Marginal Bone Response of Submerged and Nonsubmerged Osteoconductive Alkali-Etched Implants in Thick and Thin Biotypes: A 2-year Clinical Follow-up Study

Zdeněk Novák, MD[1]/Jakub Strnad, MSc, PhD[2]/Radim Nesvadba, MSc[3]/
Jan Kamprle, MSc[4]/Zdeněk Strnad, MSc, PhD[5]

Purpose: *This follow-up study evaluated the implant success rate and marginal bone response of submerged and nonsubmerged osteoconductive two-piece implants with a moderately rough implant neck in thick and thin gingival biotypes.* ***Materials and Methods:*** *The stability of the hard tissue surrounding the implants was evaluated, based on clinical and radiographic examinations performed after implant placement and every follow-up thereafter. The clinical data were processed via linear mixed-effects model statistics at the patient level.* ***Results:*** *Forty-three edentulous and partially edentulous patients were treated with a total of 97 implants with an osteoconductive surface. After 2 years in function, all the implants and dental prostheses reached a 100% success rate according to predefined criteria. Taking implantation as a baseline, the mean change in the marginal bone level (ΔMBLp) after 2 years in function was −0.36 mm (SD: 0.55), and bone resorption higher than 1 mm and less than 2.5 mm was observed for seven implants. Taking dental prosthesis placement as a baseline, the ΔMBLp after 2 years of loading was −0.13 mm (SD: 0.39), and bone resorption higher than 1 mm and less than 2.0 mm was observed only for two implants. Statistically significant differences in mean marginal bone loss were observed in the gingival biotype ($P = .006$) and submersion ($P < .05$). Their influence on the dynamics of peri-implant bone loss during the process of biologic width restoration was analyzed.* ***Conclusion:*** *This study demonstrated the high stability of peri-implant hard tissue and the 100% success rate of the implant system with a moderately rough neck. The biotype and implant submersion were evaluated as factors having a significant influence on marginal bone loss.* Int J Oral Maxillofac Implants 2019;34:1184–1194. doi: 10.11607/jomi.7399

Keywords: *biotype, dental implants, insertion depth, osteoconductive surface, peri-implant bone loss*

[1]Medical Doctor, Private Clinical Practice, Prague, Czech Republic.
[2]CEO, Research and Development Centre for Dental Implantology and Tissue Regeneration – LASAK s.r.o., Prague, Czech Republic.
[3]PhD Student, Department of Analytical Chemistry, University of Chemistry and Technology, Prague, Czech Republic; Research and Development Researcher, Research and Development Centre for Dental Implantology and Tissue Regeneration – LASAK s.r.o., Prague, Czech Republic.
[4]Design and Development Designer, Research and Development Centre for Dental Implantology and Tissue Regeneration – LASAK s.r.o., Prague, Czech Republic.
[5]Associate Professor, Department of Glass and Ceramics, University of Chemistry and Technology, Prague, Czech Republic; Design and Development Manager for Ceramics, Research and Development Centre for Dental Implantology and Tissue Regeneration – LASAK s.r.o., Prague, Czech Republic.

Correspondence to: Radim Nesvadba, Research and Development Centre for Dental Implantology and Tissue Regeneration – LASAK s.r.o., Českobrodská 1047/46, 190 01 Prague 9, Czech Republic. Fax: +420 224 319 716. Email: nesvadba@lasak.cz

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Endosteal dental implants are supposed to enable a high level of osseointegration in a short time to allow their early or immediate loading.[1–3] The development of bioactive surfaces without using coating technology has significantly helped to achieve that in the last decades. One of the advanced surface-modifying technologies is based on the chemical bioactivation of titanium, which results in a three-dimensional (3D) macro-, micro-, and nanostructured hydrophilic titanium surface with osteoconductive properties known as the BIO-surface.[4,5]

The advantages of the BIO-surface were demonstrated in a histometric study in an animal model[6] as well as in vitro. The cell behavior on this surface was observed and compared with polished, sand-blasted and acid-etched surfaces.[7] Also, the success rate of dental implants with an osteoconductive surface (IMPLADENT – BIO-surface; LASAK s.r.o.) was documented in clinical trials employing the shortened treatment protocol of early[8,9] and immediate loading.[10–12] Recently, this

surface was used in combination with a novel design of the endosteal dental implant BioniQ (LASAK s.r.o.) with a conical tapered connection between the implant and the abutment. The implant neck with the modified osteoconductive surface of lower roughness was employed for better attachment of connective tissue.[13–15]

The use of dental implants with a rough neck was considered risky because of easier microbial colonization and subsequent failure of the implant in the case of an uncovered neck. However, some studies show that the rough neck results in less marginal bone loss compared with the machined neck.[16–19] With respect to the rough implant neck, and to avoid its exposure, the depth of initial implant insertion should be taken into account as well as the thickness of the gingival biotype. These two parameters belong to those affecting marginal bone stability. Based on the studies conducted, it seems that deep implant placement leads to greater bone resorption than shallow implant placement,[20–22] although the differences are not always significant. Also, it seems that in particular, implants placed in a thin gingival biotype result in greater marginal bone loss. Contrary to this, a bone covered with a thick gingival biotype is considered to be more stable around implants.[23–26] To the best of the authors' knowledge, detailed evaluation of a biotype, together with the depth of implant insertion related to implants with a moderately rough neck, has not yet been documented in such a long-term clinical study, and this may result in new suggestions.

The aim of this follow-up study was to clinically and radiographically evaluate the implant success rate and marginal bone response of submerged and nonsubmerged hydrophilic osteoconductive two-piece implants with a moderately rough implant neck in thick and thin biotypes. The hypothesis of this study was that bone resorption in the vicinity of the implants would correspond to 0.5 mm within the first year in service and, maximally, to 0.2 mm during the second year. The value of the first-year resorption (0.5 mm) represents one-half of the maximum mean bone loss (ΔMBLp) stated by the standard norm for implant success.[27–29]

MATERIALS AND METHODS

Patient Selection

Eligible patients who received implant treatment at a private clinical practice in Prague (Radhošťská 4, 130 00, Prague 3) and met the selection criteria were included in the prospective study.

Inclusion Criteria

Inclusion criteria were as follows: male and female patients aged 18 years and older, with good oral hygiene and without signs of periodontitis, alveolus without the need for an augmentation procedure, alveolus without a significant horizontal and/or vertical bone defect, implantation into the healed alveolar site 5 to 6 months following extraction (3 to 4 months for single-rooted teeth), bone density D1 to D4 according to Misch,[30] and a noninfected alveolar site. The treated patients received full information about the treatment and the advantages and disadvantages of the chosen procedure. The patients confirmed their agreement for their participation in the trial via signed informed consent. The study was conducted in accordance with the Helsinki Declaration (1964, 2008), and the study protocol was approved by the Ethics Committee at the University Hospital Hradec Kralove, Czech Republic (201806 S13PM).

Exclusion Criteria

Patients were excluded from the study due to general health contraindications for oral surgery such as poor oral hygiene, untreated periodontitis, acute inflammation in the oral cavity, age lower than 18 years, smoking (> 10 cigarettes/day), and alcohol and drug abuse. Immunosuppressed patients, pregnant and nursing patients, patients with augmented alveolar bone, patients with unrealistic expectations, and patients with parafunctional activities (bruxism) were also excluded.

Sample Size Calculation

Before the study began, the null hypothesis that marginal bone loss would correspond to 0.5 mm within the first year in service and maximally 0.2 mm per year thereafter, together with a standard deviation of 0.5 mm, had been used for a sample size calculation. Using a test power of 0.9 at the significance level of $\alpha = .05$, the sample size equaled 26 patients. The values used in this null hypothesis were based on the standard norm,[27–29] where maximum bone resorption during the first years of loading was reduced to half.

Marginal Bone Level Measurement

For the x-ray diagnostics, an orthopantomogram Planmeca Promax with calibrated imaging was used. The intraoral imaging was performed via the paralleling technique using Super-Bite Senso and Endo-Bite Senso holders (KerrHawe SA).

Marginal bone level (MBL) was determined from radiographs perpendicular to the central axis of the implant on both sides of the implant (mesial MBLm and distal MBLd), in relation to the reference level (RL) of the implant shoulder (Fig 1). The final value, MBLp, was determined as an average of the mesial MBLm and distal MBLd values. The length of the implant was used as a reference. MBLm and MBLd were measured during the follow-up immediately after the implantation MBL

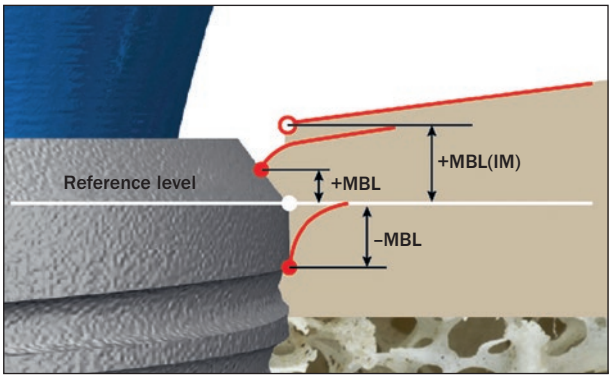

Fig 1 An illustrative scheme of the measurement of the marginal bone level (MBL). The positive or negative mark of MBL is defined according to the bone-to-implant position with respect to the reference level. MBL (IM) corresponds to the implant submersion immediately after implantation.

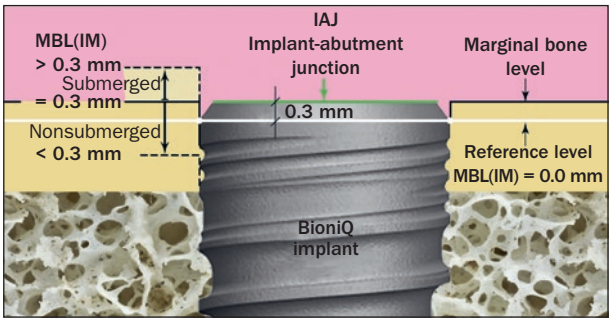

Fig 2 An illustrative scheme of the bone level with respect to the implant level during the implantation: submerged (subcrestal) and nonsubmerged (crestal and supracrestal) implant. The reference level, given by the implant collar *(white line and dots)*, is at a 0.3-mm distance from the IAJ.

(IM); at the second stage of implantation MBL (2SI); at the time of placement of the dental prosthesis MBL (DP); and after 3, 6, 12, and 24 months—MBL (DP3mo), MBL (DP6mo), MBL (DP1y), MBL (DP2y)—of the implant in service.

The change in the marginal bone over time, ΔMBLm, ΔMBLd, and ΔMBLp, was determined as the difference in the values measured at the individual time intervals in relation to the baseline at the time of implantation MBL (IM) and, alternatively, at the time of dental prosthesis placement MBL (DP).

Gingival Biotype Evaluation

The patient's gingival biotype was evaluated and categorized into two groups: thin biotype (scalloped) and thick biotype (flat or scalloped).[31] To evaluate the biotype, a black periodontal probe was placed in the sulcus at the midfacial aspect of the adjacent tooth; the biotype was categorized as "thin" if the periodontal probe was visible through the gingiva or as "thick" if the probe could not be seen.[32] The gingival biotype is connected with the biologic width. Thin biotype represents mucosa thickness of ≤ 2 mm, whereas the thick biotype represents mucosa thickness of > 2 mm.[33]

Surgical Protocol

The dental implant placement was performed in a two-stage surgery according to the manufacturer's instructions. The patient was asked to rinse with 0.12% chlorhexidine solution for 2 minutes immediately before the surgery. The implantation was performed under local anesthesia. The mucoperiosteal flaps were raised, and alveolar ridge egalization was performed, if necessary, using a rotary drill. The implants were placed according to the protocol using insertion torque up to 70 Ncm. Bone-level positioning has been preferred and recommended. Based on immediate radiographic evaluation, the final variance of the implant placement depth around the recommended position was described and categorized as nonsubmerged (MBLp ≤ 0.3 mm; crestal and supracrestal position) or submerged (MBLp > 0.3 mm; subcrestal position) (Fig 2).

The implants were covered with soft tissue during the shortened healing period of 10 weeks in both the maxilla and mandible. After this period, the second stage of the implantation (2SI) was initiated. The cover screw was removed and replaced by a healing abutment to form a mucosal peri-implant canal. The impressions were taken on the implant level. After 2 to 4 weeks, the healing abutment was replaced by an appropriate definitive abutment. The definitive abutment was attached to the internal thread of the implant using a screw and tightened using a torque of 25 Ncm. Chlorhexidine gel was applied to the screw thread prior to use. Immediately after the implantation (IM), and after the second stage of the implantation (2SI), intraoral radiographs were performed, and the stability of the implant was measured using resonance frequency analysis (RFA).

Prosthesis Protocol

To achieve good-quality and stable implant collar closure, the prosthetic phase of the implant was initiated 2 to 4 weeks after the stage-two surgery. In the single-tooth implants, the crown was positioned 0.5 to 1.0 mm below the free gingival margin and cemented.

Multiple implants were mostly drilled and treated with screw-retained or cemented restorations with passive fit and free articulation. Toothless arches were treated by insertion of two implants in the mandible in the canine region. The Locator overdenture attachment system was used. Matrix fixation was performed directly in the patient's mouth. The representation of the individual prosthesis types used in the present study and the numbers of inserted implants are shown in Table 1.

Table 1 Number of Dental Prosthesis Types and Supervised Implants

Dental prosthesis type	Single crown	Connected crown	3-membered linear bridge	Multiple bridge	Splinted bridge	Anchor dentures	Locator attachment	Total no.
Maxilla	11 (11)	3 (6)	2 (4)	3 (8)	1 (6)	1 (4)	—	21 (39)
Mandible	12 (12)	4 (8)	7 (14)	1 (1)	4 (21)	—	1 (2)	29 (58)
Total no.	23 (23)	7 (14)	9 (18)	4 (9)	5 (27)	1 (4)	1 (2)	50 (97)

Supervised implants are in parentheses.

Evaluation of Implant Success Rate

The evaluation of the success rate of the implants was performed throughout the treatment at given time intervals at the second stage of the implantation (2SI), at the placement of the dental prosthesis (DP), after 3 (DP3mo) and 6 (DP6mo) months, and after the first (DP1y) and the second (DP2y) years in function (after the placement of the dental prosthesis).

For the evaluation of a successful implant, Buser's criteria were used[34–36]: *(1)* the implant is immobile when tested clinically; *(2)* there is no evidence of peri-implant radiolucency; *(3)* there is an absence of persistent or irreversible signs and symptoms, such as pain, foreign body sensation, and/or dysesthesia; *(4)* there is an absence of a recurrent peri-implant infection with suppuration. The implants that did not meet these criteria were considered to be survivals. The removed implants were regarded as failures.

The standard norm according to Albrektsson et al,[27] Albrektsson and Zarb,[28] and Roos et al[29] is meant as a reference level to state the hypothesis of the study and to compare it with. It defines bone loss of less than 1 mm during the first year of loading and less than 0.2 mm annually thereafter, to level out at approximately −1.8 mm after 5 years of loading.

Statistical Analysis

Descriptive statistics were used to evaluate the acquired data. The data are presented as mean values ± standard deviations (SDs), in box plots and tables. Since not all the data had a normal distribution (Kolmogorov-Smirnov test), the median, maxima, minima, and quantiles were included in the descriptive statistics together with mean values and SDs. A linear mixed-effects model analysis was performed to evaluate the marginal bone loss and the influential factors. This statistical analysis corrects for clustering implants in the same patient (the patient is considered to be a random effect). To meet the assumptions of the model used, the MBL values were transformed according to the formula (MBL + 3.0 mm)^{1,2} to obtain a normal distribution of the residues, if necessary. The suitability of the model was expressed by the determination coefficient R^2 showing the percentage of variability of the dependent variable described by the model used. The statistical analysis was performed using the statistical software Statistica 12. A *P* value smaller than .05 was considered to be statistically significant. The study is in accordance with the STROBE guidelines.

RESULTS

Patients and Implants

From June 18, 2014 to March 3, 2015, a total of 43 edentulous and partially edentulous patients, whose mean age was 57.6 years (range: 18 to 75 years), were involved in the follow-up study according to the selection criteria described earlier. All the patients were treated by the same clinician (Z.N.) at the private clinical practice, Radhošťská 4, Prague 3. The patients—27 women and 16 men—were treated with 97 implants (BioniQ, LASAK s.r.o) with diameters of 3.5, 4, and 5 mm, and lengths of 8, 10, and 12 mm. The implants were placed with a final insertion torque ranging from 15 to 70 Ncm with a mean value of 41 Ncm (SD: 17). Standard (straight) and esthetic (straight/angled) definitive abutments with lengths of 0.7 to 3.0 mm were used. The implant-abutment connection was performed via the conical tapered connection Q-lock, and all the implants had a 0.5-mm-high moderately rough neck (Figs 3a and 3b). The number of attached types of dental prostheses is shown in Table 1.

Implant Survival and Success Rates

All the patients showed up for the follow-up after 3, 6, 12, and 24 months after the dental prosthesis placement. Any special complications that would considerably influence the survival of the implants were not noticed during the 2 years. No dropouts occurred. Therefore, a survival rate of 100% after 2 years in function was obtained, and according to Buser's criteria of success,[34–36] all the placed implants were successful (Table 2).

MBL and Its Changes Regarding Implantation (IM) as Baseline

The absolute positions of the mean marginal bone level (MBLp) with respect to the reference level (RL) are summarized in Table 3 and Fig 4. Regarding the implant placement IM as a baseline (Table 4), the total

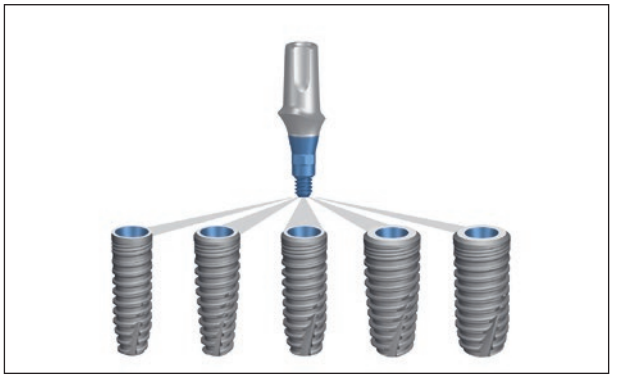

Fig 3a Cylindrical S3.5, S4.0, S5.0, and conical T4.0, T5.0 implants with a single prosthetic platform.

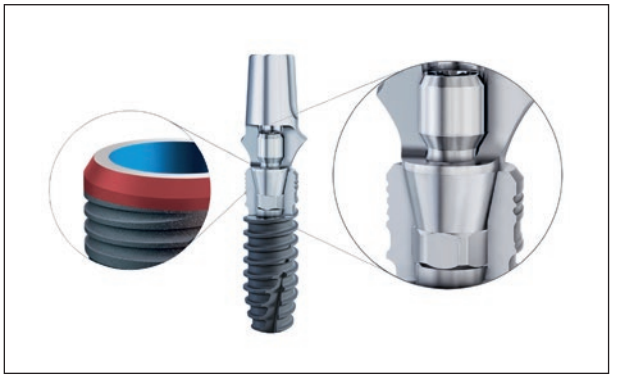

Fig 3b Q-lock connection between the intraosseous part of the implant and the abutment (anti-rotation element together with both the conical tapered and tube-in-tube connection). The modified osteoconductive surface of moderate roughness is shown as a red collar on the implant neck.

Table 2 Life-Table Analysis According to Buser's Criteria of Success[34–36]

Time interval	No. of implants in interval	No. of failed implants in interval according to criteria	No. of unaccounted for implants*	No. of assessed implants in interval	Interval success rate %	Cumulative success rate %
IM–DP	97	0	0	97	100	100
DP–DP3mo	97	0	0	97	100	100
DP3mo–DP6mo	97	0	0	97	100	100
DP6mo–DP1y	97	0	0	97	100	100
DP1y–DP2y	97	0	0	97	100	100

*Implants in patients whose follow-up ended for any reason, except failure.

MBLp change over time became ΔMBLp (DP2y – IM) = –0.36 mm (SD: 0.55; $P < .05$), thus far. However, the main bone loss occurred between the IM and the dental prosthesis placement ΔMBLp (DP – IM) = –0.23 mm (SD: 0.42; $P = .000002$).

However, the MBLp values have a limited interpretation, since the values of bone loss are compensated for by the bone growth. Therefore, the distribution of the bone changes is included for the first and the second years of function with respect to the baseline IM. This distribution showed nine implants with a loss higher than 1 mm until DP1y, and only seven implants with the same loss until DP2y (Fig 5).

MBL and Its Changes Regarding Prosthesis Placement (DP) as Baseline

Considering the dental prosthesis placement as a baseline (Table 5), the ΔMBLp (DP2y – DP) = –0.13 mm (SD: 0.39; $P = .010$). With respect to the stated null hypothesis, the first-year resorption was ΔMBLp (DP1y – DP) = –0.12 mm (SD: 0.39; $P = .022$), while during the second year, the difference was ΔMBLp (DP2y – DP1y) = –0.02 mm (SD: 0.21; $P = .77$).

The distribution of bone loss with respect to the DP is shown in Fig 6. Bone loss higher than 1 mm after 1 year of loading occurred in four implants and only in two implants after 2 years of loading, respectively. Most of the implants (67 of 97) showed zero or positive change in the MBL after the first and second years of function.

Gingival Biotype and Insertion Depth

Using the linear mixed-effects model statistics, it was found that the initial depth of insertion (submerged/nonsubmerged) and biotype (thick/thin) significantly influenced bone level changes ($P < .05$). The results of the statistical analysis are presented in Table 6.

Evaluating the thin biotype separately (Fig 7a), the results show that the change in the mean marginal bone level ΔMBLp with respect to the IM differs according to the initial submersion. Submerged implants in thin biotype result in greater bone loss (–1.11 mm, SD: 0.80, n = 11) after 2 years in service in comparison with nonsubmerged implants (–0.31 mm, SD: 0.32, n = 20); however, the difference is not statistically significant ($P = .058$).

Evaluating the thick biotype separately (Fig 7b), the ΔMBLp with respect to the IM after 2 years in function was generally lower compared to the thin biotype (Fig 7a). Nevertheless, the difference between

Table 3 Mean Marginal Bone Level (MBLp; mm) at Individual Follow-up Time Points

Time point	No. of patients[a] (implants)	Mean	Median	Minimum	Maximum	Lower quartile	Upper quartile	SD
IM	43 (97)	0.44	0.30	−0.25	2.30	0.00	0.75	0.49
2SI	43 (97)	0.35	0.30	−0.35	1.80	0.00	0.50	0.44
DP	43 (97)	0.21	0.05	−0.75	1.55	0.00	0.30	0.43
DP3mo	43 (97)	0.11	0.00	−1.70	1.55	−0.05	0.30	0.50
DP6mo	43 (97)	0.06	0.00	−1.20	1.55	−0.25	0.30	0.52
DP1y	43 (97)	0.09	0.05	−1.35	1.55	−0.20	0.30	0.55
DP2y	43 (97)	0.07	0.00	−1.25	1.55	−0.20	0.30	0.52

[a]The data were processed at the patient level. IM = implantation; 2SI = second stage of implantation; DP = dental prosthesis placement; DP3mo = 3 months; DP6mo = 6 months; DP1y = 1 year; DP2y = 2 years of the implant in service.

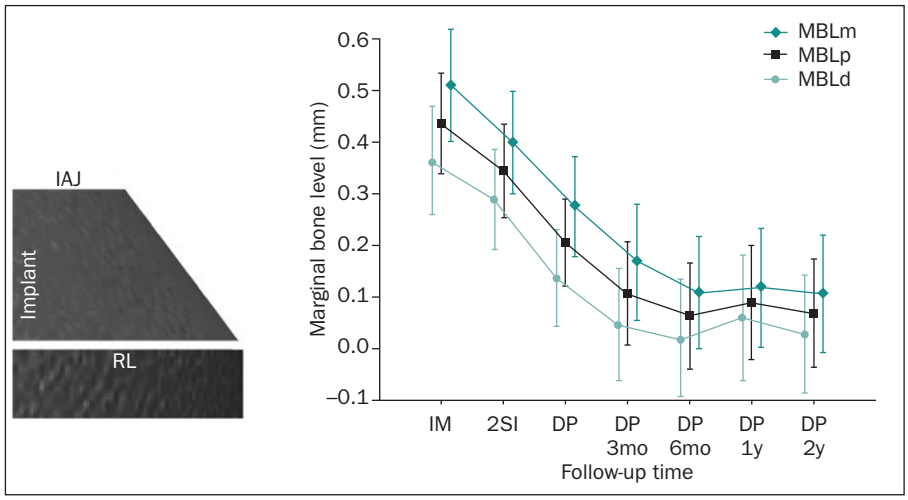

Fig 4 The development of mesial (MBLm), distal (MBLd), and mean marginal bone level (MBLp) during the 2-year follow-up with respect to the implant dimensions on the left. The vertical bars represent the 95% confidence intervals. IM = implantation; 2SI = second stage of implantation; DP = dental prosthesis placement; DP3mo = 3 months; DP6mo = 6 months; DP1y = 1 year; DP2y = 2 years of the implant in service.

Table 4 Mean Change in Marginal Bone Level (ΔMBLp; mm) During Individual Phases After Implantation

Time interval	No. of patients[a] (implants)	Mean	SD
2SI – IM	43 (97)	−0.09	0.28
DP – IM	43 (97)	−0.23	0.42
DP3mo – IM	43 (97)	−0.33	0.51
DP6mo – IM	43 (97)	−0.37	0.57
DP1y – IM	43 (97)	−0.35	0.56
DP2y – IM	43 (97)	−0.36	0.55

[a]The data were processed at the patient level. IM = implantation; 2SI = second stage of implantation; DP = dental prosthesis placement; DP3mo = 3 months; DP6mo = 6 months; DP1y = 1 year; DP2y = 2 years of the implant in service.

Table 5 Mean Change in Marginal Bone Level (ΔMBLp; mm) 3, 6, 12, and 24 months after Dental Prosthesis Placement

Time interval	No. of patients[a] (implants)	Mean	SD
DP3mo – DP	43 (97)	−0.10	0.32
DP6mo – DP	43 (97)	−0.14	0.31
DP1y – DP	43 (97)	−0.12	0.39
DP2y – DP	43 (97)	−0.13	0.39

[a]The data were processed at the patient level. IM = implantation; 2SI = second stage of implantation; DP = dental prosthesis placement; DP3mo = 3 months; DP6mo = 6 months; DP1y = 1 year; DP2y = 2 years of the implant in service.

the bone level changes of the submerged (−0.44 mm, SD: 0.48, n = 22) and nonsubmerged (−0.16 mm, SD: 0.43, n = 44) implants in the thick biotype was still statistically significant ($P < .05$).

Considering the mean marginal bone level MBLp, the graphs (Figs 8a and 8b) show stabilization of the bone at a constant vertical distance from the implant-abutment junction (IAJ) after 2 years in function. The MBLp stabilized at approximately 0.4 mm below the IAJ in both submerged and nonsubmerged implants in the thin biotype—MBLp (DP2y) = −0.06 mm, SD: 0.67, n = 11; and MBLp (DP2y) = −0.08 mm, SD: 0.33, n = 20,

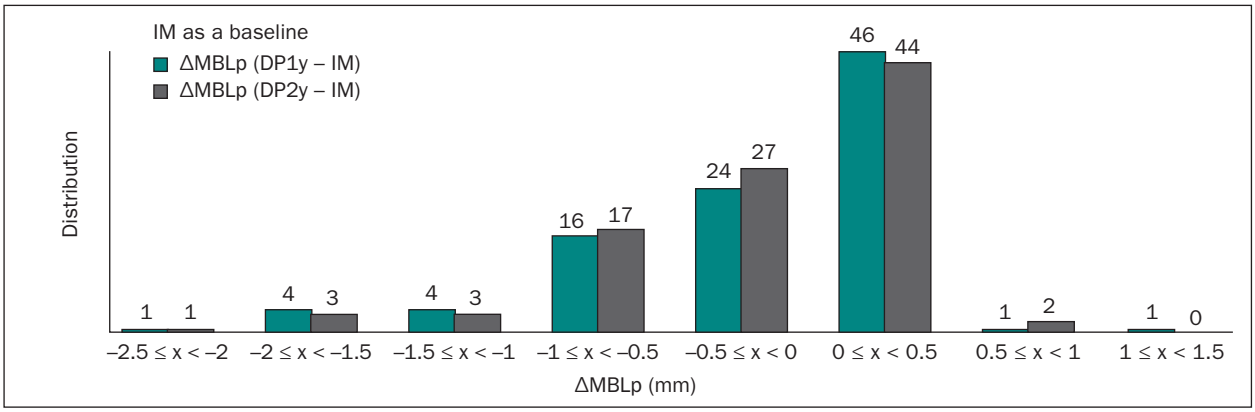

Fig 5 The relative distribution of the mean marginal bone level changes (ΔMBLp) after the first *(green)* and the second *(gray)* year in function considering the time of implantation (IM) as a baseline. A total of nine and seven pieces of the monitored implants resulted in marginal bone loss greater than 1 mm after the first and the second years in function, respectively.

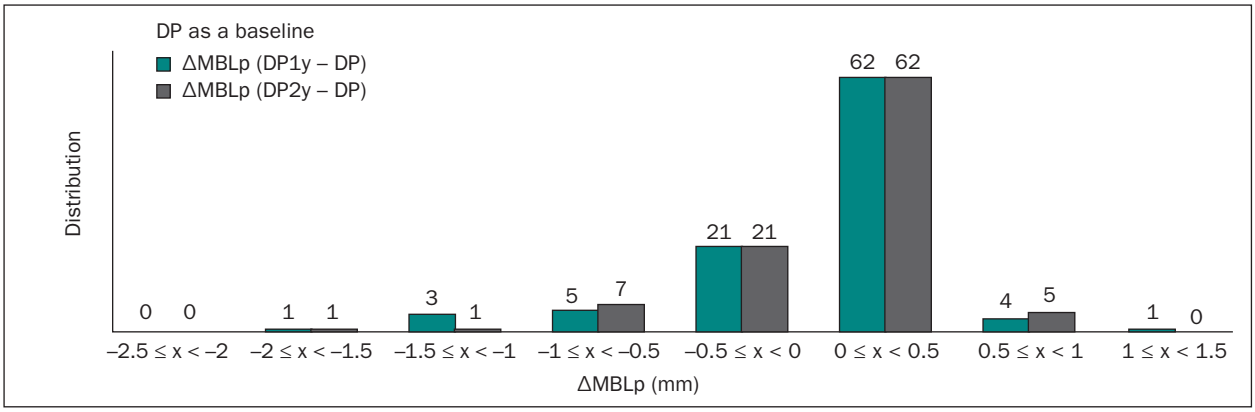

Fig 6 The relative distribution of the mean marginal bone level changes (ΔMBLp) after the first *(green)* and the second *(gray)* year in function considering the time of the dental prosthesis placement (DP) as a baseline. A total of four and two pieces of the monitored implants resulted in marginal bone loss greater than 1 mm after the first and the second years in function, respectively.

Table 6 Mean Marginal Bone Level Change—ΔMBLp (DP2y – IM)—Regarding Submersion and Gingival Biotype (mm)

Variable	No. of patients[a, b] (implants)	Mean	SD	95% CI	*P* value[c]	R^2 [%][d]
Insertion						
Submerged	25 (33)	–0.67	0.67	–0.91 to –0.42	$1 \cdot 10^{-10}$	56.1
Nonsubmerged	31 (64)	–0.21	0.40	–0.31 to –0.11		
Biotype						
Thick	30 (66)	–0.26	0.46	–0.37 to –0.14	.006	50.1
Thin	15 (31)	–0.59	0.66	–0.84 to –0.35		

[a]One patient can be included in both of the compared groups; therefore, their sum can be excessive.
[b]The data were processed at the patient level.
[c]Based on the analysis of contrasts within the general linear model analysis.
[d]The determination coefficient.

respectively. In the thick biotype, the MBLp of nonsubmerged implants stayed below the IAJ, MBLp (DP2y) = –0.04 mm (SD: 0.43, n = 44), and the MBLp of submerged implants stayed above the IAJ, MBLp (DP2y) = 0.50 mm (SD: 0.53, n = 22), throughout the follow-up (Fig 8b).

DISCUSSION

This clinical follow-up study was conducted to assess the 2-year success rate of the dental implant system. It was unambiguously proven that the observed mean marginal bone losses, ΔMBLp (DP1y – DP) = –0.12 mm

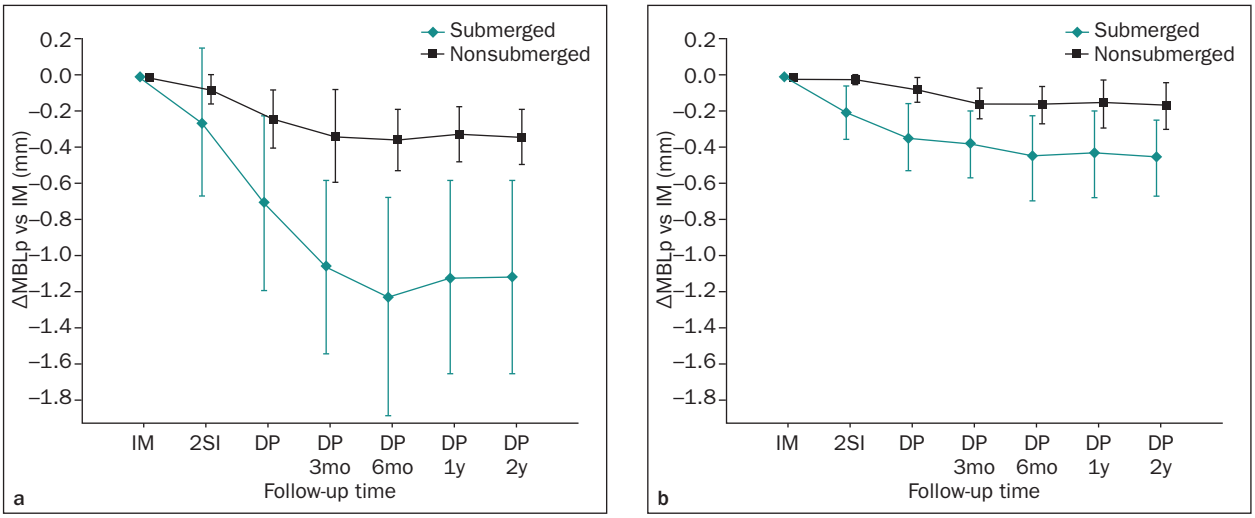

Fig 7 Comparison of the marginal bone resorption depending on the initial implant submersion within the *(a)* thin and *(b)* thick biotypes. The vertical bars represent the 95% confidence intervals. IM = implantation; 2SI = second stage of implantation; DP = dental prosthesis placement; DP3mo = 3 months; DP6mo = 6 months; DP1y = 1 year; DP2y = 2 years of the implant in service.

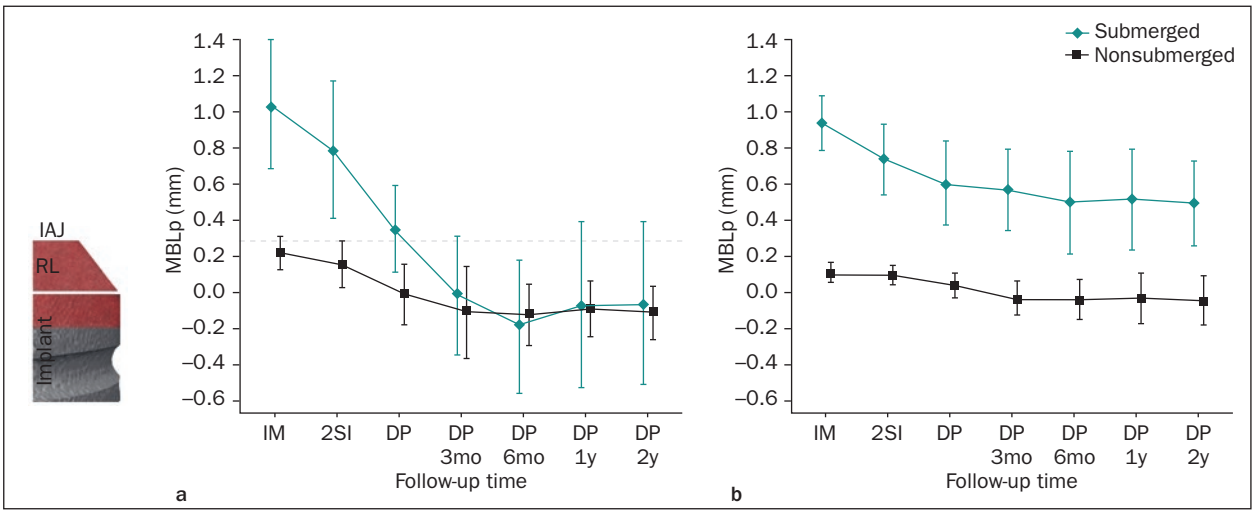

Fig 8 The evolution of the mean marginal bone level (MBLp) according to the initial implant submersion, with respect to the implant dimensions on the left. The moderately rough surface of the implant neck is shown in red. The vertical bars represent the 95% confidence intervals. *(a)* Thin biotype. *(b)* Thick biotype. IM = implantation; 2SI = second stage of implantation; DP = dental prosthesis placement; DP3mo = 3 months; DP6mo = 6 months; DP1y = 1 year; DP2y = 2 years of the implant in service.

(SD: 0.39) and ΔMBLp (DP2y – DP1y) = –0.02 mm (SD: 0.21), are lower than the stated null hypothesis on a significance level of $\alpha = .05$. The hypothesis was based on the consensually accepted standard values (maximum of 0.5 mm bone resorption per first year of loading [half of the standard] and 0.2 mm of bone resorption per second year in function).[27–29]

The results of this study, ΔMBLp (DP2y – IM) = –0.36 mm (SD: 0.55) and ΔMBLp (DP2y – DP) = –0.13 mm (SD: 0.39), are in a concordance with the best documented dental implant systems. Payne et al[37] documented ITI Dental Implants (Straumann), where the ΔMBLp (DP2y – DP) = –0.12 mm (SD: 0.17); Vervaeke et al[24] analyzed Astra Tech implants, where the ΔMBLp reached –0.90 mm (SD: 0.66) after 2 years; and Friberg et al[38] focused on the one-piece smooth-surface Brånemark System implants resulting in the ΔMBLp (DP2y – DP) of approximately –0.34 mm (only results after the first and third years of follow-up are evaluated). The multicenter study by Hämmerle et al[39] and Sanz et al[40] documented the Straumann Bone Level SLActive implants, where the monitored implants were divided into two groups—submerged and transmucosal—showing mean marginal bone changes of –0.68 mm (SD: 0.98) and –0.58 mm (SD: 0.77), respectively, from the IM up to 3 years. Moreover, Sanz et al[40] stated the distribution of bone-level change after 3 years for both groups, where 23% and 18% of

submerged and transmucosal implants, respectively, exhibited bone loss ≥ 1 mm. That is almost three times more than in this study.

Sanz et al[40] also documented that more than half of the total resorption occurred during the first year after the IM, which agrees with results in this study where almost two-thirds of the total bone loss occurred from the IM to the DP ($P = .000002$). Statistically insignificant ($P > .05$) bone loss occurred after the DP3mo, which indicates stabilization of the marginal bone and a steady state of the remodeling of the physiologically loaded bone.

The presented results have also shown greater and statistically significant bone loss around the submerged implants ($P = .005$). Most authors demonstrated the same results.[20,22,24,40–43] Nevertheless, some studies did not prove a statistically significant difference between the tested groups.[21,44]

The analysis of the submersion of the implants with a moderately rough neck, separately in thick and thin biotypes, provides a different way of bone stabilization. In the thin biotype, the bone stabilized at approximately 0.4 mm apically from the IAJ (microgap) independently on the initial submersion. This phenomenon seems to be in accordance with the statement of Hermann et al,[45] who observed that the marginal bone stabilizes in the constant vertical distance from the microgap. In this study, it was suggested that this is caused by the reestablishment of the appropriate biologic width[33,46] and by the attachment of supracrestal connective tissue to the moderately rough BIOsurface on the implant neck. Such connective tissue attachment supported by the abutment epithelial attachment,[11,12] taking place on the polished transmucosal part of the abutment, may finally establish an effective biologic barrier protecting marginal bone. However, submerged implants in the thin biotype had to pay great bone resorption for this kind of bone stabilization.

On the contrary, the thick biotype provided appropriate mucosal tissue thickness (> 2.0 mm) already at the time of implant placement. This biologic width protects marginal bone of both the submerged and nonsubmerged implants in the same way. Therefore, marginal bone loss in the thick biotype is less in comparison with the thin biotype. The difference is that the nonsubmerged implants in the thick biotype, unlike submerged ones, may create the effective connective tissue attachment due to actual mutual position of connective tissue and moderately rough implant neck.

Because of such behavior, it would be more appropriate to nonsubmerge the implants to let the connective tissue integrate with the rough implant neck. This conclusion is also in compliance with those stated by Vervaeke et al,[24] Finne et al,[20] Bae et al,[47] and Jung et al.[48] On the other hand, even though shallow implant insertion causes less resorption compared with deeper insertion, deeper insertion is more preferred when there is still a concern about an unexpected implant neck exposure, and when the risk of dehiscence can occur in thin alveolar bone.

The findings of this study have to be seen in the light of some limitations. For future research, it would be beneficial to measure the soft tissue thickness (biologic width) at the time of implant placement to get more precise description of the biotypes and the biologic width changes. A shortcoming of the study may also be the fact that the compared groups consisted of a different number of patients. Hence, the results of the smaller groups are always determined with greater SDs. The number of treated patients may seem to be quite modest; however, the patients were chosen according to the inclusion criteria described earlier, and therefore, the sample is considered to be representative. Nevertheless, in this study number, deeper analysis involving other factors that can also influence marginal bone behavior is not possible because of the shortage of analyzed samples during separation. Therefore, future studies will focus on other factors associated with implant success. Among the other factors are implant position, implant dimensions, type of definitive abutment, and type of dental prosthesis used. Such factors are often evaluated separately, which may be the reason for different opinions and interpretations of the results by other authors. Within the combination of two factors—biotype and implant submersion—that were evaluated here, this study has included a new factor, the mutual vertical positions of the implant neck with a modified osteoconductive surface and the connective tissue, that may contribute to soft tissue barrier establishment and marginal bone protection. Nevertheless, for a deeper understanding of this issue, more studies have to be undertaken.

CONCLUSIONS

This clinical and radiographic study shows that the implant system seems to be stable and predictable during the 2-year follow-up period, resulting in a 100% success rate according to Buser's criteria. The mean marginal bone loss was significantly lower than the stated hypothesis of 0.5 mm until the first year after the dental prosthesis placement and 0.2 mm per year thereafter.

It was found that the submerged implants and the thin biotype resulted in statistically significantly greater marginal bone loss compared with the nonsubmerged implants and the thick biotype, respectively.

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