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Platform-switched implants vs platform-matched implants placed in different implant-abutment interface positions: A prospective randomized clinical and microbiological study

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Abstract

Background: Placement of the implant-abutment interface (IAI) away from the bone crest has been suggested to have positive impacts on maintenance of peri-implant tissues.

Purpose: To assess the effects of platform-switched and platform-matched implants, taking into consideration the IAI at different positions relative to the bone crest, on clinical, radiographic, and microbiological outcomes during 12 months following functional loading.

Materials and Methods: The present prospective randomized study was performed upon 70 patients. Group I (n = 23) implants presenting a platform-switched implant-abutment connection design was inserted 1 mm subcrestally. Group II (n = 22) implants with similar properties were inserted crestally. Group III (n = 25) implants presenting a platform-matched approach with an internal hexagon connection design was inserted crestally. The periodontal parameters were assessed at baseline, and 3, 6, and 12 months postloading. Radiographic marginal bone level (MBL) changes were analyzed at the 12-month follow-up. The amount of DNA copies of *Porphyromonas gingivalis*, *Aggregatibacter actinomycetemcomitans*, *Tannerella forsythia*, *Provetalla intermedia* and total bacterial mean load in peri-implant sulcus fluid (PISF) were assessed at the same periods.

Results: There were no significant differences among the groups with respect to the periodontal parameters for all time periods. At 12-month follow-up, the MBL changes were 0.16 ± 0.29 mm and 0.17 ± 0.23 mm for group I, 0.15 ± 0.25 mm and 0.17 ± 0.26 mm for group II, 0.17 ± 0.26 mm and for group III in mesial and distal sites, respectively. The mean total bacterial load was found significantly higher for group III compared to the other groups in the three interval times ($P < .05$).

Conclusion: Implants restored with platform-switching and platform-matching performed equally regarding clinical and radiographic outcomes. Platform-matched implants inserted at the crestal level presented higher the mean bacterial total load in PISF.

KEYWORDS

bacterial adhesion, clinical research, implant survival, marginal bone loss, x-ray imaging

1 | INTRODUCTION

Maintenance and stability of marginal bone level (MBL) around dental implants have been considered to play a critical role in the integrity of overlaying peri-implant soft tissues, as well as avoiding further loss of peri-implant bone with possible progression to peri-implantitis.[1,2] However, marginal bone loss is mostly expected during the first year of implant installation due to several clinical, mechanical, and biological factors.[3] These factors, such as reestablishment of peri-implant supracrestal attached tissue,[4] peri-implant mucosa tissue thickness,[5] surgical manipulation of implant site,[6] thin residual buccal bone around teeth/implants,[7] presence of periodontitis,[8] interimplant distance,[9] mechanical stress at the bone-implant interface,[10] microgaps at the implant-abutment interface (IAI),[11] microdesign and macrodesign of the implant neck,[12] type of implant-abutment connection,[13] and the position of the implants relative to the bone crest level[14] aggravate this unfavorable condition. In particular, bacterial colonization in peri-implant tissues and IAI must be considered during this time period to avoid extensive marginal bone loss with respect to peri-implant pathology after the first year of implant installation.[15,16] For prevention of bone loss associated with the inflammatory reaction caused by periodontal pathogens (including *Porphyromonas gingivalis* [Pg], *Aggregatibacter actinomycetemcomitans* [Aa], *Provetalla intermedia* [Pi], and *Tannerella forsythia* [Tf]) different implant designs and also implant surgery modifications have been suggested.[2,17]

On the other hand, the initial soft tissue thickness has been considered a critical factor on peri-implant crestal bone stability.[18-20] Many studies have previously supported that the importance of having thick mucosa phenotype to preserve the crestal marginal bone.[18,19,21,22] Moreover, it has been demonstrated that marginal bone stability could not be maintained in the implants having thin soft tissue phenotype regardless of the type of implant-abutment connection or distraction of microgaps at the IAI relative to the bone crest.[22]

The strategy of subcrestal implant positioning characterized with placement of the IAI apical to the alveolar bone crest, has been proposed to help minimize peri-implant inflammation and to have stable peri-implant soft and hard tissue.[23] This approach could avoid the detrimental effects of microgap on adjacent crestal bone by bringing out the bacteria and the inflammatory cell infiltrate away from the bone.[24,25] However, recent evidence has revealed contradictory outcomes regarding the impact of the location of the IAI in apico-coronal direction with reference to the bone crest. It has been demonstrated that placing IAI subcrestally showed significantly lower crestal bone loss around the implants compared to placing equicrestally in some animal[17,26] and human clinical[13,27] studies. On the other hand, some investigations indicated that a more apical position of IAI led to a greater crestal bone loss.[7,28]

Considering the impact of the placement of the IAI away from the bone crest in horizontal off set, the concept of platform-switching has been favored in several studies.[29-32] When both vertical and horizontal positions of the implants relative to the alveolar crest are considered, platform-switching implants placed at subcrestal level have been shown to have larger epithelium and peri-implant soft tissue length, and to maintain maximum peri-implant bone level compared to the implants placed crestally in some previous reports.[14,26,33] A recent systematic review and meta-analysis have revealed that platform-switching implants placed in a subcrestal position provided less MBL changes compared to those which are placed at crestal level.[14] On the other hand, some studies reported that there were no significant differences regarding MBL changes between platform-switching and platform-matching implants regardless of implant placement depths.[34-36]

Therefore, the present study was aimed to evaluate the impacts of the platform-switched and platform-matched implants, taking into account the IAI at different positions relative to the bone crest, on clinical, radiographic parameters and the amount of DNA copies of *Pg*, *Aa*, *Pi*, and *Tf* and total bacterial mean load in peri-implant sulcus fluid (PISF) during 12 months after the functional loading.

2 | MATERIALS AND METHODS

2.1 | Study design and patient selection

The present prospective single-center randomized parallel-arm study design was reviewed and conducted in accordance with the revised World Medical Association Declaration of Helsinki. The study protocol was approved by the research ethics review committee of Ankara University, Faculty of Dentistry, Ankara, Turkey (0.21.63.00/824-02/9-8/22). All patients were informed about the objectives and methods of the study, were requested to sign a written consent form. The study participants were selected from the partially edentulous patients who referred to the Gazi University, Department of Periodontology, Ankara, Turkey, from April 2013 to February 2016.

The inclusion requirements were as follows: patients of age >18 years, who required an implant-supported, partially fixed dental prosthesis or a single-crown restorations and having intact opposing teeth and stable occlusion, presence of sufficient residual bone width (>5 mm) and length (>10 mm), sufficient keratinized gingiva crestally (≥ 4 mm), and initial mucosal thickness >2 mm (thick phenotype) that do not require any soft tissue or bone augmentation procedures on the implant insertion site, and had their teeth extracted at least 3 months before (extraction sockets completely healed). The exclusion criteria were as follows: patients who had uncontrolled systemic diseases or medications that were contraindicated for wound healing and uncontrolled bone metabolic disorders, pregnant and/or lactating females, smoking of >10 cigarettes in a day, patients who had an active periodontal disease and having deep bite, crossbite, and/or severe parafunctional habits (ie, bruxism and heavy clenching).

2.2 | Study groups and randomization

The study population consisted of 75 patients (41 females and 34 males). Patients were randomly assigned one of the three implant groups by using a specifically designed locked computer software program (SPSS 20.00, SPSS, Inc, Chicago, Illinois). Allocation concealment was implemented by a study examiner, who received a sealed opaque envelope for each patient treatment corresponding to the implant

groups. The examiner opened the envelop before implant surgery and informed the surgeon.

The implants placed in Group I (Ankylos—subcrestal) was Ankylos (DENTSPLY, Mannheim, Germany) implants presenting a conical implant-abutment connection for the platform-switching implant-abutment connection design and a rough-surfaced implant body with a special thread design (the thread depth increases gradually toward the apex). Depending upon the apico-coronal implant position on crestal bone level, implants were inserted 1 mm subcrestally. In group II (Ankylos—crestal), Ankylos implants were inserted at the bone crest level. The implants placed in group III (Xive—crestal) was Xive (DENTSPLY, Mannheim, Germany) implants presenting platform-matched with an internal hexagonal connection design in the implant neck, a stepped screw design and self-tapping apex. Xive implants were inserted at the bone crest level.

The surfaces of both commercial implant systems were the Friadent plus surfaces, which are created by blasting with large grit aluminum oxide particles (350-500 mm, time and pressure undisclosed) and by acid etching (hydrochloric acid/sulfuric acid/oxalic acid) in high-temperature processes.[37] Surgical procedures were standardized for all the groups and performed in a two-step procedure that allows submerged healing.

2.3 | Presurgical treatment

Each patient underwent a careful clinical and radiographic periodontal examination. Professional oral hygiene procedures were performed for each patient with the initial periodontal therapy including full-mouth supra and subgingival scaling and root planning. Periodontal parameters including full mouth plaque score (FMPS),[38] full mouth bleeding score (FMBS),[39] and probing depth (PD) were evaluated. FMPS and FMBS <25% were scheduled for surgical procedure.

2.4 | Surgical protocol

Patients received a bone volume analysis using cone beam computed tomography (CBCT) to determine the implant location, length, and diameter were determined. Bone quality at the implant site was estimated and categorized by the CBCT images according to the definition by classification of Lekholm and Zarb[40] before the implant insertion. All surgical procedures were performed by the same trained surgeon. At the beginning of the implant surgery, patients rinsed for 2 minutes with 0.2% chlorhexidine digluconate mouthwash. Under local anesthesia (2% lidocaine with 1:100 000 epinephrine), an intrasulcular and crestal incision, without vertical releasing incisions were made and full-thickness mucoperiosteal flaps were raised. The implant site was prepared following the drilling protocol recommended by the manufacturers and was allowed to receive an implant 3.5 to 4.5 mm in diameter and 9.5 to 14 mm in length for the Ankylos system, and 3.8 to 4.5 mm in diameter and 9.5 to 13 mm in length for the Xive system. Care was taken to ensure that the distance between the implant and the neighboring teeth was minimum 1.5 mm and the distance between two implants was minimum 3 mm for the distance. In group 1, implants were placed 1 mm below the crest, and in groups 2 and 3, implants were placed at crestal level. After implant insertion, cover screws were positioned on the implants, and the mucoperiosteal flaps were repositioned and sutured to ensure primary and tension-free closure.

2.5 | Postoperative care and maintenance

All patients were instructed to use postoperative antibiotics including 1000 mg (825 + 125 mg) of amoxicillin/clavulanate (Augmentin, GlaxoSmithKline, Brentford, UK) and to rinse twice a day with a chlorhexidine digluconate 0.12% mouthwash for 2 weeks. Sutures were removed on the seventh day after the implant surgery. Patients were recalled for control visits was at 2 weeks, 1 and 3 months postoperatively. After 3 months postoperatively, standard transmucosal healing abutments for each implant system were screwed at the second-stage implant surgery. Three weeks following the second-stage surgery, the definite abutments were fitted with 30 Ncm torque and the implants were restored using the prosthetic crown by a conventional loading protocol.[41] Follow-up of patients on maintenance therapy including full mouth scaling and polishing were scheduled after the functional loading of the implants every 3 months.

2.6 | Clinical and radiographic evaluation

Clinical evaluation was performed at the time of prosthetic loading (baseline) and 3, 6, and 12 months. Plaque index (PI) described by Silness and Löe,[38] gingival index (GI) described by Löe and Silness,[42] bleeding on probing (BOP) described by Ainamo and Bay[39] and PD were assessed using a periodontal probe (Nordent, Manufacturing, Inc, Illinois) from the four sites per implant (mesial, buccal, distal, and palatal/lingual).

To evaluate peri-implant MBL, standardized intraoral radiographs were taken using a parallel cone technique and an individual customized film holder (Rinn bite film holder, Dentsply Rinn, York, Pennsylvania). The position and the angulation of the film holder were standardized for each patient with occlusal fixation using an impression material. Measurements of digital radiographic images were performed with Sigma Scan Pro, Image Analysis software, (SPSS, Inc, Chicago, Illinois) and were adjusted for a coefficient derived from the ratio of implant length for calibration. The distance (mm) between the first bone-to-implant contact (BIC) and a well-defined reference point at the implant shoulder, as measured on both the mesial and distal aspects of the implant, was recorded as either a positive (BIC was located in the apical of the bone crest) or a negative value (BIC was located in the apical region of the implant shoulder) according to previous studies.[25,43] The MBL changes at the 12-month follow-up for both mesial and distal sites were measured as the difference between the values recorded at the time of prosthetic loading and after 12 months of loading Figure 1.

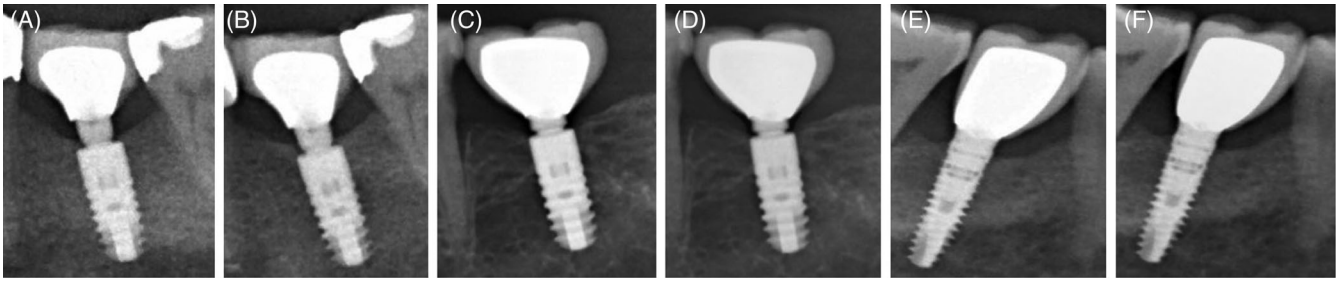

FIGURE 1 Intraoral radiographic images of the cases belonging the study groups. A, Group I (Ankylos-subcrestal) baseline. B, Group I (Ankylos-subcrestal) 1-year follow-up. C, Group II (Ankylos-crestal) baseline. D, Group II (Ankylos-crestal) 1-year follow-up. E, Group III (Xive-crestal) baseline. B, Group III (Xive-crestal) 1-year follow-up

2.7 | Microbiological analysis

Samples of submucosal biofilms were collected when clinical and radiographic evaluations were performed. After isolation of the peri-implant site, four paper strips (Periopaper, Oraflow, Inc, New York, New York) were separately inserted 1 mm below the mucosal margin in four sites of peri-implant sulcus for 30 seconds. Submucosal samples were stored at −20°C before the microbiologic analysis was performed.

The submucosal samples suspended in 200 μL 1× TAE buffer, were homogenized by vigorous mixing on a vortex. For DNA purification, the Insta-Gene Matrix Kit (Bio-Rad Labs, California) was used. The DNA samples were centrifuged for 3 minutes at 13 200 rpm, then 400 μL of supernatant was taken off and the pellet was resuspended in 200 mL of Insta-Gene Matrix (Bio-Rad Labs, California, USA). The suspension was incubated at 56°C for 30 minutes and at 100°C for 8 minutes, then the samples were vortexed for 10 seconds and centrifuged for 3 minutes at 13 200 rpm. A volume of 200 μL of supernatant sample was taken and was frozen at −20°C.

To estimate specific bacteria counts, qPCR was performed by using CFX96 Real Time System (Bio-Rad, Hercules, California) according to the manufacturer's instructions. For *Aa*, a 16S ribosomal RNA gene with the accession number (ATCC # 43718); for *Pg*, a 16S ribosomal RNA gene with the accession number (ATCC # 33277); for *Pi*, a 16S ribosomal RNA gene with the accession number (ATCC # 25611), and for *Tf*, a 16S ribosomal RNA gene with the accession number (ATCC # 33277) were used. In order to quantify total bacterial load in the samples, universal primers, 338F (5′-ACTCCTACGGG AGGCAGCAG-3′) and 518r (5′-ATTACCGCGGCTGCTGG-3′) were used with qPCR SYBR Green System (Bio-RadHercules, California). The Taqman 5′ nuclease assay qPCR method was used for detection and quantification of specific bacterial DNA. The bacterial species-specific primers were as follows, 5′-GAACCTTACCTACTCTTGACATCCGAA-3′ (forward) and 5′-TGCAGCACCTGTCTCAAAGC-3′ (reverse) for *Aa*, 5′-GCGCTCAACGTTCAGCC-3′ (forward) and 5′-CACGAATTCCGCC TGC-3′ (reverse) for *Pg*, 5′-CGGTCTGTTAAGCGTGTTGTG-3′ (forward) and 5′-CACCATGAATTCCGCATACG-3′ (reverse) for *Pi*, 5′-GGGTGA GTAACGCGTATGTAACCT-3′ (forward) and 5′-ACCCATCCGCAAC CAATAAA-3′ (reverse) for *Tf*.

The PCR thermal cycling conditions for both SYBR and Taqman assay included an initial denaturation step at 50°C for 2 minutes, followed by a denaturation step at 95°C for 10 minutes, and then 45 cycles of 95°C for 15 seconds and 60°C for 60 seconds.

2.8 | Statistical analysis

The sample size was computed considering to detect a difference of 0.2 mm of peri-implant MBL changes and 0.3 mm SD observed in a previous study[30] with an α set at .05 and a power of 0.80. A minimum of 20 patients per group was required according to the calculation. Statistical analysis was performed using the software IBM SPSS Statistics version 20.0. Descriptive statistics were described by mean and SD and number (percentage) for quantitative and nominal variables, respectively. Data were explored for normality using Kolmogorov-Smirnov test. Regarding the comparison of demographic characteristics, analysis of variance (one-way ANOVA) was performed for quantitative variables, while Pearson chi-square test was performed for categorical variables. The clinical, radiographic, and microbiological parameters were compared among the groups by the one-way ANOVA. The paired sample *t* test was used to investigate the changes of the parameters between the time points within each group. A linear regression model was carried out to analyze the influence of patient and implant characteristics (gender, age, localization of implants, bone quality at the implant site, augmentation procedures, implant diameter and length, and placement of IAI) on the mean MBL for both mesial and distal sites. The significance level was set at $P < .05$.

3 | RESULTS

The present study comprised a total of 70 patients. Two patients from group I and three patients from group II were dropped out of the study within 1 year postloading. Group I consisted of 23 patients (10 males, 13 females) with a mean age of 49.6 ± 7.1 years, group II consisted of 22 patients (9 males, 13 females) with a mean age of 47.7 ± 8.9 years, and group III consisted of 25 patients (15 males, 10 females) with a mean age of 52.7 ± 6.6 years. There were no significant differences between the groups in terms of age and gender ($P = .356$ and $P = .80$, respectively). Demographic characteristics of the patients and implant sites, and implant distributions regarding implant diameter, length and location were presented in Table 1.

TABLE 1 Demographical parameters of study population and implanted sites

Demographic	Group I (n = 23)	Group II (n = 22)	Group III (n = 25)	*P* value
Gender n (%)				.356[a]
Female	13 (56.5)	13 (59.0)	10 (45.0)	
Male	10 (43.5)	9 (41.0)	15 (55.0)	
Age (years; mean ± SD)	49.6 ± 7.1	47.7 ± 8.9	52.7 ± 6.6	.080[b]
Implant location n (%)				.060[a]
Maxilla	8 (34.7)	13 (59.0)	15 (55.0)	
Mandible	15 (65.3)	9 (41.0)	10 (45.0)	
Bone quality n (%)				.746[a]
Type I	2 (8.7)	0	2 (8.0)	
Type II	14 (60.8)	16 (72.7)	15 (60.0)	
Type III	7 (30.5)	6 (27.3)	8 (32.0)	
Type IV	0	0	0	
Implant diameter n (%)				.102[a]
3.5 mm	10 (43.5)	11 (50.0)	0	
3.8 mm	0	0	17 (68.0)	
4.5 mm	13 (56.5)	11 (50.0)	8 (32.0)	
Implant length n (%)				.058[a]
9.5 mm	9 (39.1)	10 (45.4)	5 (20.0)	
11 mm	11 (47.8)	10 (45.4)	15 (60.0)	
13 mm	0	0	5 (20.0)	
14 mm	3 (13.1)	2 (9.2)	0	

Note: $P < .05$ considered statistically significant.
[a]Chi-square test.
[b]One-way ANOVA.

Table 2 showed clinical findings of the study groups during a 12-month follow-up. In all the groups, no significant differences were identified regarding the mean PI values for intragroup comparisons within the study periods as well as for intergroup comparisons at all the study time points ($P > .05$). The mean GI values for all the groups presented tendencies an increase toward the 3-month follow-up according to the baseline. These increments were statistically significant for groups I and II ($P = .033$ and $P = .007$, respectively). Moreover, in group II, a significant increase was found at the 6-month evaluation compared to baseline ($P = .042$). For the mean BOP and PD values, statistical analysis failed to reveal any significant difference for the groups at any time point of the study ($P > .05$). For the intergroup comparisons, no significant difference was found among the groups with respect to PI, GI, BOP, and PD for any time period ($P > .05$).

Figure 2 presents MBL changes at both mesial and distal sites for the groups at the 12-month follow-up. The mean MBL changes were 0.16 ± 0.29 mm and 0.17 ± 0.23 mm for group I, 0.15 ± 0.25 mm and 0.17 ± 0.26 mm for group II, 0.17 ± 0.26 mm and for group III, in mesial and distal sites, respectively. No statistically significant difference was observed in the mean MBL changes around the implants for any group ($P > .05$). To investigate the association between patient and implant site characteristics and MBL changes at the 12-month follow-up, linear regression models were performed (Table 3). According to the models of the mesial site, no significant relationship was found between the variables and MBL changes ($P > .05$). However, a significant relationship was observed between bone quality and MBL changes at the distal site ($P = .011$).

PISF levels of DNA copies of *Pg*, *Aa*, *Pi*, *Tf*, and total bacterial mean load of all the groups for each time point were shown in Figure 3. All groups presented an increasing trend for the counts of DNA copies of *Pg* at the end of the study. The mean levels of *Pg* in the PISF increased significantly at the 12-month evaluation compared to the baseline for group I ($P = .046$) and group II ($P = .005$), whereas there was not a statistically significant difference between the time points of the study for group III ($P > .05$). The levels of *Aa* in the PISF were detected in quite low rates for all groups. No statistically significant differences regarding the mean levels of DNA copies of *Aa* were observed in any of the groups at any time point ($P > .05$). In terms of the mean levels of *Pi* in PISF, a statistically significant increase was observed only for group II at the 12-month follow-up compared to the baseline ($P = .047$). Group I had significantly higher levels of *Tf* in PISF at the 6-month evaluation compared to the baseline ($P = .02$) and at the 12-month evaluation compared to the 6-month ($P = .016$), while other groups did not reveal any statistically significant difference at the time points of the study ($P > .05$). On the other hand, there were no statistically significant differences between the groups for the levels of any of the selected periodontal pathogens ($P > .05$). When the mean total bacterial load in PISF was evaluated, group III presented

TABLE 2 The mean values of periodontal parameters of the study groups at 3, 6, and 12 months of follow-up

Parameters		N	Baseline Mean ± SD	3 months Mean ± SD	6 months Mean ± SD	12 months Mean ± SD	*P* value[a] Baseline vs 3 months	Baseline vs 6 months	Baseline vs 12 months
PI	Group I	23	0.43 ± 0.45	0.35 ± 0.39	0.29 ± 0.35	0.57 ± 0.40	.642	.453	.292
	Group II	22	0.37 ± 0.48	0.21 ± 0.35	0.31 ± 0.34	0.40 ± 0.45	.578	.283	.307
	Group III	25	0.35 ± 0.41	0.30 ± 0.36	0.28 ± 0.33	0.46 ± 0.37	.238	.612	.756
	P value[b]		.802	.443	.892	.383			
GI	Group I	23	0.84 ± 0.37	1.07 ± 0.11	1.00 ± 0.30	0.92 ± 0.25	.033	.938	.448
	Group II	22	0.79 ± 0.46	1.02 ± 0.44	1.06 ± 0.36	0.89 ± 0.35	.007	.042	.399
	Group III	25	0.90 ± 0.44	1.12 ± 0.24	0.90 ± 0.27	0.85 ± 0.42	.160	.106	.394
	P value[b]		.710	.488	.216	.769			
BOP	Group I	23	11.59 ± 15.43	12.32 ± 15.25	15.94 ± 20.39	15.94 ± 15.46	.657	.152	.425
	Group II	22	11.36 ± 15.75	16.66 ± 20.57	15.90 ± 19.57	15.91 ± 19.57	.468	.750	.483
	Group III	25	16.66 ± 20.97	13.33 ± 13.60	14.66 ± 18.83	13.66 ± 15.12	.054	.781	.486
	P value[b]		.505	.658	.967	.457			
PD	Group I	23	2.34 ± 0.59	2.31 ± 0.47	2.34 ± 0.56	2.29 ± 0.43	.037	1.00	.036
	Group II	22	2.28 ± 0.79	2.28 ± 0.44	2.33 ± 0.49	2.37 ± 0.49	1.00	.839	.620
	Group III	25	2.50 ± 0.85	2.25 ± 0.53	2.13 ± 0.56	2.31 ± 0.72	.744	.540	.960
	P value[b]		.569	.917	.330	.901			

Note: $P < 0.05$ considered statistically significant.
Abbreviations: PI, plaque index; GI, gingival index; BOP, bleeding on probing; PD, probing depth.
[a]One-way ANOVA.
[b]Paired sample *t* test.

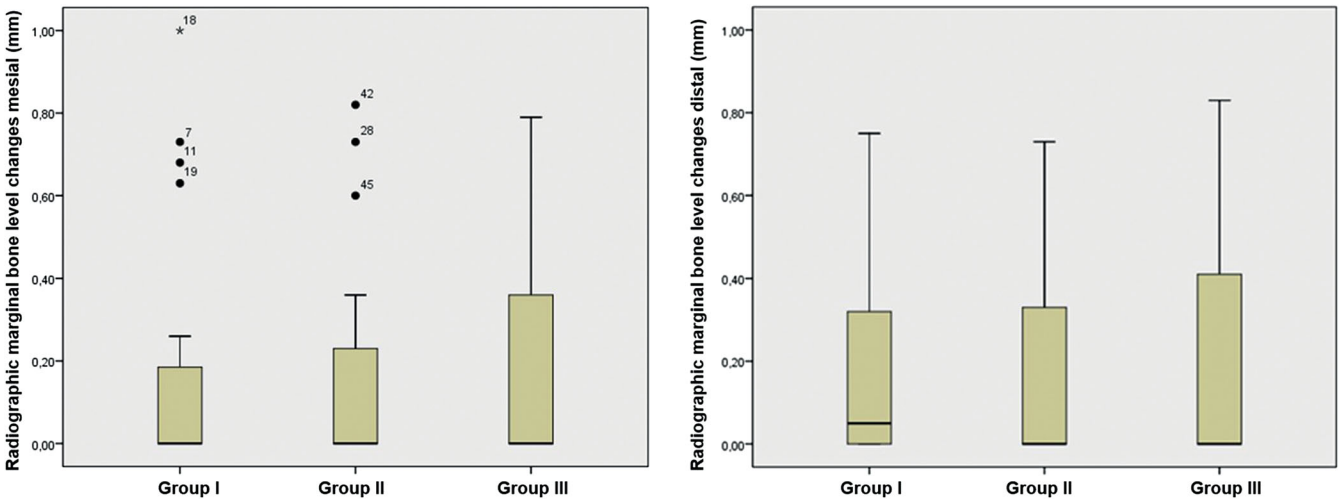

FIGURE 2 Marginal bone level changes at mesial and distal sites for the groups at the 12-month follow-up. *$P < .05$, one-way ANOVA

significantly higher levels than the other groups at the 3-, 6-, and 12-month follow-ups ($P = .23$, $P = .13$, and $P = .49$, respectively).

4 | DISCUSSION

The present study was conducted to assess the impacts of different IAI positions in both vertical and horizontal directions relative to the bone crest on clinical and radiographic parameters and peri-implant microbiology. The clinical and radiographic findings of this investigation demonstrated no significant differences between platform-switched and platform-matched implants with regard to IAI at different positions relative to the bone crest. However, platform-matched implants with crestal IAI position had significantly higher the mean bacterial total load in PISF compared to platform-switched implants with both crestal and subcrestal IAI positions.

TABLE 3 Univariate linear regression analysis of marginal bone level changes of mesial and distal sites at 12 months follow-up

	Mesial site				Distal site			
Variables	β	**SE**	R^2	***P* value**	β	**SE**	R^2	***P* value**
Gender	.097	0.064	0.009	.426	.165	0.058	0.027	.172
Age	.062	0.004	0.004	.611	.054	0.004	0.003	.658
Implant location (Maxilla-Mandible)	.090	0.065	0.008	.458	.246	0.057	0.060	.040
Bone quality	−.152	0.062	0.023	.209	−.304	0.054	0.092	.011
Implant diameter	−.110	0.070	0.012	.364	−.024	0.064	0.001	.844
Implant length	.144	0.026	0.021	.234	−.008	0.024	0.000	.947
Placement of IAI	−.006	0.069	0.000	.959	−.047	0.063	0.002	.699

Note: $P < .05$ considered statistically significant.
Abbreviations: β, beta coefficient; SE, SE of estimate.

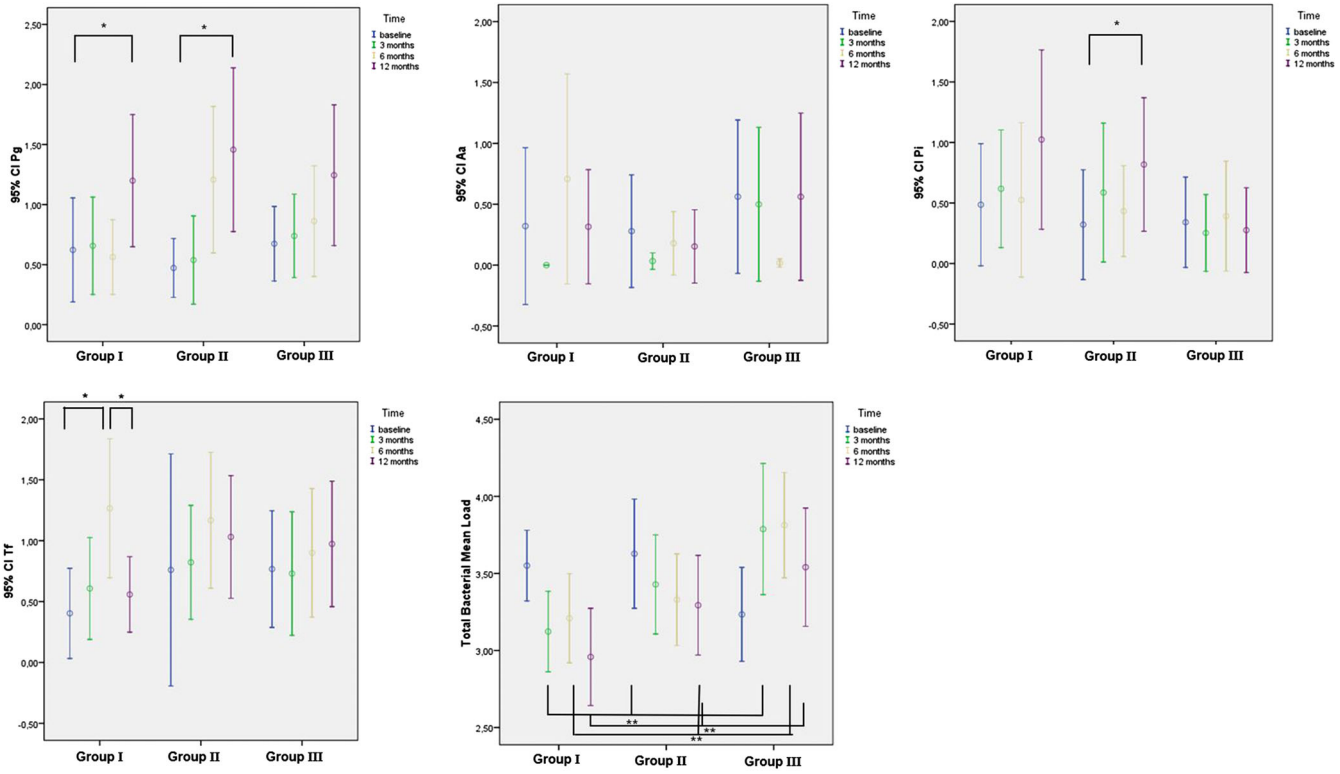

FIGURE 3 Peri-implant sulcular fluid (PISF) levels of DNA copies of Pg, Aa, Tf, and total bacterial mean load of all the groups for each time point. *$P < .05$, Paired sample *t* test. **$P < .05$, one-way ANOVA

Placement of the IAI more subcrestally has been suggested to support the re-establishment of favorable marginal tissue architecture and to minimize crestal bone resorption around the implants.[2,15,27,44] On the contrary, some reports indicated that subcrestal implants showed no superiority against equicrestal implants with regard to the preservation of peri-implant crestal bone levels.[1,13,45] The findings of the present clinical trial are in line with the study conducted by Amri et al[1] in which no statistically significant differences were found between crestal and subcrestal implants for the mean MBL changes at 6, 18, and 36 months. A recent systematic review and meta-analysis reported that for bone level implants, the weighted mean of crestal bone loss before and after abutment connection was 0.03 ± 0.30 mm and 0.66 ± 0.11 mm when IAI placed subcrestally and 0.57 ± 0.29 mm and 0.80 ± 0.30 mm when IAI placed equicrestally.[24] The mean MBL changes of platform-switched implants in our study were 0.16 ± 0.29 mm and 0.17 ± 0.23 mm for subcrestal IAI position 0.15 ± 0.25 mm and 0.17 ± 0.26 mm for crestal IAI position in mesial and distal sites, respectively. It is pertinent to mention that the mean of MBL changes of the present study seems to be lower according to this meta-analysis. This might be attributed to the differences of the distance between IAI and bone crest and implant surface characteristics with respect to a variety of implant brands in the studies mentioned here in. Moreover, it can be also attributed with that no

inclusion criteria were defined for oral soft tissue phenotype and soft tissue thickness at implant site in this meta-analysis.

The platform-switching implant-abutment configurations, which allow inward reposition of the IAI, have been reported to show favorable outcomes compared to platform matching in several systematic reviews and meta-analyses.[31,46,47] However, some studies could not find any significant differences in terms of MBL changes between the implants restored with platform-switching and platform-matching.[35,36,48] The present investigation yielded the mean MBL changes from prosthetic loading to 1-year follow-up of 0.15 ± 0.25 mm and 0.17 ± 0.26 mm for platform-switching and 0.17 ± 0.26 mm and for platform-matching in mesial and distal sites when the implants were placed at crestal position. Both implant-abutment configurations showed similar effects on crestal bone level changes. These findings are comparable with those of Enkling et al[49] who indicated no significant differences in the mean radiographic vertical bone loss between the implants restored with platform-switching and platform-matching after 1-year implant surgery. Similarly, a recent 5-year ongoing pragmatic multicenter randomized clinical trial evaluating implants with an internal connection which restored with platform-switching vs implants with external connections which restored with platform-matching revealed no statistically significant differences between the two connection types.[48] However, two different connection and neck design types were analyzed in that study. Despite the fact that the present study compared the implants restored with platform-switching and platform-matching having different types of implant-abutment connections and neck designs, it should be noted that the differences related to microgap in the IAI and macrodesign and microdesign of the implant neck could potentially affect crestal bone loss. Palaska et al[13] highlighted that implant-abutment connection design rather than apico-coronal implant placement position in relation to crestal bone level might affect peri-implant bone loss. In another recent investigation, Valles et al[12] demonstrated in their study that the surface treatment of the implant neck showed no significant influence on MBL changes, while vertical implant positions revealed more pronounced influence on MBL changes in their study. Moreover, many factors related to patient and implant characteristics have also been associated to peri-implant marginal bone loss such as systemic factors, history of periodontitis, tobacco consumption, peri-implant keratinized mucosa phenotype, bone quality at the implant site, implant diameter and length.[1,5,32,35] Taking into consideration of these possible influencing factors, a multilevel regression model was built to analyze the effects of the factors on peri-implant MBL changes in this investigation. Nevertheless, according to the model, no significant relationship was found between the variables and peri-implant MBL changes at both mesial and distal sites.

It has been proved that bacteria could penetrate into the IAI microgaps and colonize in the inner region that could lead to peri-implant soft tissue inflammation and crestal bone loss.[50,51] However, internal microbial colonization may not only depend on the microgap size at the IAI but the positioning of the IAI both vertically and horizontally with regard to the alveolar crest could also impact bacterial colonization.[52] Zhu et al[52] compared peri-implant microbial colonization between the implants inserted at different vertical placement depths to peri-implant infection, and reported that implants placed subcrestally could increase *Tf* level in PISF at the early stage of peri-implant infection, regardless of the microgap size at the IAI. In the present study, the mean levels of *Pg*, *Aa*, *Pi*, and *Tf* between platform-switched implants both placed subcrestally and crestally and platform-switched implants placed crestally were comparable in all time periods of the study. In parallel with, Canullo et al[53] found no significant differences for periodontopathogen bacteria in subgingival biofilm samples from the implants restored platform-switching and platform-matching. On the other hand, our findings demonstrated significantly lower total bacterial load in favor of the platform-switched implants, in contrast to the study by Enkling et al[49] that reported no significant differences in the total counts between the platform-switched and nonplatform-switched implants at any time point. However, this difference could be related to the patients' oral microbiologic status at the time of implant insertion, which could be another relevant issue affecting microbial colonization in PISF.

Another relevant limitation of the present investigation might be that the patients were not evaluated for the changes in peri-implant soft tissue thickness during the study time period. The effects of IAI location both vertically and horizontally on peri-implant keratinized tissue dimensions could be better to analyze with this study. Thin peri-implant mucosa phenotype was found to be associated with higher crestal bone loss in previous studies.[18,19,21,22] Therefore, it could influence crestal bone loss around the implants in different implant placement levels in the vertical dimension in relation to the alveolar crest using platform-switching and platform-matching concepts. Furthermore, more comprehensive studies assessing both hard and soft tissue are needed to understand to the impacts of these concepts on the peri-implant biology.

Despite of the limitations, the present investigation did not support the positive influence of subcrestal placement of IAI and platform-switching concepts on the preservation of the peri-implant marginal bone crest. Even if all the study approaches performed equally regarding clinical and radiographic outcomes, implants restored with platform-matching and inserted at the crestal level presented higher the mean bacterial total load in PISF.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in this study.

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