obtaining primary stability during the surgical phase; and in whom immediate or early loading was not necessary.

The exclusion criteria applied were: clinical history contraindicating the performance of any oral implantology technique; smoker; full-mouth plaque score[19] or full-mouth bleeding score[20] > 25%; presence of local infection; and/or patients with systemic disease and/or on chronic pharmacologic treatment.

Treatment

All surgical interventions were performed by the same surgeon under the same technical and aseptic conditions. Clinical measurements were performed by the same observer (M.A.G.) under the same conditions.

The bone crest was measured three-dimensionally in thickness, width, and height. Patients with at least 5.3 mm of bone in the buccolingual direction and 6.3 mm of bone in the mesiodistal direction were included in the study. Using paraxial computerized tomography images, measurements of the horizontal dimension (thickness) were recorded at the most coronal point of the ridge and every 2 mm in the apical direction at 2, 4, 6, 8, 10, and 12 mm after the first measured point. Implant placement was planned following the type 2, type 3, and type 4 procedure,[21] with a one-stage nonsubmerged technique and a conventional loading protocol.[22]

NDIs with sandblasted acid-etched (SLA) and modified sandblasted acid-etched (SLActive) surfaces were randomly used. All bone-level and bone level–tapered (Straumann) implants had a diameter of 3.3 mm, and the design and length were decided by the surgeon. In the coronoapical direction, the implant platform was positioned approximately 3.0 mm apical to the mid-vestibular mucosa margin of the future implant crown. In the buccolingual direction, the implant shoulder was positioned approximately 1 to 1.5 mm palatally to the prosthetic emergence point. Implant stability was checked using resonance frequency analysis. A transgingival healing abutment was placed in a nonsubmerged manner immediately after implant placement. Dehiscence, fenestration, or other small intraosseous defects, with a coronoapical dimension of < 2 mm, were grafted with particulate deproteinized bovine bone (Bio-Oss, Geistlich) and covered with a collagen membrane (GBR Membrane, Straumann).

Eight weeks after implant placement, the healing abutment was removed for the first time for impressions, and the resonance frequency analysis was checked. The healing abutment was removed a second time before restoration placement, and the screw-retained acrylic resin provisional restoration, using a provisional abutment directly connected to the implant, was placed with occlusal contact. Between 1 and 2 months after provisional restauration placement, the definitive prosthetic abutments were used. The final cobalt-chromium (Co-Cr) alloy metal-ceramic restoration was fabricated in all patients and screwed to the implant.

Clinical, Radiographic, and Photographic Examinations

At 6 months and 1 year after the implants were placed in function, the clinical, radiographic, and photographic follow-up visits were performed. Different clinical parameters were recorded: presence of the implant; mechanical probing to record the probing pocket depth (PPD); modified Plaque Index (mPI) and modified Sulcus Bleeding Index (mSBI)[23]; and presence of biologic and/or mechanical complications.

X-ray sensor positioners with individualized holders were used, and the sensor (RVG 6100, Carestream) was placed parallel to the implant axis with the cone of the radiographic apparatus (CS 2200, Carestream Dental) perpendicular to the sensor. The radiographic measurements were all taken by an independent observer on the same day under the same magnification conditions and repeated after 1 week. The final value was the average of the two values recorded. The photographs were always taken with the same equipment, under the same technical and lighting conditions, and were analyzed on the same day, by the same observer.

Outcomes

The outcomes of the study were:

- Survival rate, which is the percentage of implants that remain in the mouth 1 year after loading.
- MBL, where the level of peri-implant marginal bone was recorded and quantified by radiographic analysis immediately after implant placement (MBL_0); after the osseointegration period (MBL_0_1); from implant placement to 6 months after loading (MBL_0_2); and from implant placement to 1 year after loading (MBL_0_3). Using the chamfer 0.2 mm above the implant neck as reference, the value was obtained by measuring the distance in millimeters (0.01 mm) between this most coronal point of the implant neck and the first bone-implant contact point, mesially and distally, using measurement software (ImageJ 1.51J8, NIH). The MBL takes on a value of 0 when the marginal bone is located coronal to or in the same vertical plane as the implant neck and takes on negative values when the bone is located apical to the implant neck, with the maximum negative value corresponding to the implant length. The MBL value was calculated by averaging the records obtained mesially and distally. Each recorded value at each time point is considered to correspond to the accumulated MBL value from implant placement to the day of recording.
- The seven parameters for PES[16] were recorded from photographs taken before surgery (PES_i); on the day of loading (PES_1); 6 months after loading (PES_2); and 1 year after loading (PES_3). A 0-1-2 rating system was used for each parameter, with 0 being the lowest value and 2 being the highest value.

Statistical Methods

To characterize the study population, descriptive statistics were used for each of the study variables: *(1)*

Table 1 Descriptive Statistics of the Categorical Variables

Categorical variables	N	%
Gender		
Male	7	23.3
Female	23	76.7
Age, y		
18–30	5	16.7
31–40	10	33.3
41–50	7	23.3
51–60	4	13.3
61–80	4	13.3
Anatomical zone		
13–23	13	43.3
14–15 or 24–25	13	43.3
16–17 or 26–27	2	6.7
33–43	0	0
34–35 or 44–45	1	3.3
36–37 or 46–47	1	3.3
Cause		
Agenesis	3	10.0
Inclusion	2	6.7
Caries	5	16.7
Periodontal	7	23.3
Unknown	13	43.3
Design length		
BL 10	8	26.7
BL 12	17	56.7
BL 14	2	6.7
BLT 10	1	3.3
BLT 12	2	6.7
Surface		
SLA	18	60.0
SLActive	12	40.0
Healing abutment		
024.2222S	12	40.0
024.2224S	5	16.7
024.2244S	12	40.0
024.2246S	1	3.3
GBR		
0 (No)	15	50.0
1 (Yes)	15	50.0
Temporary crown		
0 (No)	21	70.0
1 (Yes)	9	30.0
Abutment		
Variobase 1 mm	5	16.7
Cares 0.5 mm	3	10.0
Cares 1 mm	3	10.0
Cares 1.5 mm	3	10.0
Cares 2 mm	2	6.7
Cares 2.5 mm	1	3.3
Alkom 0.5 mm	5	16.7
Alkom 1 mm	6	20.0
Alkom 1.5 mm	1	3.3
Alkom 2.5 mm	1	3.3

The following variables were studied: gender; age; anatomical zone of implant placement (FDI classification); cause of tooth absence (agenesis, dental inclusion, exodontia due to tooth decay, exodontia due to periodontal causes, or unknown cause); implant shape (bone level [BL] or bone level tapered [BLT]) and length (10, 12, and 14 mm); sandblasted acid-etched (SLA) and modified sandblasted acid-etched (SLActive) surface; healing abutment used (024.2222S, 024.2224S, 024.2244S, or 024.2246S); performance of guided bone regeneration (GBR); temporary crown placement; prosthetic abutment shape and size (Variobase, Cares, or Alkom 0.5–2.5 mm).

minimum, first quartile, median, mean, third quartile, and maximum were used for continuous or integer variables; and *(2)* frequency (count) and percentage (proportion) were used for categorical variables (factors). Normality of the variable's distribution was assessed with Shapiro-Wilk test. To assess the correlation between two numeric variables, Spearman correlation coefficient (R*s*) was used, and to assess the correlation between a categorical independent variable and a numeric dependent variable, the simple linear correlation coefficient (*R*) was used. Bivariate linear regressions (unadjusted) were performed between each of the potential factors (independent variables) and each of the outcome variables of interest (dependent variables). Multivariate linear regressions were also performed to investigate the combined influence of several covariates (independent variables) on MBL. The covariates used in the multivariate models were selected based on prior knowledge. For each of the multivariate models, in addition to the coefficients and respective 95% CI, the adjusted R^2, and the Akaike information criterion (AIC), the relative importance of each dependent variable in each model was also estimated. To ensure compliance with the assumptions of multivariate linear regression, collinearity was assessed using the variance inflation factor (VIF), and a global diagnosis of model assumptions was performed, including global assumptions, asymmetry, kurtosis, and heteroscedasticity. Statistical analysis was performed with RStudio software, version 1.1.463. The level of statistical significance was set at .05 unless otherwise stated.

RESULTS

Participants

A total of 30 patients were included, in whom 30 implants were placed. Eighteen implants with SLA surfaces (60%) and 12 implants with SLActive surfaces (40%) were placed. All patients included in the study fulfilled all follow-up phases.

Descriptive Analysis

Tables 1 and 2 show the distribution of the values obtained for each categorical and continuous variable, respectively.

The study participants were predominantly female, and the mean age was 43.5 years. The distribution of implants by anatomical area resulted in a predominance of the maxillary incisor and canine and the maxillary premolar sectors, and the main cause of tooth loss was unknown, followed by exodontia due to periodontal causes. The mean vertical gingival thickness of the sample was 2.79 mm (range: 2.0 to 3.5 mm).

Table 2 Descriptive Statistics of the Continuous Variables

Continuous variables	Minimum	1st quartile	Median	Mean	3rd quartile	Maximum
Gingival thickness (mm)	2.00	2.50	2.80	2.79	3.00	3.50
FMPS (%)	0	10	10	11	15	20
FMBS (%)	0	0	0	2	5	5
Level (mm)	0.14	0.49	0.71	0.78	0.90	1.99
RFA_0 (0–100)	55	63	65	67	68	82
RFA_1 (0–100)	68	72	74	74	77	82

The following variables were studied: gingival thickness; full-mouth plaque index (FMPS); full-mouth bleeding index (FMBS); level of implant placement in the vertical plane; resonance frequency analysis on the day of implant placement (RFA_0); and resonance frequency analysis on the day of loading (RFA_1).

Table 3 Descriptive Statistics of the MBL Values (in mm) at the Different Time Intervals Recorded

MBL	Minimum	1st quartile	Median	Mean	3rd quartile	Maximum
MBL_0	0.00	0.00	0.00	0.00	0.00	0.00
MBL_0_1	–1.33	–0.07	0.00	–0.14	0.00	0.00
MBL_0_2	–1.50	–0.27	–0.07	–0.27	0.00	0.00
MBL_0_3	–1.77	–0.53	–0.17	–0.36	0.00	0.00
MBL_1_2	–0.80	–0.17	–0.05	–0.13	0.00	0.01
MBL_1_3	–0.81	–0.38	–0.15	–0.22	0.00	0.01
MBL_2_3	–0.47	–0.14	–0.03	–0.09	0.00	0.00

Values were recorded immediately after implant placement (MBL_0); after the osseointegration period (MBL_0_1); implant placement to 6 months after loading (MBL_0_2); implant placement to 1 year after loading (MBL_0_3); the first 6 months after loading (MBL_1_2); the first year after loading (MBL_1_3); and the last 6 months of the follow-up period (MBL_2_3).

More than half of the implants placed were of the bone-level design, with a length of 12 mm. All implants were submerged and had their necks surrounded by bone. The neck of the implants was located on average 0.78 mm below the most coronal point of the bone crest. Mainly 2-mm– and 4-mm–high healing abutments were used. Guided bone regeneration was performed in 15 patients. Temporary crowns were placed in 9 of the 30 patients. Alkom (Alkom Digital) custom prosthetic abutments with 0.5-mm and 1-mm height and Variobase (Institut Straumann) prefabricated 1-mm height were most often used.

The mean implant stability quotient (ISQ) obtained at implant placement was 67 and increased to 74 at loading.

Survival Rate, MBL, PES, Clinical Parameters, and Complications

No implant loss was recorded; thus, a 100% survival rate was determined (n = 30).

Table 3 shows the mean, median, and quartile distribution of the values obtained for MBL in the different time intervals recorded. The measured MBL at 1 year after loading ranged from 0 to –1.77 mm, with a mean value of –0.36 mm. It was found that during the osseointegration period, the mean MBL was –0.14 mm; in the first 6 months after loading, the MBL was higher than in the second 6 months. In 23.33% of the implants placed, an MBL of 0 was recorded at 1 year after loading.

Table 4 shows the mean, median, and quartile distribution of the values obtained for PES in the different time intervals recorded. The mean value obtained at the beginning of the study was 7.58, ranging from 4 to 12. There was a positive evolution, as the value was 11.37 1 year after implant placement in function.

The mean probing depth in the sulcus was 2.93 mm after 1 year. There was no statistically significant variation between 6 months and 1 year. The mean mPI recorded was 0.5 and 0.6 after 6 months and 1 year, respectively. The mean mSBI obtained a value of 0.3 after 6 months and 1 year.

One biologic complication, classified as mucositis, was observed in one patient, with an mSBI of 1 recorded at the 6-month and 1-year follow-ups. No other biologic and/or mechanical complications were observed.

Correlation Between Different Variables and MBL

The linear correlation between MBL and PES at the different time intervals was recorded. The correlations were very low for all intervals and not statistically significant ($P > .05$).

Table 5 shows the linear correlation between MBL and different variables. A strong and statistically significant ($P < .01$) positive correlation was found between implant shape (design and length) and MBL as well

Table 4 Descriptive Statistics of the Pink Esthetic Score (PES) Values

PES	Minimum	1st quartile	Median	Mean	3rd quartile	Maximum
PES_i	4	6	8	7.58	9	12
PES_1	4	7	8	8.37	10	11
PES_2	6	10	11	11.13	12	14
PES_3	6	10	12	11.37	13	14

Values were recorded before implant placement (PES_i), on the day of loading (PES_1), and 6 months (PES_2) and 1 year (PES_3) after loading.

Table 5 Linear Correlation Between Different Variables and Marginal Bone Loss

	MBL_0_1		MBL_0_2		MBL_0_3		MBL_1_2		MBL_1_3		MBL_2_3	
	Correlation coefficient	*P*	Correlation coefficient	*P*	Correlation coefficient	*P*	Correlation coefficient	*P*	Correlation coefficient	*P*	Correlation coefficient	*P*
Gender	0.006	.973	0.113	.553	0.084	.659	0.228	.225	0.150	.430	0.081	.672
Age	0.366	.443	0.349	.497	0.378	.405	0.264	.758	0.353	.484	0.428	.263
Anatomical zone	0.379	.401	0.378	.406	0.340	.526	0.275	.728	0.198	.903	0.094	.994
Cause of absence	0.339	.531	0.386	.382	0.405	.324	0.343	.518	0.363	.452	0.440	.232
Gingival thickness	−0.182	.125	−0.061	.208	0.071	.361	0.012	.911	0.131	.865	0.206	.335
FMPS	0.157	.383	0.054	.571	0.075	.702	0.089	.722	0.074	.718	0.000	.578
FMBS	0.233	.286	0.283	.211	0.303	.131	0.320	.305	0.327	.136	0.208	.193
Shape	0.259	.771	0.481	.145	0.465	.177	**.760**	**< .01**	**0.657**	**< .01**	0215	.874
Surface	0.024	.901	0.098	.605	0.062	.744	0.172	.363	0.087	.647	0.114	.548
Level	0.399	.111	0.527	.043	0.538	.017	0.398	.068	**0.467**	**.014**	0.471	.068
RFA_0	0.249	.588	0.241	.322	0.244	.226	0.170	.202	0.231	.108	0.211	.268
Healing abutment	0.418	.164	0.511	.045	0.547	.024	0.503	.051	**0.534**	**.030**	**0.303**	**.046**
GBR	0.093	.623	0.059	.755	0.005	.978	0.015	.936	0.127	.505	0.235	.211
RFA_1	0.066	.924	0.192	.548	0.230	.464	0.201	.151	0.264	.129	0.217	.129
Temporary crown	–	–	0.171	.366	0.177	.350	0.141	.458	0.083	.663	0.069	.718
Abutment shape	–	–	0.113	.840	0.125	.809	0.191	.606	0.204	.563	0.096	.882
Abutment size	–	–	**0.345**	**.061**	**0.420**	**.020**	0.317	.088	**0.448**	**.012**	0.386	**.035**
PPD_2	–	–	0.124	.907	0.122	.689	−0.09	.231	−0.065	.668	0.209	.251
mPI_2	–	–	0.218	.517	0.161	.701	0.290	.306	0.179	.643	0.176	.655
mSBI_2	–	–	0.327	.218	0.355	.161	0.191	.606	0.267	.369	0.227	.491
PPD_3	–	–	–	–	0.063	.745	–	–	−0.153	.311	0.030	.686
mPI_3	–	–	–	–	0.289	.308	–	–	0.246	.430	0.206	.556
mSBI_3	–	–	–	–	0.200	.577	–	–	0.368	.141	0.266	.372

The following variables were studied: gender; age; zone of implant placement (FDI classification); cause of tooth absence (agenesis, dental inclusion, exodontia due to tooth decay, exodontia due to periodontal causes, or unknown cause); gingival thickness (in mm); full-mouth plaque index (FMPS); full-mouth bleeding index (FMBS); implant shape (bone level [BL] or bone level tapered [BLT]) and length (10, 12, or 14 mm); implant sandblasted acid-etched (SLA) and modified sandblasted acid-etched (SLActive) surface; level of implant placement in the vertical plane; resonance frequency analysis on the day of implant placement (RFA_0); healing abutment used (024.2222S, 024.2224S, 024.2244S, or 024. 2246S); guided bone regeneration (GBR); resonance frequency analysis on the day of loading (RFA_1); temporary crown placement; prosthetic abutment shape (Variobase, Cares, or Alkom); prosthetic abutment size (0.5–2.5 mm); probing depth at 6 months (PPD_2) and 1 year (PPD_3); modified Plaque Index at 6 months (mPI_2) and 1 year (mPI_3); and modified Sulcus Bleeding Index at 6 months (mSBI_2) and at 1 year (mSBI_3).
MBL values were recorded immediately after implant placement (MBL_0); after the osseointegration period (MBL_0_1); implant placement to 6 months after loading (MBL_0_2); implant placement to 1 year after loading (MBL_0_3); the first 6 months after loading (MBL_1_2); the first year after loading (MBL_1_3); and the last 6 months of the follow-up period (MBL_2_3).
Bolded values are statistically significant ($P < .05$).

Table 6 Summary of the Multivariate Model for Marginal Bone Loss at 1 Year (MBL_0_3)

Determinants	β (95% CI)	*P* (Wald test)	*P*	R^2 adjusted	AIC	Relative importance (%)
(Interception)	0.56 (−0.51, 1.62)	0.29	.006*	0.387	33.9	–
Gingival thickness	−0.41 (−0.81, 0.02)	0.04*	–	–	–	15
Level	0.34 (−0.06, 0.74)	0.09	–	–	–	23
Abutment size (ref: 0.5–1)			–	–	–	19
1.5–2.5	0.25 (−0.16, 0.66)	0.21	–	–	–	
Healing abutment						
(ref: 024.2222S)			–	–	–	44
024.2224S	−0.52 (−0.94, −0.11)	0.02*	–	–	–	
024.2244S	−0.01 (−0.39, 0.38)	0.98	–	–	–	
024.2246S	−0.19 (−1.15, 0.77)	0.69	–	–	–	

AIC = Akaike information criterion. *Statistically significant (*P* < .05).

as between implant placement level and MBL. The results show that MBL decreases as the implant is placed deeper, with lower MBL values obtained with bone-level implants. A strong positive correlation was also found between the healing abutment used and MBL. The results showed higher MBL when using the 4-mm–high healing cylindrical abutment (024.2224S). Moderate/strong positive correlations were found between prosthetic abutment size and MBL, with lower MBL observed in taller abutments. A moderate positive correlation was found between mSBI and MBL.

Table 6 shows the relative importance of the influence of different variables on MBL at 1 year after implant placement in function. In the multivariate analysis performed, a statistically significant relationship (*P* < .05) and a decreasing relative importance was observed between healing abutment, implant placement level, prosthetic abutment size used, gingival thickness, and MBL. The healing abutment used assumes the greatest relative importance in influencing MBL after 6 months and 1 year of follow-up.

DISCUSSION

MBL values similar to those achieved in the present study have been reported by other authors.[3,24,25] In a multicenter prospective study with 69 patients and 97 NDIs with 3.0 mm diameter, an MBL of −0.44 mm was recorded between surgery and loading, and −0.32 mm between loading and 6 months. In the following 6 months, up to 1 year after loading, an MBL of −0.07 mm was recorded. Most implants (51.3%) showed no bone loss between placement and the end of the first year in function.[24] A 5-year prospective study with 22 NDIs reported an MBL of −0.41 mm in the first year and −0.03 mm between the second and fifth years of follow-up.[25] These results are in agreement with data reported in a previous clinical study with NDI Ti-Zr implants.[26] In a systematic review by Klein et al, a mean MBL of −0.31 mm was observed 2 years after NDI placement.[3] Other papers have compared narrow and regular-diameter implants.[8,27,28] The results of Ioannidis et al suggested that 3.3-mm–diameter Ti-Zr implants and 4.1-mm–diameter Ti implants have no MBL differences from implant placement to 3 years in function. In this 3-year, randomized, prospective clinical study with 40 participants, the mean MBL for the regular-diameter implants Ti group was −0.31 mm and −0.40 mm for the NDI Ti-Zr group, with no statistically significant differences between the two groups.[8]

In the present study, the recorded survival rate was 100% (n = 30). Other authors report that NDIs have shown lower survival rates than regular-diameter implants.[29,30] In contrast, other studies indicate that NDIs and regular-diameter implants have similar survival rates.[3,8,28,31–33]

Regarding the influence of MBL on PES, no statistically significant linear correlation was found. Either there is no correlation or the sample size was not sufficient to show it. However, according to some authors, the marginal bone level forms the basis for the supracrestal soft tissues around implants, conditioning the final position of the papilla and the harmony between the new restoration, the remaining teeth, and the surrounding soft tissues.[34] It has also been reported that soft tissue topography is determined by parameters such as implant diameter, contact point position, crown dimensions and provisionalization, and tooth-implant distance.[5,34,35] According to Belser et al, several factors are described that can influence a positive esthetic result, such as the level of stable bone over time, adequate 3D implant planning, and optimal bone volume and soft tissue dimensions around the implant.[36]

In the present study, a strong positive linear correlation was found between implant shape (design and length) and MBL. The correlation was statistically significant between implant shape and MBL in the period from loading to 6 months and in the period from loading to 1 year, with lower MBL values obtained with bone-level implants compared to bone level–tapered implants. The results obtained agree with Petrie and Williams, who stated that long, wide, parallel-walled implants are the best option when reducing loads on the crestal bone. The authors reported that tapered implants increase the load on the crestal bone around the implants by about 1.65 times, especially in NDIs and short implants,[37] which is in agreement with later results obtained by other authors.[11,38] In contrast, in a systematic review by Jokstad and Ganeles, the authors compared the results of three different studies with a minimum follow-up of 3 years and found no clinically relevant differences between cylindrical and tapered implants.[39]

When linear regression was performed, a statistically significant positive linear correlation was also observed between implant placement level and MBL in the period between implant placement and 6 months after loading, 1 year after loading, and in the first 6 months from the day of loading. The results show a decrease in MBL as the implant is placed deeper. Placing the implants in a subcrestal position may create the conditions for biologic space formation without the occurrence of a significant MBL,[40] especially in cases where the mucosal thickness is < 2 mm. However, it is reported that the position of the microgap at a level below the bone crest results in more intense remodeling and more apical repositioning of the surrounding bone as a consequence of microbial colonization,[41] a fact that was not observed in this study.

A strong positive statistically significant linear correlation was found between the healing abutment used and MBL. The results show higher MBL when using the 4-mm–high cylindrical abutment. During the present study, the healing abutment was removed twice; once for taking the impressions and once for placing the prosthetic restoration. In 2003, Abrahamsson et al investigated the influence of abutment manipulation on peri-implant tissue integrity and found that removal and relocation of the abutment compromises the mucosa barrier and induces apical migration of connective tissue, causing bone resorption.[42] In contrast, Alves et al reported that the connection/disconnection of abutments on implants with platform switching during the prosthetic phase did not induce marginal bone resorption. However, the authors reported that there seemed to be a negative influence on the connective tissue, with this influence increasing the thinner the gingival biotype.[43]

A statistically significant moderate/strong positive linear correlation was found between prosthetic abutment size and MBL. A lower MBL was observed between placement and the end of the first year for taller abutments. These results have been previously observed by Vervaeke et al, who concluded in their retrospective study of 158 implants in mandibular overdentures that implants with lower abutments (< 2 mm), reflecting the smaller initial gingival thickness, lost more bone around the implants, possibly due to the establishment of biologic space.[44] The same results were observed in other studies where the authors observed a higher MBL when abutments with a height < 2 mm were used compared to abutments with a height ≥ 2 mm.[45,46] Other clinical studies have found significantly higher MBL around 1-mm–high abutments compared to heights of 2.5 mm[47] or 3.0 mm.[48]

Regarding the influence of a combination of variables in MBL, multivariate analysis showed a statistically significant relationship between gingival thickness, implant placement level, healing abutment used, and prosthetic abutment size used and MBL. The healing abutment used assumes the greatest relative importance in influencing MBL after 6 months and 1 year of follow-up. The results indicated lower MBL values when implants were placed deeper, with thinner gums and longer prosthetic abutments. When longer healing abutments are used, the MBL seemed to increase.

Initial gingival thickness may be the main factor in preserving or resorbing crestal bone.[49] Thin soft tissues with a thickness of 2 mm or less may promote greater MBL during biologic space formation in animal experimentation.[50] In the bivariate analysis performed in the present study, no correlation was found between MBL and gingival thickness. Gingival thickness alone did not seem to directly influence MBL, which can be explained by the nonexistence in the sample of gingival thicknesses < 2 mm. However, in the multivariate model, gingival thickness assumes great relevance, with better results being observed in thinner gingivae in conjunction with implants placed deeper and the use of longer prosthetic abutments.

The limitations of this study are the sample size and the follow-up time. Another limitation is the fact that the implants were used with a nonrandomized length and design, which may have influenced some of the results obtained. Likewise, the healing abutments and prosthetic abutments used were selected according to local characteristics and not randomly. In the present study, only 3.3-mm–diameter NDIs were used, so it was not possible to make comparisons with implants of different diameters, and it was not possible to assess whether implants with larger or smaller diameters would have different results in terms of MBL and PES.

One of the problems of MBL analysis in 2D radiographs is that measurements are performed on intraoral radiographs only mesially and distally, and the buccal and lingual bone is not measured. This is therefore a limitation of the present study, although it is a limitation across all similar studies.[8,51] When implants are placed in narrow ridges, one hypothesis that has to be established is that MBL should occur more markedly in buccal and lingual walls, which were not quantified in the present work. Measurements were made by a single independent observer at two different times spaced 7 days apart. In a previous paper, measurements were taken by two calibrated examiners and averaged.[48]

The main clinical question is still being studied and aims to clarify whether Ti-Zr NDIs represent a valid alternative to regular-diameter implants. The results obtained agree with other authors who suggest that NDIs could be used with high success rates in all anatomical regions, including single restorations in posterior sections.[28] To date, long-term studies performed are scarce, and there is a lack of data regarding peri-implant tissues and prosthetic components, such as the possible risk of biologic and/or mechanical complications with wide-platform crowns in NDIs.

It will be important to conduct further studies, especially prospective ones, that analyze and combine the different variables that may influence MBL and the other success criteria in the longest possible time frame. Likewise, it will be important to clarify whether satisfactory esthetic results and soft tissue stability can be achieved with the use of NDIs. Future work may help to clarify whether NDIs can be used with long-term predictability in all anatomical areas with reduced risk of complications, thus reducing the complexity and duration of surgical interventions. It will be important to understand whether NDIs, together with the high strength of new materials and biocompatible surfaces, can be used in single rehabilitations in areas with bone availability, low or no MBL, and with high survival and success rates.

CONCLUSIONS

Considering the sample under study, the defined objectives, and the results achieved, the main conclusion of this research is that the NDIs used show reduced MBL values and remained stable after 1 year of follow-up.

It can also be concluded that the MBL did not show different values on SLA and SLActive surfaces during the whole study period and seems to have been mainly influenced by the gingival thickness, the implant placement level, the healing abutment, and the size of the prosthetic abutment used. Deeper implant placement and the use of longer prosthetic abutments seem to be the best combination in using NDIs to reduce MBL in gingiva with a thickness of 2 mm or more.

MBL does not seem to influence the esthetic outcome after 1 year of follow-up.

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REFERENCES

1. Rozé J, Babu S, Saffarzadeh A, Gayet-Delacroix M, Hoornaert A, Layrolle P. Correlating implant stability to bone structure. Clin Oral Implants Res 2009;20:1140–1145.
2. Winkler S, Morris HF, Ochi S. Implant survival to 36 months as related to length and diameter. Ann Periodontol 2000;5:22–31.
3. Klein M, Schiegnitz E, Al-Nawas B. Systematic review on success of narrow-diameter dental implants. Int J Oral Maxillofac Implants 2014;29(suppl):43–54.
4. Jung RE, Al-Nawas B, Araujo M, et al. Group 1 ITI Consensus Report: The influence of implant length and design and medications on clinical and patient-reported outcomes. Clin Oral Implant Res 2018;29(suppl 16):69–77.
5. Froum SJ, Cho SC, Cho YS, Elian N, Tarnow D. Narrow-diameter implants: A restorative option for limited interdental space. Int J Periodontics Restorative Dent 2007;27:449–455.
6. Bornstein MM, Al-Nawas B, Kuchler U, Tahmaseb A. Consensus statements and recommended clinical procedures regarding contemporary surgical and radiographic techniques in implant dentistry. Int J Oral Maxillofac Implants 2014;29(suppl):78–82.
7. Papadimitriou DE, Friedland B, Gannam C, Salari S, Gallucci GO. Narrow-diameter versus standard-diameter implants and their effect on the need for guided bone regeneration: A virtual three-dimensional study. Clin Implant Dent Relat Res 2015;17:1127–1133.
8. Ioannidis A, Gallucci GO, Jung RE, Borzangy S, Hämmerle CH, Benic GI. Titanium-zirconium narrow-diameter versus titanium regular-diameter implants for anterior and premolar single crowns: 3-year results of a randomized controlled clinical study. J Clin Periodontol 2015;42:1060–1070.
9. Al-Nawas B, Schiegnitz E. Augmentation procedures using bone substitute materials or autogenous bone—A systematic review and meta-analysis. Eur J Oral Implantol 2014;7(suppl 2):s219–s234.
10. Cehreli MC, Akça K. Narrow-diameter implants as terminal support for occlusal three-unit FPDs: A biomechanical analysis. Int J Periodontics Restorative Dent 2004;24:513–519.
11. Ding X, Liao SH, Zhu XH, Zhang XH, Zhang L. Effect of diameter and length on stress distribution of the alveolar crest around immediate loading implants. Clin Implant Dent Relat Res 2009;11:279–287.
12. Schwarz MS. Mechanical complications of dental implants. Clin Oral Implants Res 2000;11:156–158.
13. Zinsli B, Sägesser T, Mericske E, Mericske-Stern R. Clinical evaluation of small-diameter ITI implants: A prospective study. Int J Oral Maxillofac Implants 2004;19:92–99.
14. Gottlow J, Dard M, Kjellson F, Obrecht M, Sennerby L. Evaluation of a new titanium-zirconium dental implant: A biomechanical and histological comparative study in the mini pig. Clin Implant Dent Relat Res 2012;14:538–545.
15. Saulacic N, Bosshardt DD, Bornstein MM, Berner S, Buser D. Bone apposition to a titanium-zirconium alloy implant, as compared to two other titanium-containing implants. Eur Cell Mater 2012;23:273–286.
16. Fürhauser R, Florescu D, Benesch T, Haas R, Mailath G, Watzek G. Evaluation of soft tissue around single-tooth implant crowns: The pink esthetic score. Clin Oral Implants Res 2005;16:639–644.
17. Tonetti MS, Greenwell H, Kornman KS. Staging and grading of periodontitis: Framework and proposal of a new classification and case definition. J Periodontol 2018;89(suppl 1):s159–s172.
18. Lekholm U, Zarb GA. Patient selection and preparation. In: Brånemark PI, Zarb GA, Albrektsson T (eds). Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985:199–209.

19. O'Leary TJ, Drake RB, Naylor JE. The plaque control record. J Periodontol 1972;42:38.
20. Ainamo J, Bay I. Problems and proposals for recording gingivitis and plaque. Int Dent J 1975;825:229–235.
21. Hämmerle CH, Chen ST, Wilson TG Jr. Consensus statements and recommended clinical procedures regarding the placement of implants in extraction sockets. Int J Oral Maxillofac Implants 2004;19:26–28.
22. Esposito M, Ardebili Y, Worthington HV. Interventions for replacing missing teeth: Different types of dental implants. Cochrane Database Syst Rev 2014;(7):CD003815.
23. Mombelli A, van Oosten MA, Schurch E Jr, Land NP. The microbiota associated with successful or failing osseointegrated titanium implants. Oral Microbiol Immunol 1987;2:145–151.
24. Galindo-Moreno P, Nilsson P, King P, et al. Clinical and radiographic evaluation of early loaded narrow diameter implants—1-year follow-up. Clin Oral Implants Res 2012;23:609–616.
25. Comfort MB, Chu FC, Chai J, Wat PY, Chow TW. A 5-year prospective study on small diameter screw-shaped oral implants. J Oral Rehabil 2005;32:341–345.
26. Quirynen M, Al-Nawas B, Meijer HJ, et al. Small-diameter titanium Grade IV and titanium-zirconium implants in edentulous mandibles: Three-year results from a double-blind, randomized controlled trial. Clin Oral Implants Res 2015;26:831–840.
27. de Souza AB, Sukekava F, Tolentino L, César-Neto JB, Garcez-Filho J, Araújo MG. Narrow- and regular-diameter implants in the posterior region of the jaws to support single crowns: A 3-year split-mouth randomized clinical trial. Clin Oral Implants Res 2018;29:100–107.
28. Schiegnitz E, Al-Nawas B. Narrow-diameter implants: A systematic review and meta-analysis. Clin Oral Implants Res 2018;29(suppl 16):21–40.
29. Andersen E, Saxegaard E, Knutsen BM, Haanaes HR. A prospective clinical study evaluating the safety and effectiveness of narrow-diameter threaded implants in the anterior region of the maxilla. Int J Oral Maxillofac Implants 2001;16:217–224.
30. Romeo E, Lops D, Amorfini L, Chiapasco M, Ghisolfi M, Vogel G. Clinical and radiographic evaluation of small-diameter (3.3-mm) implants followed for 1–7 years: A longitudinal study. Clin Oral Implants Res 2006;17:139–148.
31. Herrmann J, Hentschel A, Glauche I, Vollmer A, Schlegel KA, Lutz R. Implant survival and patient satisfaction of reduced diameter implants made from a titanium-zirconium alloy: A retrospective cohort study with 550 implants in 311 patients. J Cranio-Maxillofacial Surg 2016;44:1940–1944.
32. Altuna P, Lucas-Taulé E, Gargallo-Albiol J, Figueras-Álvarez O, Hernández-Alfaro F, Nart J. Clinical evidence on titanium-zirconium dental implants: A systematic review and meta-analysis. Int J Oral Maxillofac Surg 2016;45:842–850.
33. Badran Z, Struillou X, Strube N, et al. Clinical performance of narrow-diameter titanium-zirconium implants: A systematic review. Implant Dent 2017;26:316–323.
34. Tarnow DP, Cho SC, Wallace SS. The effect of inter-implant distance on the height of inter-implant bone crest. J Periodontol 2000;71:546–549.
35. Jemt T. Restoring the gingival contour by means of provisional resin crowns after single-implant treatment. Int J Periodontics Restorative Dent 1999;19:20–29.
36. Belser U, Buser D, Higginbottom F. Consensus statements and recommended clinical procedures regarding esthetics in implant dentistry. Int J Oral Maxillofac Implants 2004;19:73–74.
37. Petrie CS, Williams JL. Comparative evaluation of implant designs: Influence of diameter, length, and taper on strains in the alveolar crest. A three-dimensional finite-element analysis. Clin Oral Implants Res 2005;16:486–494.
38. Degidi M, Piattelli A, Carinci F. Clinical outcome of narrow diameter implants: A retrospective study of 510 implants. J Periodontol 2008;79:49–54.
39. Jokstad A, Ganeles J. Systematic review of clinical and patient-reported outcomes following oral rehabilitation on dental implants with a tapered compared to a non-tapered implant design. Clin Oral Implants Res 2018;29(suppl 16):41–54.
40. Vervaeke S, Matthys C, Nassar R, Christiaens V, Cosyn J, De Bruyn H. Adapting the vertical position of implants with a conical connection in relation to soft tissue thickness prevents early surface exposure: A 2-year prospective intra-subject comparison. J Periodontol 2018;45:605–612.
41. Broggini N, McManus LM, Hermann JS, et al. Peri-implant inflammation defined by the implant-abutment interface. J Dent Res 2006;85:473–478.
42. Abrahamsson I, Berglundh T, Sekino S, Lindhe J. Tissue reactions to abutment shift: An experimental study in dogs. Clin Implant Dent Relat Res 2003;5:82–88.
43. Alves CC, Muñoz F, Cantalapiedra A, Ramos I, Neves M, Blanco J. Marginal bone and soft tissue behavior following platform switching abutment connection/disconnection—A dog model study. Clin Oral Implants Res 2015;26:983–991.
44. Vervaeke S, Dierens M, Besseler J, De Bruyn H. The influence of initial soft tissue thickness on peri-implant bone remodeling. Clin Implant Dent Relat Res 2014;16:238–247.
45. Galindo-Moreno P, León-Cano A, Ortega-Oller I, et al. Prosthetic abutment height is a key factor in peri-implant marginal bone loss. J Dent Res 2014;93(7 suppl):80s–85s.
46. Galindo-Moreno P, León-Cano A, Monje A, Ortega-Oller I, O'Valle F, Catena A. Abutment height influences the effect of platform switching on peri-implant marginal bone loss. Clin Oral Implants Res 2016;27:167–173.
47. Nóvoa L, Batalla P, Caneiro L, Pico A, Liñares A, Blanco J. Influence of abutment height on maintenance of peri-implant crestal bone at bone-level implants: A 3-year follow-up study. Int J Periodontics Restorative Dent 2017;37:721–727.
48. Blanco J, Pico A, Caneiro L, Nóvoa L, Batalla P, Martín-Lancharro P. Effect of abutment height on interproximal implant bone level in the early healing: A randomized clinical trial. Clin Oral Implants Res 2018;29:108–117.
49. Puisys A, Linkevicius T. The influence of mucosal tissue thickening on crestal bone stability around bone-level implants. A prospective controlled clinical trial. Clin Oral Implants Res 2013;26:123–129.
50. Linkevicius T, Apse P, Grybauskas S, Puisys A. The influence of soft tissue thickness on crestal bone changes around implants: A 1-year prospective controlled clinical trial. Int J Oral Maxillofac Implants 2009;24:712–719.
51. Benic GI, Gallucci GO, Mokti M, Hämmerle CH, Weber HP, Jung RE. Titanium-zirconium narrow-diameter versus titanium regular-diameter implants for anterior and premolar single crowns: 1-year results of a randomized controlled clinical study. J Clin Periodontol 2013;40:1052–1061.