Minimum Abutment Height to Eliminate Bone Loss: Influence of Implant Neck Design and Platform Switching

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Purpose: *This retrospective study quantitatively analyzed the minimum prosthetic abutment height to eliminate bone loss after 4.7-mm-diameter implant placement in maxillary bone and how grafting techniques can affect the marginal bone loss in implants placed in maxillary areas.* ***Materials and Methods:*** *Two different implant types with a similar neck design were singularly placed in two groups of patients: the test group, with platform-switched implants, and the control group, with conventional (non–platform-switched) implants. Patients requiring bone augmentation underwent unilateral sinus augmentation using a transcrestal technique with mineralized xenograft. Radiographs were taken immediately after implant placement, after delivery of the prosthetic restoration, and after 12 months of loading.* ***Results:*** *The average mesial and distal marginal bone loss of the control group (25 patients) was significantly more than twice that of the test group (26 patients), while their average abutment height was similar. Linear regression analysis highlighted a statistically significant inverse relationship between marginal bone loss and abutment height in both groups; however, the intercept of the regression line, both mesially and distally, was 50% lower for the test group than for the control group. The marginal bone loss was annulled with an abutment height of 2.5 mm for the test group and 3.0 mm for the control group. No statistically significant differences were found regarding marginal bone loss of implants placed in native maxillary bone compared with those placed in the grafted areas.* ***Conclusion:*** *The results suggest that the shorter the abutment height, the greater the marginal bone loss in cement-retained prostheses. Abutment height showed a greater influence in platform-switched than in non–platform-switched implants on the limitation of marginal bone loss.* Int J Oral Maxillofac Implants 2017 (7 pages). doi: 10.11607/jomi.5604

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The amount of marginal bone loss occurring around implant necks has been used for many years as a criterion for defining long-term implant success.[1] The etiology of marginal bone loss is not well understood, even if several theories have been proposed to explain it.[2] An adaptive change of crestal bone level after implant placement and subsequent prosthetic restoration was first described by Adell et al.[3] Subsequently, some authors attributed early bone loss to mechanical stresses transferred from the coronal part of the implant to the alveolar crest[4] or, around cement-retained prostheses, to 'foreign-body reaction' stimulated by the presence of cement in soft tissues.[5] Other studies, however, suggested that crestal bone loss may be related to the presence of a microgap at the implant-abutment interface.[6] Irrespective of the implant system used, this internal space of approximately 10 microns would invariably be colonized by bacteria,[7] causing inflammatory cell infiltration around the implant-abutment microgap, as histologically demonstrated in a dog model.[8]

A subsequent report suggested that bone resorption would be reduced as a consequence of increased distance between the bone crest and the area of inflammation produced by bacteria in the implant-abutment microgap.[9] Consequently, a narrow abutment and the resulting mismatch with the implant neck (ie, the platform-switching concept) could reduce the vertical component of biologic width and generate a

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greater horizontal distance, limiting inflammatory cell infiltration and resulting crestal bone loss.[10] This concept could explain the clinical effectiveness of platform switching in the prevention of peri-implant marginal bone loss.[11] In addition, other factors related to implant neck design, such as the use of microthreads and modifications in implant surface characteristics, could preserve peri-implant bone.[12,13]

However, the influence of mucosal thickness and biologic width formation on marginal bone loss around implant necks has been discussed by Cochran et al,[14] who suggested that soft tissues serve as a protective mechanism for underlying crestal bone. Moreover, some studies hypothesized that the limited amount of marginal bone loss, ranging between 1.5 and 2.0 mm, could occur to provide space for the reestablishment of the biologic width around the implant neck[15] and remains constant over time after delivery of a prosthetic restoration.[16] Therefore, it could be concluded that marginal bone loss should be influenced more by the prosthetic phase than by postsurgical bone remodeling and healing processes.[17]

More recently, some authors demonstrated significantly higher marginal bone loss rates around implants with shorter compared with longer prosthetic abutments.[18,19] In agreement with these data, the marginal bone loss around healthy implants could be produced by the simultaneous actions of two different factors: the biologic width reestablishment and the inflammation caused by bacteria present in the microgap forming around implant-prosthesis connections. Recently, Galindo-Moreno and coworkers also demonstrated that the height of the abutment plays a critical role in the marginal bone maintenance in screw-retained prostheses, in spite of the platform-switching distance.[20] Theoretically, the placement of platform-switched implants and the use of high abutments connecting cemented crowns to implants would provide greater height for biologic width reestablishment, allow easier removal of excess cement from soft tissues, and reduce bacteria-induced inflammation, consequently decreasing marginal bone loss around implants.

Bone features also play a role in the marginal bone loss around implants. Simons et al demonstrated that the ratio of cortical to medullar bone is a key factor in bone resorption around implants, and consequently that cortical bone could jeopardize the bone maintenance in the critical cervical area.[21] In this sense, implants placed in type 4 bone have demonstrated the best behavior in terms of marginal bone loss and success in comparison to those placed in any other locations.[22] However, in terms of implant placement, there is an important limitation in the area where type 4 bone is located due to the presence of the maxillary sinus and the availability of disposable native bone, which often requires grafting in order to place implants in this region. There has been debate about marginal bone in implants placed in maxillary grafted areas and how this remnant native bone is affected by types of grafting techniques.[23,24] Finite element analyses have shown that the load distribution and marginal bone loss around implants placed in grafted sinus cavities may be strongly conditioned by the characteristics of the grafting material.[25,26] Huang and coworkers reported that if the grafted area was less stiff than the pristine bone, functional loading increased the concomitant stress at the crestal bone level,[27] which is typically associated with marginal bone loss.[28] Clinically, Galindo-Moreno et al observed a slight, but nonetheless significant, greater crestal bone loss around implants placed in grafted bone after sinus augmentation than in pristine bone.[20]

Therefore, the aim of this study was to verify *(1)* the minimum prosthetic abutment height to minimize the bone loss after wide-diameter implant placement in maxillary bone, and *(2)* if this marginal bone loss could be associated with grafting using a transcrestal technique, given that this technique, unlike lateral approaches, uses the same surgical bed for sinus elevation that is created to place the implant.

MATERIALS AND METHODS

Patient Selection

Consecutive Northern Italian adult patients undergoing prosthetic restoration of the posterior maxilla were independently examined and treated by two operators (S.S. and F.B.) in their private dental offices. Patients required placement of a single delayed posterior implant adjacent to natural teeth in the presence of at least 6 mm of ridge width below the maxillary sinus floor and in presence of occlusal contacts with the opposing dentition. Additional inclusion criteria were good general health, nonsmokers, absence of diseases affecting bone metabolism and wound healing, absence of uncontrolled periodontitis, no specific disease of the maxillary sinus, and no regular medication consumption for at least 3 months prior to treatment. Patients were instructed in oral hygiene and, when necessary, treated with nonsurgical periodontal therapy before implant insertion. Crestal bone height and sinus health were checked by pre-op CBCT.

Contrary to public and private health centers, Italian law neither contemplates nor provides any form of ethical committee approval for clinical research performed in private dental offices. Nevertheless, all research was conducted in full accordance with ethical principles, including the 2008 WMA Helsinki Declaration.[29] All patients signed the informed consent in which all procedures of the study were detailed.

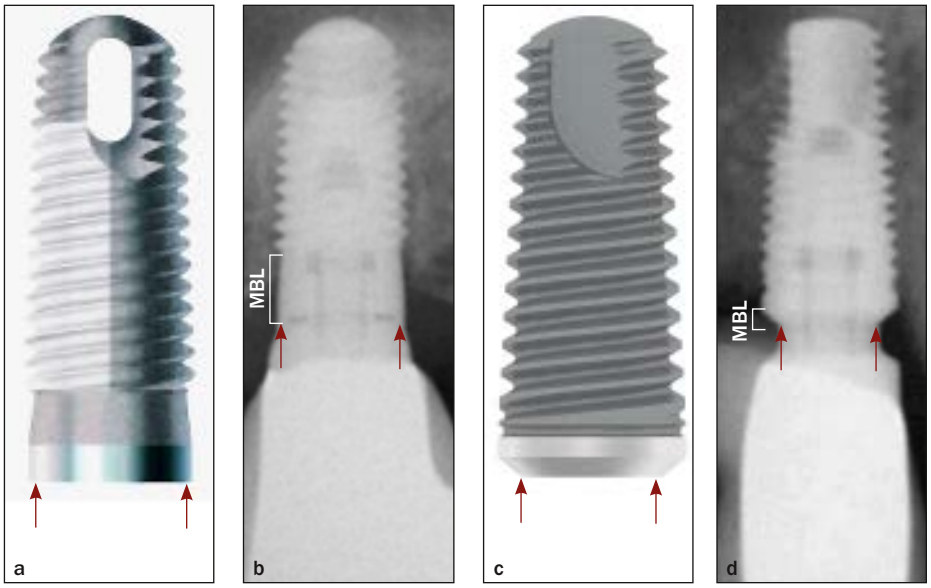

Fig 1 Marginal bone loss (MBL) was calculated by linear measurement of the distance between two points, the most coronal point of the implant platform and the most coronal bone-to-implant contact. The red arrows indicate the implant platform reference points in both the (*a*, *b*) control group (non–platform-switched) and (*c*, *d*) test group (platform-switched) implants.

Surgical Procedure

Under local anesthesia, a full-thickness flap was opened and the implant site was initiated with a small-diameter pilot drill using a prefabricated surgical guide.

Two wide-diameter implant types were used in this study: For the control group, Screw Vent Tapered, 4.7-mm diameter (Zimmer Dental, cat. nr. TSVWB10/11) conventional implants with internal abutment connection and a 1-mm machined collar, without platform-switched design; and for the test group, Shape1, 4.7-mm diameter (I-RES, cat. nr. S1B47 10C/11C) implants with internal abutment connection and a 1-mm machined collar, with platform-switched design.

Patients with at least 6 mm of crestal bone height and requiring bone augmentation underwent a crestal sinus augmentation procedure (sequential drills Coscitechnique)[30] with mineralized xenografts (Smartbone, IBI), thus forming the graft subgroup. An implant of 10 or 11.5 mm in length was then inserted at the crestal bone level.

Patients with at least 10 mm of crestal bone height and not requiring bone augmentation, thus forming the no-graft subgroup, received a 10- or 11.5-mm implant inserted at the crestal bone level using conventional implant protocol.

Antibiotic and germicidal mouthwash treatment was performed after surgery. Sutures were removed 12 to 14 days later. During the healing period, no removable prostheses were used by patients.

Implants were exposed 4 months after their insertion. Healing abutments were placed during this second surgical phase, and implant-supported prostheses were delivered approximately 4 weeks later. The height of the customized titanium abutments used to connect crown to implant were chosen for each patient in order to obtain optimal crown retention and an acceptable esthetic emergence profile. The finished abutments were torqued to 30 Ncm, and all single-tooth restorations were cemented. A thin layer of petroleum jelly was placed on the apical margin of the crown immediately before cementation to facilitate excess cement removal from the porcelain surface. After cementation, particular care was taken to remove excess cement using curettes and dental floss. This same procedure was accurately reperformed 1 week later by an external hygienist.

Radiography

Digital radiographs were taken using a long-cone paralleling technique with a Rinn-type film holder at the times of surgical implant placement, final prosthetic restoration delivery (baseline), and 12 months after prosthetic loading.

Marginal bone loss was calculated by linear measurement of the distance between two points, the most coronal point of the implant platform, and the most coronal bone-to-implant contact (Fig 1) on each radiograph corrected referring to the known height (10 or 11.5 mm) and diameter (4.7 mm) of each implant. The vertical distance between the most coronal point of the implant platform and the most coronal bone-to-implant contact was measured on both mesial and distal sides of each radiograph at baseline and at the12-month follow-up. Mesial and distal marginal bone loss were calculated as bone changes between baseline and 12 months. Therefore, an increase in vertical distance between the implant platform reference point and crestal bone (the most coronal bone-to-implant contact) in the two radiographs taken at

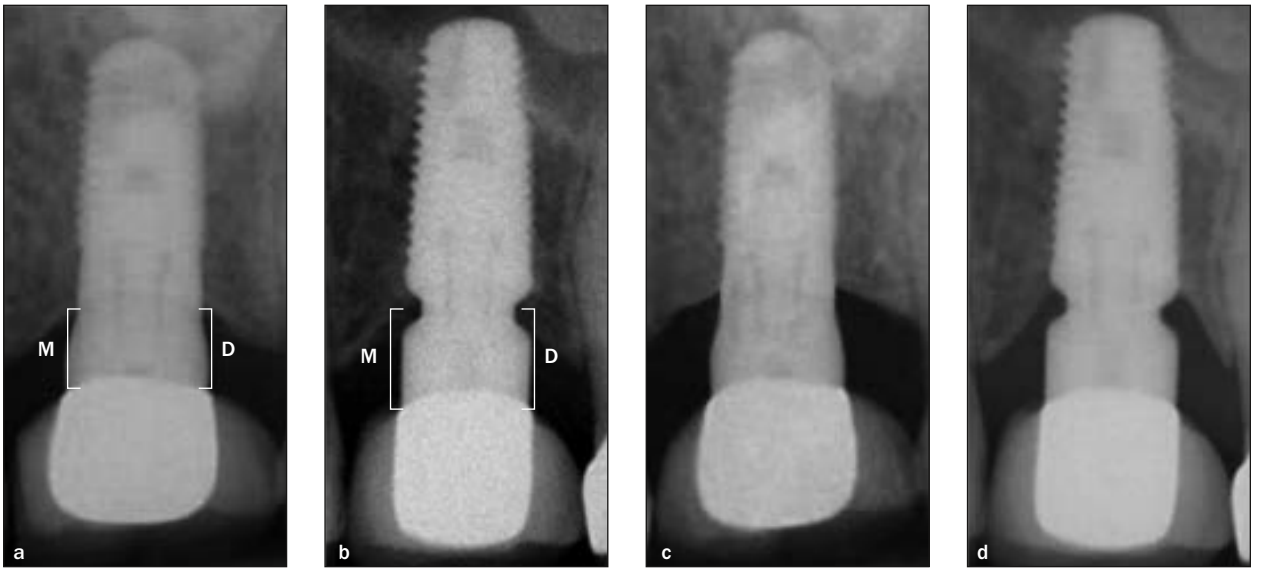

Fig 2 Radiographs showing abutment height linear measurements, taken mesially (M) and distally (D) from the most coronal point of the implant platform to the lowest point of the edge of the crown, of the two implant types: *(a)* control group (non–platform-switched) at baseline; *(b)* test group (platform-switched) at baseline; *(c)* control group after 12 months; *(d)* test group after 12 months.

baseline and at 12 months was considered indicative of bone loss, while a decrease in distance was considered indicative of bone gain (Fig 1).

Abutment height was calculated mesially and distally by linear measurements, taken from the most coronal point of the implant platform to the lowest point of the edge of the cemented crown (Fig 2).

Radiographs showing signs of deformation, darkness, or other complications were retaken. Kodak Digital Imaging Software was used to measure radiographs (to the nearest 0.01 mm) by an impartial examiner (D.Z.).

Statistical Analysis

Statistical analysis was performed by Primer of Biostatistics,[31] using the one-way analysis of variance (ANOVA) test to compare results. Post-hoc power analysis for testing the hypothesis (based on kM results) was performed (assuming error type I = 0.05).[32] Simple linear regression was used to analyze trends. Overall analysis for coincidence was performed to compare the two regression lines. The critical significance level of $P < .05$ was used to reject the null hypothesis H_0.

RESULTS

This retrospective study analyzed a total of 51 implants placed in 51 selected patients (28 females and 23 males aged between 25 and 75 years, mean 47.6 years); 23 patients underwent unilateral maxillary sinus augmentations (grafted sites). A total of 25 Screw Vent Tapered (non–platform-switched) implants was inserted (control group), 15 in nongrafted sites and 10 in grafted sites. A total of 26 Shape1 (platform-switched) implants was inserted (test group), 13 in nongrafted sites and 13 in grafted sites (Table 1). The mean patient age was similar not only across both implant groups ($P = .21$), but also across both grafting subgroups ($P = .21$ and.43, respectively) (Table 1). Primary wound closure was obtained in all surgeries, and no complaints or adverse effects were registered or observed during follow-up.

Within the control and test groups, no statistical difference ($P > .1$) was found when comparing average mesial and distal (Fig 2) marginal bone loss (control group, range 0–2.3 mm; test group, range 0–1.4 mm) or when comparing mesial and distal abutment height (control group, range 0–3.9 mm; test group, range 0.3–3.5 mm) of the no-graft subgroups with those of the graft subgroups (Table 1). After subgroup data merging, results showed that control and test groups had a similar average mesial and distal abutment height (Table 1), while both average mesial and average distal marginal bone loss at 12 months (Table 1) were always greater in the control group (mesial +0.48 mm, distal +0.52 mm) than in test group, with high statistical significance ($P = .002$ and .001, respectively).

In both control and test groups, the simple linear regressions of mesial and distal marginal bone loss (Fig 3) had a significant inverse relationship ($P < .001$) with their corresponding abutment heights. Specifically, marginal bone loss was greater (1.4–2.3 mm) when abutment height was close to 0 mm, while marginal bone loss was close to 0 mm when abutment height was greater (3.5–3.9 mm). Both mesially and distally,

Table 1 Gender and Mean (± SD) Age, Marginal Bone Loss, and Abutment Height of Patient Groups

	Control group (conventional implants)				Test group (platform-switched implants)			
	No-graft	Graft	All	*P*	No-graft	Graft	All	*P*
Gender	11 F; 4 M	7 F; 3 M			4 F; 9 M	6 F; 7 M		
Age	47.8 ± 12.66	42.3 ± 5.38		.21	51.2 ± 7.11	47.7 ± 13.89		.43
			45.6 ± 10.58				49.4 ± 10.96	.21
Mesial MBL	0.83 ± 0.75	0.7 ± 0.59		.65	0.31 ± 0.32	0.28 ± 0.38		.82
			0.78 ± 0.68				**0.30 ± 0.34**	.002
Distal MBL	0.90 ± 0.73	0.91 ± 0.62		.47	0.40 ± 0.33	0.36 ± 0.42		.14
			0.90 ± 0.67				**0.38 ± 0.37**	.001
Mesial AH	1.67 ± 1.20	1.67 ± 0.79		.98	1.77 ± 0.64	2.00 ± 0.91		.45
			1.67 ± 1.04				1.88 ± 0.78	.41
Distal AH	1.59 ± 1.12	1.76 ± 0.98		.69	1.66 ± 0.78	2.08 ± 0.88		.22
			1.66 ± 1.05				1.87 ± 0.84	.43

F = female; M = male; MBL = marginal bone loss; AH = abutment height; *P* = probability after ANOVA test.
Numbers in bold represent statistical significance.

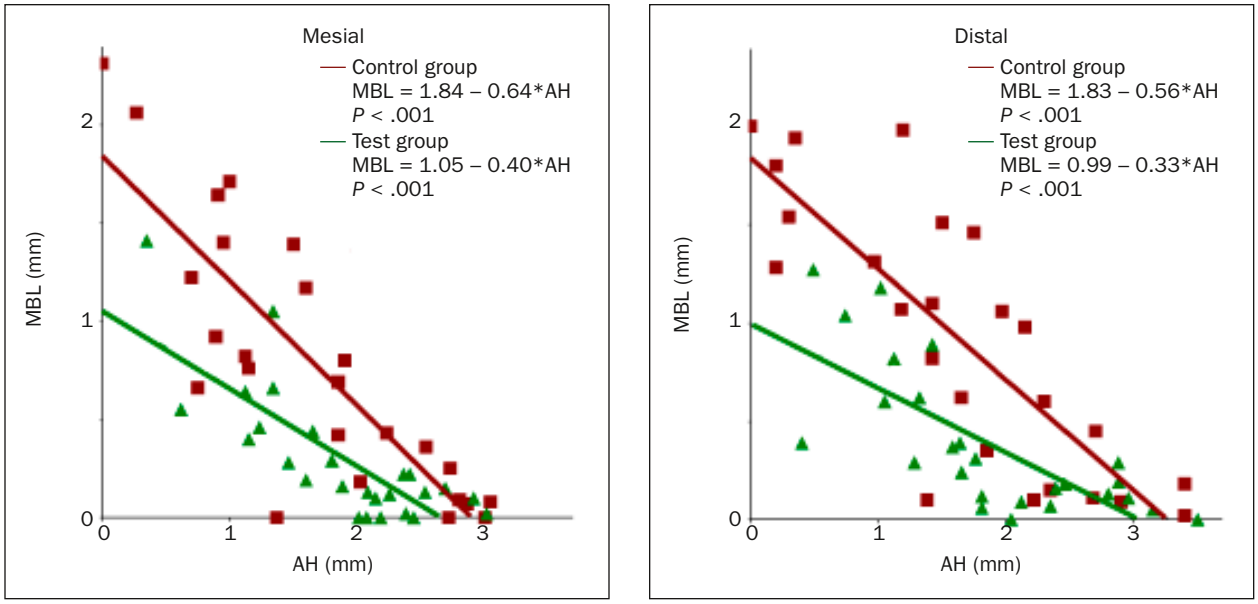

Fig 3 Trend of mesial and distal marginal bone loss (MBL, y axis), recorded 12 months after implant insertion in relation to mesial and distal abutment height (AH, x axis) of the 51 patients. Note in both test and control groups: *(1)* the inverse marginal bone loss relationship with abutment height, *(2)* the highly significant correlation (*) of all regression lines, and *(3)* the lower intercept value of test-group regression lines.

the two regression lines of the control and test groups had a slope of negative value, close to 0.4 in the test group and a value approximately 50% greater in the control group (Fig 3). Nevertheless, the intercept of control-group regression lines was twice that of the test group (approximately 1.0 mm). Moreover, overall analysis of the coincidence of the regression lines of the control and test groups showed a statistical significance (degrees of freedom, 2 numerator and 47 denominator; mesial, F = 10.8, *P* = .001; distal: F = 12.7, *P* = .001) between the two lines.

The regression lines allow calculation of the theoretical minimum abutment height annulling the marginal bone loss: 2.5 mm (test group) and 3.0 mm (control group) at the mesial aspect, and 3.0 mm (test group) and 3.3 mm (control group) at the distal aspect.

DISCUSSION

The platform-switching concept seeks to eliminate oral microflora and consequent inflammatory response from crestal bone in order to limit bone resorption and thus reestablish biologic width.[9,10] The present study confirms that the platform-switching concept can minimize marginal bone loss over a 1-year period,

in agreement with a previous trial[11] and recent meta-analysis.[33] Specifically, average marginal bone loss around non–platform-switched implants (0.78 mm mesially and 0.90 mm distally) was more than twice the average marginal bone loss around platform-switched implants (0.30 mm mesially and 0.38 mm distally).

The hypothetical inverse correlation between the degree of mismatching distance and extent of marginal bone loss suggested in some articles[11] was not investigated in the present study because only one type of platform-switched and one type of non–platform-switched implants were compared. A limitation of this study was due to the slight heterogeneity of the two implant neck designs. In fact, the two groups differ in neck design not only in terms of the presence/absence of platform-switching design, but also in terms of the presence/absence of threads and different surface textures. On the other hand, all implants had the same 4.7-mm diameter, a machined collar, and hexagonal internal connection. It can therefore be stated that not only the platform-switching design but also the aforementioned implant neck-shape factors might contribute to minimizing crestal bone loss.

The present study found that in both implant groups, marginal bone loss was significantly determined by abutment height, in close agreement with Galindo-Moreno et al.[18] However, that study examined only screw-retained prostheses. Therefore, the present study is the first to demonstrate that around implants with cement-retained prostheses, the shorter the abutment height, the greater the marginal bone loss. From a clinical point of view, the presence of a high abutment could allow easier excess cement removal, preventing bone loss progression in cement-retained restorations.[34]

An interesting goal of the present study was to calculate the optimal distance from the prosthetic crown to the bone crest to eliminate bone loss. The optimal distance was evaluated as being 2 mm in a previous study,[18] which used standardized uni-abutments of 0, 0.5, 1, 2, or 4 mm to connect implants to screw-retained restorations. However, in the present study, only customized abutments were used to connect implants to cement-retained restorations. The regression line analyses indicate an inverse relationship between marginal bone loss and abutment height. The two implant types had marginal bone loss close to 2.0 mm in the control group and 1.0 mm in the test group when the abutment height was zero. However, as abutment height (distance from the prosthetic crown to the bone crest) increased, marginal bone loss tended toward zero. The distance at which marginal bone loss became zero was estimated as being 2.5 mm for platform-switched implants and 3.0 mm for non–platform-switched implants. The inferior amount of marginal bone loss recorded in platform-switched implants can be explained by the fact that the vertical space required for the reestablishment of the biologic width was less for platform-switched implants due to the mismatching between the implant neck and a narrower abutment creating a greater horizontal space for such biologic width reestablishment. In non–platform-switched implants, however, only vertical space exists for biologic width reestablishment. Consequently, in the limitation of marginal bone loss, abutment height is of greater significance in platform-switched implants than in non–platform-switched implants, probably due to a synergic action of these two factors.

Linkevicius et al[35] stated that keratinized tissue width may be an important factor in limiting peri-implant marginal bone loss, with 2 mm being the minimum width of keratinized tissue required to preserve crestal bone around implant necks. In the present study, however, prosthetic abutment height was chosen in order to maximize cemented crown retention and to improve the esthetic emergence profile. Consequently, abutment height was not determined by soft tissue width, in agreement with a recent study, in which the use of prosthetic abutments shorter than 2 mm significantly increased marginal bone loss irrespectively of keratinized tissue width.[18] In fact, keratinized tissue can be compressed apically[36] by short abutments and subsequent crown placement, reducing the distance from the prosthetic crown to crestal bone. These concepts partially disagreed with Vervaeke et al,[19] who hypothesized that abutment height should reflect soft tissue width. In fact, in this latter study, abutments were placed at the time of implant placement and heights were adapted to site-specific soft tissue width.

In relation to the bone substratum, grafted areas should theoretically behave differently than native bone when subjected to loading forces.[37] In the present study, the bone substratum was found to have no significant role in marginal bone loss around either platform-switched or non–platform-switched implants, in slight disagreement with previous clinical trials.[17,38] However, in the aforementioned study,[37] sinus augmentation procedures by lateral window were performed, meaning that an extensive area was grafted and subjected to long and significant graft resorption and new bone regeneration. On the contrary, only small amounts of graft were utilized in the present study, as crestal sinus augmentation procedures were performed with at least 6 mm of basal bone. These two different surgical techniques could have produced two dissimilar "bone substrata," which may lead to a different loading force distribution at the crestal level.

CONCLUSIONS

Within the limits of this study, the following conclusions can be drawn: *(1)* the shorter the prosthetic abutment height, the greater the marginal bone loss

around implants with cement-retained prostheses; *(2)* regarding limitation of marginal bone loss, abutment height benefits are maximized by platform-switched rather than non–platform-switched implants.

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