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Original

A 36-month follow-up prospective cohort study on peri-implant bone loss of Morse Taper connection implants with platform switching

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Abstract: A prospective cohort study was designed to measure marginal bone level changes at 36-month follow-up and to evaluate the influence of biologically relevant, anatomic and stress-related variables. STROBE guidelines were followed. Totally, 748 implants were inserted into 350 patients. Standardized periapical radiographs were taken at 2- (stage-two surgery), 12-, 24-, and 36-month follow-ups. Descriptive statistics were used and inter- and intra-examiner reliability were determined. A mixed-model was used to evaluate predictor variables. Statistical analysis was performed at implant level (statistical significance: $P < 0.05$). A total of 34 (4.5%) implants failed; of the 34 implants, 6 were early failures (0.8%) and 28 were late failures (3.7%). A total of 576 implants reached 36-month follow-up (mean follow-up: 25.58 months; SD: 10.32). Mean marginal bone remodeling was −0.56 mm. (SD: 1.30; range: −6.80 ± 3.65). A statistically significant, higher marginal bone loss was found for subcrestal implants and subcrestal implants inserted into the maxilla, for implants inserted into patients aged over 50 years, and for early-delayed implants inserted into patients aged over 50 years. In conclusion, a low, mean crestal bone loss at 36-month follow-up was recorded but implant positioning in the apico-occlusal dimension was found to be the most significant variable that influenced bone loss.
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Keywords: dental implant platform switching; Morse Taper dental implant-abutment connection; prospective study; dental radiography.

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Introduction

The replacement of missing teeth with implant-borne restorations has become a treatment modality accepted for partially and completely edentulous patients (1). Implant marginal bone loss seems to be unavoidable, especially after abutments connection, and minimal or no marginal bone loss after implant-abutment connection is considered to be an indicator of long-term success of implant restoration (2,3). Modifications of the implant-abutment connection were made over the last few years to prevent or reduce marginal bone loss and platform switching, and Morse Taper connections or one-piece implants have been proposed as suitable alternatives (4).

The primary aim of this study was to measure marginal bone level changes in the time period between initial implant loading and 36-month follow-up, when Morse Taper connection implants with platform switch were used. The secondary aim was to evaluate the influence of biologically relevant, anatomic and stress-related variables. It was hypothesized that peri-implant bone loss would already be present after the implant-abutment connection. Furthermore, it was hypothesized that at least one variable would be associated with increased rates of

peri-implant bone loss that the clinician would be able to modify to improve the outcome.

Materials and Methods

The present, prospective cohort study was conducted at the Department of Oral and Maxillofacial Sciences of Sapienza University of Rome between February 2008 and February 2013. The STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines for prospective cohort studies were followed. The clinical investigation for the present study was conducted in accordance with the ethical principles of the World Medical Association Declaration of Helsinki and the laws of Italy. The clinical investigation was undertaken after informing patients of the content, risk, and benefits of the study and after obtaining written consent from each participant. The investigation was independently reviewed and approved by the Ethics Committee of Policlinico Umberto I, Rome, Italy (Prot.304/07).

The main inclusion criteria were as follows: 1) systemically healthy patients between the ages of 18 and 85 years who were in need of an implant-supported, fixed dental prosthesis (IFDP) or an implant-supported single crown (ISC), 2) presence of bone volume (minimum 2 mm of bone around the implant) in prospective implant regions sufficient enough to receive implants with a diameter of at least 3.5 mm and minimal length of 10 mm, 3) patients who were in a stable occlusal relationship with no parafunctional habits (clenching and/or bruxing), and 4) implant sites that were free of infection and/or tooth remnants. The exclusion criteria were as follows: 1) alcohol or drug abuse, 2) smoking more than 10 cigarettes per day, 3) general health conditions not conducive to a surgical procedure, 4) local contraindications, such as tumors and ulcers, and 5) indications (or reasons to believe) that the treatment might have a negative effect on the patient's psychological situation.

Each patient had undergone clinical and radiographic examinations before the treatment began. The areas of implantation were evaluated with orthopanoramic and intraoral periapical radiographies. A CT was required only when clinicians had diagnostic doubts. The two-piece, cylindrical implant, made from Ti 6Al-4V alloy (grade 5) and characterized by a modified sand-blasted/acid-etched titanium surface (SLA), extended onto the implant shoulder with a Morse Taper connection was used. The abutments had smaller diameters than their respective implants platforms (platform-switching) (Osseothread, Impladent, Formia, LT, Italy). The implant lengths used were 10, 12, and 14 mm and the diameters were 3.5, 4.2, 4.8, 5.5, and 6.5 mm.

Antibiotic therapy (1 g of amoxicillin) was prescribed 1 h before intervention and twice a day post-intervention for 5 days. All patients were treated with two-stage, implant surgery and a cemented provisional acrylic restoration 2 months after implant insertion. In no case was a temporary removable prosthesis used to avoid hampering the healing process. The abutment, which was placed permanently by the operator, was milled and refined chairside when necessary. The definitive restoration, a conventional metal-ceramic, ISC or a conventional metal-ceramic, IFDP was delivered at 6-month follow-up. The impression was made from the abutment level. The dental prostheses were cemented using glass ionomer cement (KetacTM Cem, 3M Espe, Neuss, Germany). The cement remnants were carefully removed.

If any mucositis or peri-implantitis did occur, affected implants were included in recalls for special care. If this treatment resulted in persistent inflammation or showed an initial mobility, it was considered unsuccessful and the implants were removed. The level of the marginal bone was recorded by taking standardized radiographs. Standardized periapical radiographs were obtained with the use of the long-cone parallel technique and the Rinn XPC (Rinn XCP, Dentsply Rinn, Elgin, IL, USA) film-holding system. Care was taken to parallel the alignment of the x-ray film in the film holder to the long axis of the implants. Digital radiographs were stored using a digital intraoral imaging system (DenOptix QST Digital X-ray Phosphor Plate System Gendex, Hatfield, PA, USA). The stored images were displayed on a monitor and direct measurements were performed using dental imaging software (VixWinPRO, Gendex). Linear measurements from the implant shoulder to marginal bone level were obtained mesially and distally using the software program to analyze each image (Fig. 1). The radiographs at the time of implant-abutment connection and prosthetic loading (T0) were used as baseline values (Fig. 2B).

Baseline measurements (T0) were used to determine the amount of marginal bone remodeling at 12-, 24-, and 36-month follow-ups (Fig. 2C-E). These measurements were either a positive number (if the marginal bone level was coronal to implant shoulder), zero (when the marginal bone level was located at the implant shoulder), or a negative number (if the marginal bone level was located apical to the implant shoulder). The average change in mesio-distal, peri-implant bone levels (AvBL) was obtained for each implant. An object of known size (i.e., the known length of the implant) was used to make calibrated measurements. The two researchers, who evaluated the radiographs independently (S.C.; M.G.),

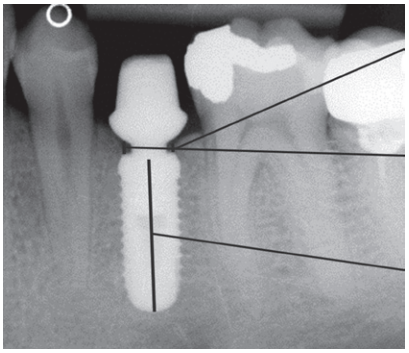

Fig. 1 Image of a single implant, diameter 4.8 mm and length 12 mm, inserted 4 weeks after the extraction of 3.5 fractured (early delayed implant placement). To adjust the measurements for magnification error, the following equation was used to determine the corrected crestal bone levels: Corrected crestal bone level = Measured crestal bone level X (actual implant length e.g., length of implant based on manufacturing standards/measured implant length).

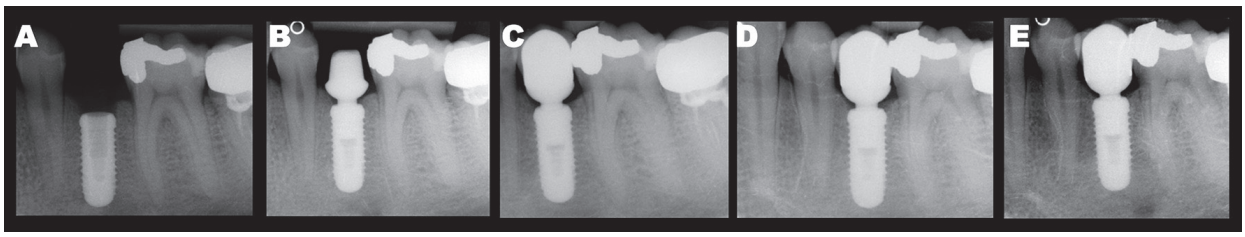

Fig. 2 The marginal bone level at the time of implant placement below the ridge (A), at 2- (B), 12- (C), 24- (D), 36-month follow-ups (T3) (E) by taking standardized periapical radiograph.

were not involved in the clinical part of the investigation.

Inter-examiner and intra-examiner reliability were determined. To determine intra-examiner reliability, each examiner measured and re-measured a set of 25 random implants. The measurements were made 2 months apart. To determine inter-examiner reliability, each examiner measured the set of 25 random implants previously measured by the other examiner. Kappa statistics were used to compute intra- and inter-examiner reliability. The intra-examiner kappa coefficients were 0.86 and 0.84, respectively. The inter-examiner kappa coefficient was 0.79.

The predictor variables (i.e., clinical exposures factors correlated with changes in peri-implant bone level) were grouped into the following categories: 1) biologically relevant variables; sex (male or female) and age. The study population was differentiated into two groups according to the age at the time of implant placement, age ≤50 years and age >50 years. Placement depth of inserted implant; the position of the implant shoulder, related to the average values of mesial and distal bone levels, clinically determined at the time of insertion, allowed the division of the study population into two classes (crestal implants, with the implant shoulder placed within 0.5 mm or less of the alveolar ridge level, and sub-crestal implants, with the implant shoulder placed at least 0.5 mm below the alveolar ridge level). Implant placement timing; classified in relation to tooth extraction in two categories ("early delayed", defined as implant placement 4 weeks after tooth extraction, and "prolonged delayed", defined as implant placement ≥3 months after tooth extraction). 2) anatomic variables; jaw (maxilla or mandible) and implant location (anterior, incisive and canine area, or posterior, premolar and molar area). 3) stress-related variables; stress is defined as a force divided by the functional area over which it is applied. Stress-related variables were divided into two groups (force and area factors). Force factors are dental factors that increase or decrease the stress exerted on dental implants. The numbers of implants that support the prosthetic rehabilitation are force factors. The study sample was divided on the basis of the type of prosthetic restoration in ISC or IFDP, supported by two or more implants. The area factors, variables known to increase or decrease the surface area on dental implants, are represented by the following: implant width and length. Considering the length, the sample was divided into three subgroups: long implants (14 mm), standard implants (12 mm), and short implants (10 mm). Considering the width, the sample was divided into three subgroups: narrow implants,

Table 1 Descriptive analysis of bone loss at 36-month follow-up based on the variables evaluated

Variables		T-36 months					
		n	%	Mean	Std	Min	Max
Sex	F	370	64.2%	−0.57	1.32	−6.8	3.1
	M	206	35.8%	−0.57	1.3	−3.75	3.65
Class of age	>50	398	69.1%	−0.65	1.33	−6.8	3.1
	≤50	178	30.9%	−0.39	1.26	−3.1	3.65
Implant depth	Crestal implant	132	22.9%	−0.2	0.94	−1.85	3.1
	Sub-crestal implant	444	77.1%	−0.68	1.38	−6.8	3.65
Time of implant placement	Early delayed	300	52.1%	−0.51	1.42	−6.8	3.65
	Prolonged delayed	276	47.9%	−0.64	1.18	−3.65	2.25
Jaw	Mandible	294	51.0%	−0.37	1.23	−3.55	3.65
	Maxilla	282	49.0%	−0.78	1.36	−6.8	3.1
Implant location	Anterior	90	15.6%	−1.04	1.34	−4.25	2
	Posterior	486	84.4%	−0.48	1.29	−6.8	3.65
Type of prosthesis	Partial fixed dental prosthesis	394	68.4%	−0.67	1.28	−6.8	2.95
	Single crown	182	31.6%	−0.35	1.34	−4.25	3.65
Implant diameter	Narrow	174	30.2%	−0.72	1.06	−3.15	2.7
	Standard	192	33.3%	−0.7	1.22	−3.65	2.25
	Wide	210	36.5%	−0.32	1.53	−6.8	3.65
Implant length	Long	100	17.4%	−0.77	1.3	−4.25	2.7
	Short	214	37.2%	−0.62	1.22	−3.75	3.1
	Standard	262	45.5%	−0.45	1.37	−6.8	3.65

n = 576
Number of implants (*n*), Rate (%), Mean, Standard deviations (Std), Minimum (Min), and Maximum (Max) values.

diameter 3.5 mm; standard implants, diameter 4.2 mm; and wide implants, diameter 4.8 mm, 5.5 mm, and 6.5 mm. The horizontal displacement (platform-switch) was different according to different implant diameters (i.e., the abutments had a smaller diameter than their respective implants platforms that vary according to the implant diameter).

To reduce potential sources of bias, the same operator, a prosthodontist and oral surgeon with 25 years of experience, performed all surgeries, prosthetic rehabilitations, and follow-ups (M.C.). Two researchers, who were not involved in the clinical part of the investigation, evaluated the periapical radiographs independently (S.C., M.G.).

Descriptive statistics, including mean values and standard deviations, were used. A database was created with appropriate checks to identify errors. Statistical analysis was performed at implant level. A mixed model was used to evaluate the predictor variables at 12, 24, and 36 months. A single model was used for every time considered. The response variables were the changes in marginal bone level at 12, 24, and 36 months, respectively. Fixed and random effects were the same for each model. The random effect considered was the patient identification code. The correlation among multiple implants inserted into a single patient, intraclass correlation coefficient (ICC), was considered. An estimated intraclass correlation close to 0 was designated to show that the genetic component was strong. Initially, for each follow-up, all single variables and all double possible interactions between variables were taken into the model. Single variables and interactions between non-significant variables were not included in the final model. If a single variable initially considered not significant became significant when included in an interaction, it was taken into consideration for the final model at that time. The fixed effects that were included in the final mixed-model were as follows: implant depth, implant placement timing, age, jaw, implant placement timing × age, and implant depth × jaw. Significance was assessed using the Type 3 test. The Type 3 test examined the significance of an effect with all other effects in the considered model. Sensitivity analyses were conducted by removing one or more variables from the models and controlling for the robustness of the results. Multiple comparison analyses of the predicted means (LS-means) for all significant variables were performed. The Tukey-Kramer adjustment for the *P* values and confidence limits for the differences of LS-means for unbalanced data was used. A *P* value less than 0.05 was considered statistically significant.

Results

A total of 434 patients were assessed for eligibility. Of the 434 patients, 80 were not eligible, because they had failed to meet inclusion criteria. Two patients did not provide consent. A total of 352 patients were consecutively enrolled in this study and treated. During

Table 2 Estimated intraclass correlation (ICC) parameters

ICC parameter	Bone loss at T-12 months				Bone loss at T-24 months				Bone loss at T-36 months			
	Estimate	SE	Z Value	Pr > Z	Estimate	SE	Z Value	Pr > Z	Estimate	SE	Z Value	Pr > Z
Patient code	0.3500	0.1317	2.66	0.0039*	0.3240	0.1410	2.30	0.0108*	0.4283	0.1781	2.41	0.0081*
Residual	0.9876	0.1167	8.46	<0.0001*	1.1968	0.1386	8.63	<0.0001*	1.1360	0.1464	7.76	<0.0001*

*: A *P* value <0.05 indicates that both covariance parameters are statistically significant.

Table 3 Type 3 tests of fixed effects: results of hypothesis tests for significance of each fixed effect in the mixed model

Variables	Bone loss at T-12 months		Bone loss at T-24 months		Bone loss at T-36 months	
	F value	Pr > F	F value	Pr > F	F value	Pr > F
Implant depth	1.78	0.1845	5.26	0.0234*	5.38	0.0219*
Age	0.08	0.779	3.89	0.0507	4.02	0.0471*
Implant placement timing	1.52	0.2199	0.95	0.3315	0.09	0.7633
Jaw	1.12	0.2914	1.87	0.1739	1.21	0.2728
Age* implant placement timing	1.21	0.2735	2.87	0.0924	4.09	0.0452*
Implant depth* jaw	1.44	0.2314	4.5	0.0356*	7.05	0.0089*

*: A *P* value <0.05 indicates that both covariance parameters are statistically significant.

follow-up, two patients died and were removed from the sample. No other patients dropped out.

A total of 748 implants were inserted into a patient pool of 350 patients (*n* = 188 females [53.7%]; *n* = 162 males [46.3%]; age range at time of implant placement [20-82 years]; mean, 55.09 years [SD: 12.85]). Of the 748 implants inserted, 34 (4.5%) failed; six were early failures (0.8%) before loading, and 28 were late failures (3.7%) after loading. In all of these cases, failure was due to peri-implant tissue infection with varying degrees of suppuration and progressive bone loss.

The 36-month follow-up was reached by 576 implants. The average length of follow-up was 25.58 months (SD: 10.32). At 12-month follow-up, a mean bone loss of 0.26 was recorded (*n*: 632; median: −0.30; SD: 1.15; range: −6.80 ± 3.65); at 24-month follow-up, a mean bone loss of 0.46 was determined (*n*: 602; median: −0.40; SD: 1.29; range: −7.15 ± 3.65); at 36-month follow-up a mean bone loss of 0.56 mm was observed (*n*: 576; median: −0.50; SD: 1.30; range: −6.80 ± 3.65).

Marginal bone level changes were determined at 36-month follow-up for the single variables (Table 1). A total of 158 implants (27.4%) gained bone and 380 implants (65.9%) lost bone. A total of 38 implants (6.5%) did not show bone gain or bone loss. A total of 58 implants (10%) lost more than 2 mm of peri-implant bone. A bone loss of more than 3 mm occurred in about 18 implants (3.1%). The estimate of ICC showed that the genetic component was strong; that is, the marginal bone loss for implants of the same patient was less variable than between unrelated implants (Table 2). At 12-month follow-up, no association was noted between marginal bone level changes and the considered variables (Table 3). At 24- and 36- month follow-up, implant depth and the interaction between implant depth and jaw were statistically significant (Table 3). At 36-month follow-up, age and the interaction between age and implant placement timing were statistically significant (Table 3). The sensitivity analysis showed that results were robust even though some effects had been removed from the model. The LS-means analysis revealed the following: at 24- and 36-month follow-up, marginal bone loss was higher for the subcrestal implants (single variable) and for the subcrestal implants inserted into the maxilla (interaction between two variables) (Table 4); at 36-month follow-up, marginal bone loss was higher for the implants inserted into patients older than 50 years (single variable) and for the early-delayed implants inserted into patients older than 50 years (interaction between two variables) (Table 4).

Discussion

The present study measured the peri-implant, bone level changes of Morse Taper-connection implants with platform switching at 36-month follow-up. The hypotheses of the study were confirmed as follows: at 36-month follow-up, a mean bone loss was observed and certain variables were associated with increased rates of peri-implant bone loss.

In terms of study limitations, standardized, digital peri-apical radiographs were used to evaluate marginal, bone level changes. As stated by De Smet et al. (5), absolute and corrected radiographic measurements of mean, bone level differences around implants taken from digital and conventional intraoral films are within a range of 0.2 mm, indicating that standardized, peri-apical

Table 4 LS-means analysis at 36-month follow-up of significant variables and significant interactions between variables and their standard errors (SE)

			Bone loss at T-36 months						
Effect	Implant depth	Age	Implant placement timing	Jaw	Estimate	SE	DF	t-value	Pr > |t|
Implant depth	subcrestal				−0.6807	0.1402	130	−4.86	<0001
Implant depth	crestal				−0.2565	0.1990	130	−1.29	0.1998
Implant depth*Jaw	subcrestal			maxilla	−1.0250	0.1700	130	−6.03	<0001
Implant depth* Jaw	subcrestal			mandible	−0.3364	0.1694	130	−1.99	0.0492
Implant depth* Jaw	crestal			maxilla	−0.1161	0.2633	130	−0.44	0.6598
Implant depth* Jaw	~~sub~~crestal			mandible	−0.3968	0.2433	130	−1.63	0.1053
Age		<50			−0.2521	0.2014	130	−1.25	0.2130
Age		≥50			−0.6851	0.1591	130	−4.31	<0001
Age* Implant placement timing		<50	prolonged delayed		−0.3988	0.2316	130	−1.72	0.0875
Age* Implant placement timing		<50	early delayed		−0.1054	0.3063	130	−0.34	0.7314
Age* Implant placement timing		≥50	prolonged delayed		−0.4602	0.1755	130	−2.62	0.0098
Age* Implant placement timing		≥50	early delayed		−0.9100	0.2334	130	−3.90	0.0002

The Tukey-Kramer adjustment for the *P* values and confidence limits for the differences in LS-means for unbalanced data were used.

radiographs are precise (5). Using the intraoral radiographs, however, only mesial and distal bone levels were assessed; no assessment was made of facial or lingual sites. This is an intrinsic limitation in interpreting periapical films; however, using the intraoral radiographs is also a common method used for bone level assessment around teeth and implants (6). A further limitation of the study was that no customized radiographic jig was used to take reproducible radiographs. Considering this limitation, Brägger et al. stated (7) that methodological limitations may result in false diagnoses when assessing small peri-implant, bone-height changes. False diagnoses may be related to measuring errors and/or variation in projection (7). Brägger et al. (7) also pointed out that the main source of error, however, seemed to be the recognition of reference points on the interface between the alveolar bone and implants. According to these authors (7), it is possible to standardize the procedures used in radiographic, long-term assessments of bone changes using a film-holder system and parallel projection. This method was used in the present study to assess marginal, bone level changes.

Moreover, it should be considered that not all patients reached 36-month follow up. The variable follow-up, with a mean of 25.58 months, is certainly a further source of bias of the present study. The results need validation from other research, particularly studies using a larger sample and a longer follow up; however, the findings of the present study may aid in obtaining better results with a more stable implant restoration.

Regarding amount of bone loss, Malevez et al. (8), in a retrospective study using submerged implants, reported an annual, mean-bone loss of 0.8 mm after 1 year in function and 0.1 mm during the second year. Considering the results of a recent, retrospective study conducted by Romanos et al. (9), aimed to evaluate the long-term outcomes of implants that incorporate platform shifting, as well as a tapered connection, this implant system design proved to have a positive effect on peri-implant bone preservation. The results of the present study confirmed that mean marginal bone loss using Morse Taper connection implants with platform switching is minimal at 36-month follow-up. It is worth mentioning that in the present study immediately definitive abutments were used, in order to avoid abutment removal. As stated by Cochran et al. (10) the most marginal, bone level changes take place between implant placement and final restoration and result from prosthetic manipulation and apical migration of the biologic width. The use of an immediately definitive abutment may have contributed to reducing marginal bone loss.

The results of the present study suggest that the amount of peri-implant bone loss is influenced by certain variables that include the following: implant placement depth, patient age, and the interaction between implant depth and jaw and between age and implant placement timing. The present study showed that these variables statistically significantly influence the bone remodeling around Morse Taper connection implants with platform switching. While arch and patient age are not modifiable variables, depth and implant placement timing are determined by the surgeon. Some authors recommended a subcrestal placement of two-piece implants, 2 to 3 mm below the cement-enamel junction of the neighboring teeth in esthetic areas, in order to achieve an "acceptable emergence profile" (11). Furthermore, apical positioning of the implant shoulder is often recommended as the discrepancy increases between

the diameter of the implant and the natural tooth to be replaced (12). This apical positioning of the implant, however, (due to the marginal bone loss that occurs from healing) results in an excessive length of the soft tissue dimension with concomitant persistent inflammation and possibly further loss of supporting bone (11). The manufacturers of implants with Morse Taper connection recommend inserting the implant 2 to 3 mm subcrestally in clinical practice (13). However, few clinical studies have analyzed the influence on peri-implant, hard tissue of implant-placement depth. Some studies reported bone growth onto the implant shoulder when using implants with platform switching, Morse Taper connection, and a microstructured surface that extended onto the implant shoulder (14,15). Romanos et al. (9), in a retrospective clinical study, stated that the values found for marginal bone loss around implants placed both crestally and subcrestally were comparable to those reported previously in the literature. According to Romanos et al. (9), however, the implant placement at bone level may be associated with a higher risk of implant exposure (9). Placing the implant subcrestally minimizes that risk, and subcrestal placement of platform-switched implants enables bone stability or growth over the implant shoulder (9). In a recent study aimed at measuring any changes in peri-implant marginal bone levels in the interval of time between implant placement and the completion of the implant-abutment connection 2 months later, Cassetta et al. (16) demonstrated that the implant placement depth had a statistically significant influence on early, peri-implant marginal bone loss. In this previous study, a greater early, peri-implant bone loss was recorded when the implant was placed below the alveolar crest (16).

In the present study, similarly, the implants inserted subcrestally recorded a statistically significantly higher marginal bone loss, especially when inserted into the maxilla. Considering the influence of the arch on bone loss, Yoo et al. (17) conducted a study finalized to measure marginal bone level changes in subjects with immediately loaded implants. Yoo et al. (17), using Morse Taper connection implants with platform switching, evaluated the influence of demographic, health status-related, anatomic, implant-specific, prosthetic, and surgical variables on peri-implant bone loss. Considering the influence of variables investigated, the mandible showed a higher risk for marginal bone loss compared to the maxilla (17). On the basis of the present study, marginal bone loss was statistically significantly higher in the maxilla, but the implants were loaded at 2-month follow-up rather than immediately. Past studies have shown greater bone loss in the maxilla and in anterior regions of the jaws, when using delayed-loading protocol, which was also used in the present study (18).

Evaluating the influence of age on marginal bone loss, Meijer et al. (19) showed comparable bone level changes for younger and older patients. Other authors have reported that bone and soft tissue healing after implant placement can be compromised by aging (20). Mumcu et al. (21) investigated the effect of several variables on marginal bone levels around fixed dentures supported by dental implants at 36-month follow-up; no significant relationship was noted between marginal bone loss and implant length or diameter, whereas age, gender, and cantilevers affected bone loss rates. Marginal bone loss was notable in older and female patients, as well as in patients who had received cantilevers. Marginal bone loss was found to proceed more slowly in patients under 45 years of age, possibly due to lower bone vascularity and healing potential in older individuals (21). In the present study, patients over the age of 50 years showed statistically significantly greater bone loss. A higher level of bone loss was recorded also when the variable age was associated with an implant placement 4 weeks after tooth extraction. The ‘early delayed’ implant placement, 4 weeks after tooth extraction, significantly reduced overall treatment time for patients. Hsu et al. (22) described increased bone loss on buccal aspects with low osseointegration when immediate implant placement protocol was used, although, other studies have argued that crestal bone loss after immediate implant placement with/without bone grafting is clinically acceptable (6,23). Considering the results of a recent review aiming to determine the influence of platform switching on peri-implant bone loss, the implants that followed delayed placement protocol showed less crestal bone resorption than implants that were placed immediately after extraction (24). These findings were confirmed by the results of the present study. Implants that were delayed early, in fact, showed a statistically significant higher level of marginal bone resorption, when treatment involved patients older than 50 years.

On the basis of the results of the present study, the type of prosthesis did not have a statistically significant influence on marginal bone loss. While the results of the present study need validation from other research, particularly studies with larger samples and a longer follow ups, the clinician would be advised to pay close attention to the biomechanical aspects of planning and to the surgical and prosthetic phases of implant rehabilitation. Indeed, when using Morse Taper connection implants, an increased difficulty to determine excessive or incongruous masticatory loads is present due to the

absence of a screw connection (25).

In conclusion, only a few studies have been noted with a long follow-ups that evaluated the crestal, bone level changes of Morse Taper connection implants with platform switching and the influence of biologically relevant, anatomic and stress-related variables. The results of the present study showed low mean crestal bone loss during 36-month follow-up. Implant positioning in an apico-occlusal dimension, however, is a variable that determines the amount of the peri-implant bone resorption. A statistically significantly greater bone loss was recorded when the implant was placed below the alveolar crest. It is essential to determine the amount of bone loss that is related to different positions of the implant shoulder on the bone crest. The understanding of factors that influence peri-implant bone loss and, therefore, an accurate positioning of the implant shoulder can enhance the esthetic predictability and success of the final restoration.

Conflicts of interest

The authors disclose any actual or potential conflict of interest including any financial, personal or other relationships with other people or organizations within 3 years of beginning the submitted work that could inappropriately influence, or be perceived to influence, their work.

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