The Effect of Interimplant Distance on Peri-implant Bone and Soft Tissue Dimensional Changes: A Nonrandomized, Prospective, 2-Year Follow-up Study

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Purpose: *To prospectively evaluate peri-implant bone and soft tissue dimension changes around adjacent implants placed at different horizontal interimplant distances.* ***Materials and Methods:*** *Thirty partially edentulous patients, who underwent rehabilitation with two adjacent implant-supported crowns as part of their treatment plan, were assigned to three groups based on their prosthetic needs. Patients in group A (10 patients, 20 implants) were to have two implants placed at a 2-mm interimplant distance, patients in group B (10 patients, 20 implants) were to have two implants placed at a 3-mm interimplant distance, and patients in group C (10 patients, 20 implants) were to have two implants placed at an interimplant distance of > 4 mm according to their prosthetic needs. All patients received single-crown restorations after 3 months. Clinical examinations were performed at the time of crown placement (T3), and 6 months (T6), 12 months (T12), and 24 months (T24) after implant placement. Peri-implant bone levels were assessed radiographically at the time of implant placement (T0), and at T3, T12, and T24.* ***Results:*** *One patient from group C did not return for follow-up examinations after implant placement. The mean (± standard deviation) horizontal interimplant distance was 1.97 ± 0.44 mm for implants in group A, 3.12 ± 0.15 mm for implants in group B, and 5.3 ± 0.64 mm for implants in group C. For group A, the mean marginal bone loss was 0.29 ± 0.51 mm at the T0–T3 interval, 0.31 ± 0.36 mm at the T0–T12 interval, and 0.27 ± 0.33 mm at the T0–T24 interval. For group B, the mean marginal bone loss was 0.16 ± 0.29 mm at the T0–T3 interval, 0.20 ± 0.28 mm at the T0–T12 interval, and 0.23 ± 0.28 mm at the T0–T24 interval. For group C, the mean marginal bone loss was 0.51 ± 0.84 mm at the T0-T3 interval, 0.45 ± 0.72 mm at the T0–T12 interval, and 0.44 ± 0.74 mm at the T0–T24 interval. For group A, the mean midproximal bone loss was 0.33 ± 0.50 mm at the T0–T3 interval, 0.45 ± 0.35 mm at the T0–T12 interval, and 0.40 ± 0.32 mm at the T0–T24 interval. For group B, the mean midproximal loss was 0.31 ± 0.37 mm at the T0–T3 interval, 0.32 ± 0.39 mm at the T0–T12 interval, and 0.33 ± 0.42 mm at the T0–T24 interval. For group C, the mean midproximal bone loss was 0.40 ± 0.44 mm at the T0–T3 interval and 0.41 ± 0.50 mm at both the T0–T12 and T0–T24 intervals. There were no statistically significant differences in marginal and midproximal bone crest loss between the different groups at any time point.* ***Conclusion:*** *The study failed to support the hypothesis that horizontal interimplant distance has an effect on peri-implant bone and soft tissue dimension changes for implants with internal conical implant-abutment interface connection and platform-switching characteristics.* Int J Oral Maxillofac Implants 2015;30:900–908. doi: 10.11607/jomi.4040

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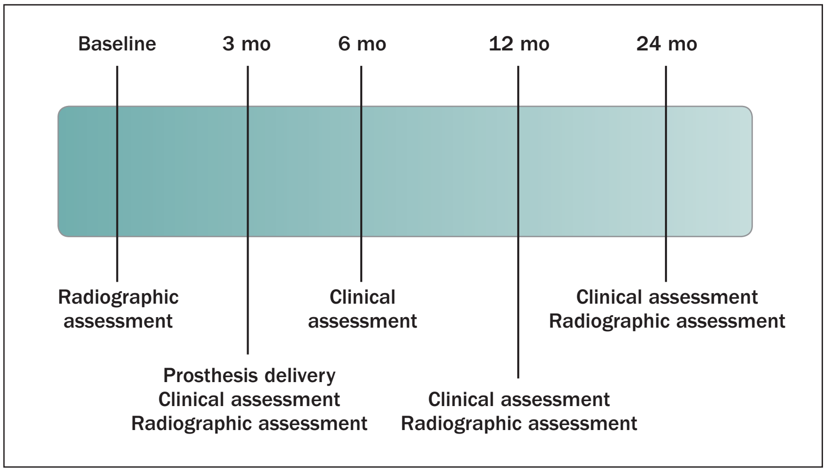
The soft tissue topography, in conjunction with multiple implant restorations, is crucial for successful treatment outcomes and is likely a reflection of the peri-implant bone topography. The interaction of interimplant distance with peri-implant soft tissue and bone topography has been the subject of several experimental[1–5] and clinical studies.[6–11] Experimental studies have shown conflicting results when evaluating the effect of interimplant distance on peri-implant bone topography. Scarano et al[1] reported a negative effect of the reduced interimplant distance on midproximal

Fig 1 Design of the study.



crestal bone levels. This negative effect was attributed to the lateral component of peri-implant bone loss and the overlap that can occur when implants are placed in close proximity. However, other experimental studies did not report significant differences in midproximal bone crest resorption in relation to the horizontal distance between implants with an internal conical implant-abutment connection and an altered horizontal relationship between the implant diameter and abutment diameter (platform switching).[2–5] A systematic review found that platform-switched implants exhibited marginal bone loss that was significantly smaller than conventionally restored implants, with marginal bone loss being less when platform-switching showed a larger mismatching.[12] Thus, the reduced marginal bone loss observed for platform-switched implants may in part explain the lack of significant interaction between midproximal bone crest resorption and horizontal interimplant distance.

Several clinical studies that have evaluated the effect of interimplant distance on peri-implant tissue topography have shown similar trends as described in the experimental studies. Prospective[10] and retrospective[11] studies showed that the horizontal interimplant distance was a significant predictor for 3-year midproximal bone level changes in implants with an external hex connection; 5-year midproximal bone level changes showed borderline significance in implants with conical, platform-switched implant-abutment connections. There is limited information from prospective studies on the effect of interimplant distance on peri-implant bone and soft tissue dimensional changes in implants with conical, platform-switched connections. Thus, the aim of the study was to prospectively evaluate peri-implant bone and soft tissue dimension changes around adjacent implants placed at different horizontal interimplant distances.

MATERIALS AND METHODS

This study was designed as a prospective, nonrandomized, controlled, parallel clinical trial. Thirty partially edentulous patients who, as part of their treatment plan, underwent rehabilitation with two adjacent implant-supported crowns were enrolled at the Department of Periodontology Clinic, College of Dentistry, University of Florida, Gainesville. A total of 19 women with a mean age of 56.1 years and 11 men with a mean age of 60.3 years participated in this study. The study protocol was reviewed and approved by the institutional review board of the University of Florida. All subjects received detailed information about the study and signed a written consent before the start of treatment. Screening of patients, enrollment, study procedures, and data collection were performed from 2011 to 2014, by two periodontists (T.K., R.N.).

The recruited subjects had to meet the following inclusion criteria: *(1)* good general health; *(2)* absence of oral and dental disorders; *(3)* ≥ 21 years of age; *(4)* at least two missing neighboring teeth; *(5)* a healed osseous architecture (enough to receive an implant with a diameter of ≥ 3.5 mm and length of ≥ 8 mm); *(6)* no smoking, *(7)* not pregnant at the screening visit.

The design of the study is described in Fig 1. Patients were allocated to one of the following treatment groups based on their prosthetic needs. Patients of group A (10 patients, 20 implants) were to have two implants placed with a 2-mm interimplant distance; patients of group B (10 patients, 20 implants) were to have two implants placed with a 3-mm interimplant distance; and patients of group C (10 patients, 20 implants) were to have two implants placed at a > 4 mm interimplant distance based on their prosthetic needs. Patients were allocated to their group based on diagnostic wax-up and radiographic survey after the screening examination.

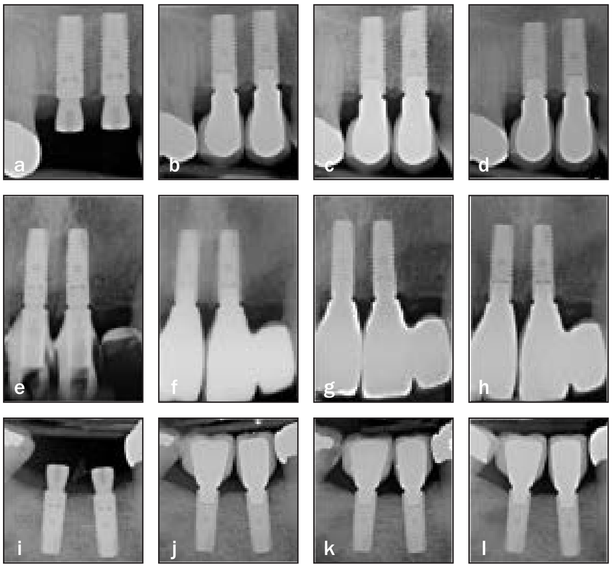


Fig 2 Radiographs of patients in group A, group b, and group C. Case in group A *(a)* at implant placement (T0); *(b)* at crown placement (T3); *(c)* at 12 months after implant placement (T12); and *(d)* at 24 months after implant placement (T24). Case in group B *(e)* at T0; *(f)* at T3; *(g)* at T12; and *(h)* at T24. Case in group C *(i)* at T0; *(j)* at T3; *(k)* at T12; and *(l)* at T24.

Implant Treatment

The implants (Astra, Osseospeed, Dentsply Implants) used in the current study had diameters of 3.5 or 5.0 mm with lengths varying from 8 to 13 mm. The selection of implant size was based on existing bone dimensions.

Immediately after local anesthesia, an endodontic file with a rubber stop was inserted into the buccal mucosa perpendicularly at a point 5 mm apical to the crest of the edentulous ridge until bone contact was perceived for each implant site. The rubber stop was positioned at the mucosal surface, and the distance from the rubber stop to the tip of the endodontic file was measured to the lowest 0.5 mm to determine mucosal thickness.

Crestal incisions were used and full-thickness flaps were elevated to expose the bone. The recipient sites were enlarged according to the manufacturer's protocol and patient's prosthetic treatment plan.

Subsequent to osteotomy preparation, the thickness of buccal and lingual bony plates was measured at a point 2 mm apical to the crest of the ridge with the caliper at the lowest 0.5 mm. Dental implants were placed in the edentulous segments according to the treatment allocation group. After implant placement, healing abutments were placed and extended transmucosally. For patients having implants in the anterior maxilla (n = 2), provisional restorations were fabricated. All restorations were kept out of occlusion. Flaps were closed with interrupted sutures, and each patient received 500 mg amoxicillin three times daily from the day of the implant surgery for 7 days and chlorhexidine 0.12% rinse twice daily for 2 weeks. Sutures were removed 2 weeks after the implant surgery.

All implants were restored with single crowns 3 months after implant placement. For six of the 30 patients, the crowns were splinted because of anticipated heavy occlusal forces based on the patient's history of parafunctional activity.

Clinical Examinations

At the 3-month (crown delivery, T3), 6-month (T6), 12-month (T12), and 24-month (T24) re-examinations, the following clinical parameters were recorded at the implant sites: probing depth, peri-implant mucosal height (PMH), bleeding on probing at six sites of each implant (mesiobuccal, buccal, distobuccal, distolingual, lingual, and mesiolingual), presence of visible plaque at four sites of each implant (mesial, distal, buccal, and lingual surfaces), and width of buccal keratinized mucosa (KM) at the midbuccal surface of each implant. PMH was recorded as the distance between the peri-implant mucosal margin and the most coronal part of the restoration, and KM was recorded as the linear distance from the mucosal margin to the mucogingival line. All measurements were performed with a manual probe (PCP 15, Hu-Friedy) to the lowest 0.5 mm.

The periodontists who performed the treatment procedures also performed all clinical examinations in a crossover manner. Thus, examinations were performed by the periodontist not involved in the treatment of the patient. Before the start of the study, the examiners were trained to adequate levels of accuracy and reproducibility for the various clinical parameters to be used. The mean interexaminer difference between repeated measurements was 0.12 (95% confidence interval [CI], –0.02 to 0.3) for PD and 0.07 (95% CI, –0.09 to 0.24) for PMH.

Radiographic Examination

Radiographic examinations were performed immediately after the surgical procedure (T0), and at the T3, T12, and T24 follow-up visits (Fig 2). Standard periapical radiographs were taken using a paralleling device (Dentsply Rinn) and a digital imaging software system (MiPacs, Medicor Imaging). One periodontist (T.L.) not involved in the implant therapy interpreted the radiographs.

Marginal bone levels (MBL) were assessed as the vertical distance from the implant-abutment level to the first bone-to-implant contact. With the use of a reference line drawn perpendicular to the implant surface at the corner between the vertical and conical parts of the implant head (0.3 mm) below the implant-abutment level (Fig 3), the following linear distances were assessed: *(1)* interimplant distance—the distance between two neighboring implants at the reference level of the anterior implant

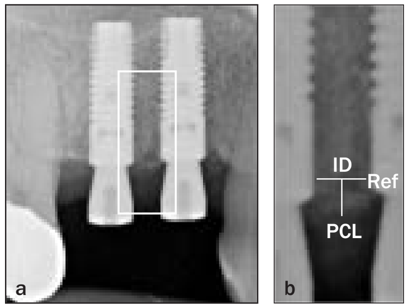


Fig 3 Radiograph of implants at #4 and #5 position of a patient in group A. *(a)* At implant placement, the white area shows interimplant and midproximal bone measurements; *(b)* white area magnified. Ref = reference line; ID = interimplant distance; PCL = midproximal bone crest level.

Table 1 Frequency (%) of Sites with Plaque, BoP, and PD ≤ 3 mm or 4–5 mm at Follow-up Examinations

Group/ Time	Plaque (%)	BoP (%)	PD ≤ 3 mm (%)	PD 4–5 mm (%)
Group A	(n = 80)	(n = 120)	(n = 120)	
T3	20*	11.7	92.9	7.1
T6	8.9	16.7	92.9	7.1
T12	7.1	28.6	95.2	4.8
T24	12.5	32.1	85.7**	14.3***
Group B	(n = 80)	(n = 120)	(n = 120)	
T3	43.8*	9.7	99.1	0.8
T6	17.5	19.2	100	0
T12	12.5	26.7	94.2	5.8
T24	16.2	34.2	95	5
Group C	(n = 72)	(n = 108)	(n = 108)	
T3	27.1	15.3	100	0
T6	14.3	13.1	91.7	8.3
T12	7.1	20.2	98.8	1.2
T24	19.6	17.9	98.8**	1.2***

*$P < .05$ group A vs group B; all analyses were based on the Fisher exact test.
**$P < .05$ group A vs group C.
***$P < .05$ group A vs group C.
BoP = bleeding on probing; PD = probing depth.

(at implant placement), and *(2)* midproximal bone crest level —the midproximal vertical distance between the bone crest and the reference level.

All measurements were determined at the mesial and distal surface of each implant with the images magnified (×7). The radiographs were downloaded as 16-bit JPEG files and analyzed with an image processing system (NIH Image J, version 1.39F, National Institutes of Health). The known geometry of each implant was used to assess the distortion of the images. The error of the method used for appraising the measurements on the radiographs was calculated by reassessing 10 randomly selected cases including 160 sites. The mean difference between repeated measurements of the 60 sites was found to be 0.06 mm (standard deviation [SD], 0.45 mm).

Statistical Analysis

For describing mean values of the data, SDs and frequencies were calculated. The primary outcome variable was MBL changes. The Fisher exact test was used to evaluate differences in frequencies of plaque, bleeding on probing, and probing depth categories between the treatment groups. The Student-Newman-Keuls test (analysis of variance) was applied to evaluate differences between the three treatment groups regarding changes in PMH, buccal width of KM, MBLs, and midproximal bone crest levels. Pearson correlation analysis was performed to evaluate MBL changes from T0 to T24, thickness of the bone wall after osteotomy (buccal and lingual), and thickness of buccal mucosa before implant placement. In addition, Pearson correlation analysis was performed to evaluate midproximal crestal bone level changes and MBL changes at proximal interimplant distances at 24 months. $P < .05$ was considered statistically significant.

RESULTS

The study commenced in July 2011, and the last patient visit included was in June 2014. A total of 40 subjects were screened, with 30 subjects assigned to different groups and treated. One patient from group C did not return for follow-up after the implant placement surgery; therefore, the data were not included in the analysis. Twenty-nine subjects completed treatment and follow-up evaluations. The distribution of implants according to position, size, and group is illustrated in Figs 4 and 5. Osseointegration was successful with all implants in all groups. The mean interimplant distance was 1.97 ± 0.44 mm (range, 1.2 to 2.6 mm) for group A implants; 3.12 ± 0.15 mm (range, 3 to 3.5 mm) for group B, and 5.3 ± 0.64 mm (range, 4.5 to 6.5 mm) for group C. The results of the clinical evaluations are illustrated in Tables 1 and 2. There was a statistically significant difference between groups A and B in the percentage of sites exhibiting plaque at the T3 follow-up examination (20% vs 43.8%, $P < .05$). At the T24 follow-up examination, compared with group C, group A had statistically

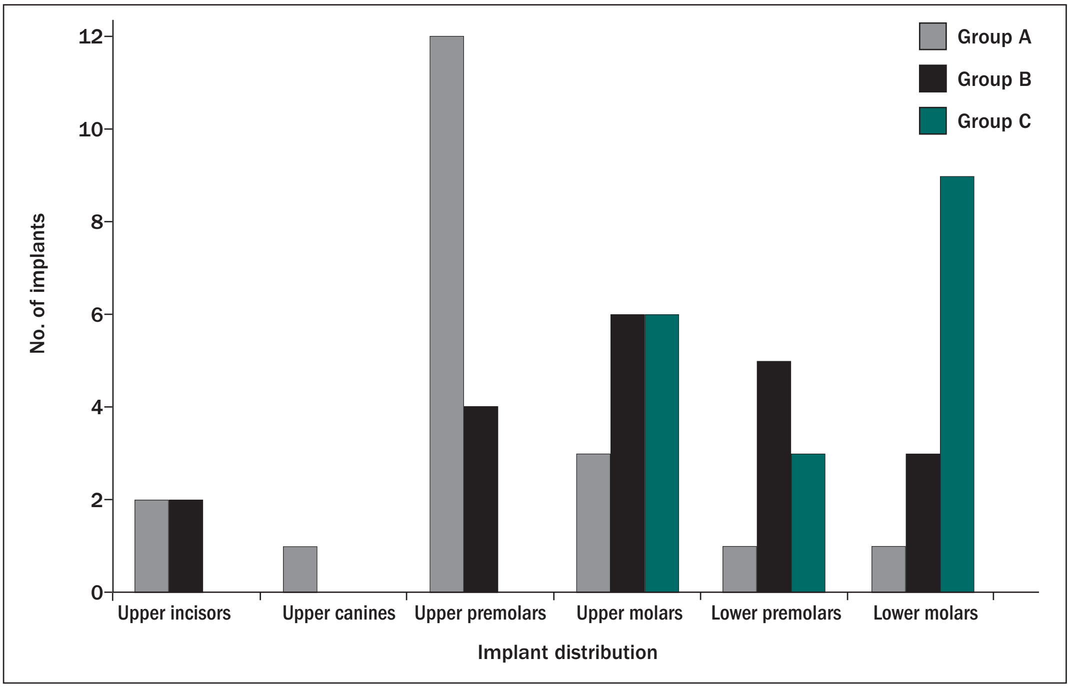


Fig 4 Distribution of implants based on jaw positions and groups.

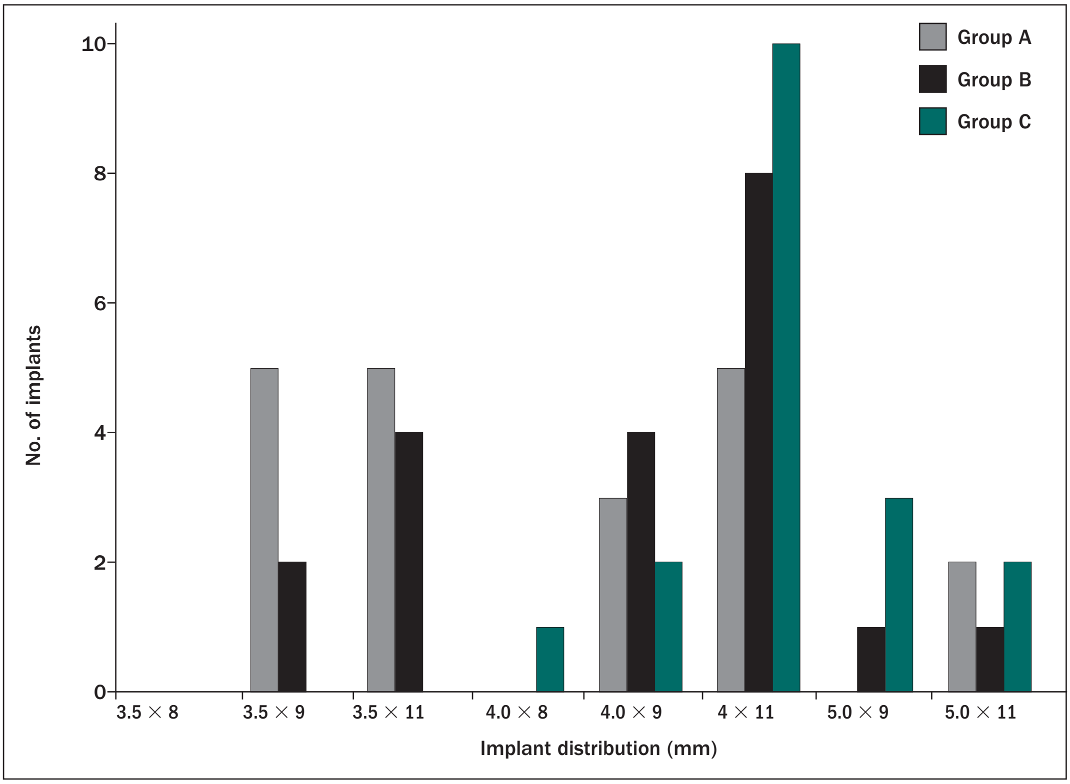


Fig 5 Distribution of implants based on sizes and groups.

significantly greater percentage of sites with PDs of 4 to 5 mm (14.3% vs 1.2%, $P < .05$) and statistically lower percentage of sites with PDs ≤ 3 mm (85.7% vs 98.8%). There were no statistically significant differences between groups for PMH changes over time. For the buccal surfaces, a mean negative change was observed for the T3 to T6 interval with a subsequent positive change thereafter. A mean positive change (coronal) in

Table 2 Changes in PMH and Width of KM (in mm) over Time*

Group/time	Mean (SD) changes in mucosa height (mm) Mesial	Distal	Buccal	Lingual	Mean changes in KM (mm) Buccal
Group A (n = 20)					
T3–T6	0.25 (0.61)	0.10 (0.78)	–0.28 (0.46)	0.35 (0.49)	0.07 (0.61)
T3–T12	0.57 (0.82)	0.64 (0.77)	0.21 (0.89)	0.50 (1.09)	0.14 (0.61)
T3–T24	0.61 (0.72)	0.65 (0.67)	0.34 (0.54)	0.64 (1.15)	0.21 (0.80)
Group B (n = 20)					
T3–T6	0.3 (0.65)	0.25 (0.63)	–0.19 (0.42)	0.14 (0.30)	0.25 (0.85)
T3–T12	0.8 (0.84)	0.62 (0.79)	0.01 (0.86)	0.42 (0.47)	0.30 (0.92)
T3–T24	0.85 (0.77)	0.75 (0.76)	0.21 (0.42)	0.53 (0.45)	0.40 (0.88)
Group C (n = 18)					
T3–T6	0.14 (0.3)	0.00 (0.39)	–0.21 (0.57)	0.07 (0.26)	0.00 (0.39)
T3–T12	0.42 (0.47)	0.39 (0.34)	0.28 (0.72)	0.21 (0.89)	0.14 (0.53)
T3–T24	0.43 (0.45)	0.57 (0.42)	0.30 (0.63)	0.50 (0.85)	0.21 (0.42)

*P > .05, using analysis of variance with Bonferroni correction.
PMH = peri-implant mucosal height; KM = keratinized mucosa.

Table 3 Marginal Bone Level Changes over Time According to Treatment Groups*

Time	Mean (SD) bone level change (mm) Group A (n = 20)	Group B (n = 20)	Group C (n = 18)
T0-T3	–0.29 (0.51)	–0.16 (0.29)	–0.51 (0.84)
T0-T12	–0.31 (0.36)	–0.20 (0.28)	–0.45 (0.72)
T0-T24	–0.27 (0.33)	–0.23 (0.28)	–0.44 (0.74)

*P > .05 using analysis of variance with Bonferroni correction.

Table 4 Midproximal Bone Level Changes over Time According to Treatment Groups*

Time	Mean (SD) midproximal bone level change (mm) Group A (n = 10)	Group B (n = 10)	Group C (n = 9)
T0–T3	–0.33 (0.50)	–0.31 (0.37)	–0.40 (0.44)
T0–T12	–0.45 (0.35)	–0.32 (0.39)	–0.41 (0.50)
T0–T24	–0.40 (0.32)	–0.33 (0.42)	–0.41 (0.50)

*P > .05 using analysis of variance with Bonferroni corrections.

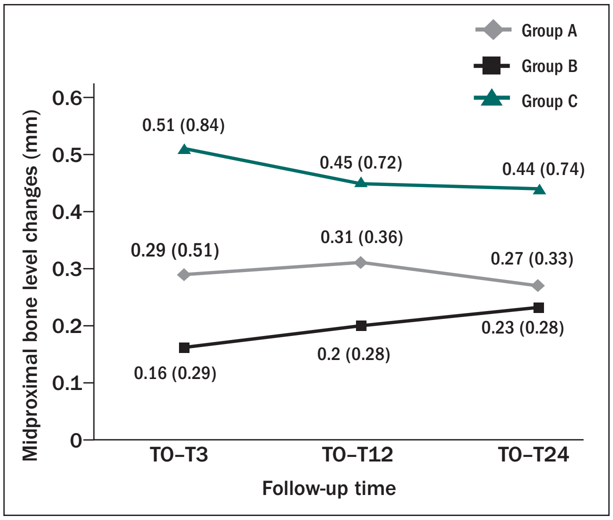


Fig 6 Mean (standard deviations) marginal bone level changes over time according to treatment groups.

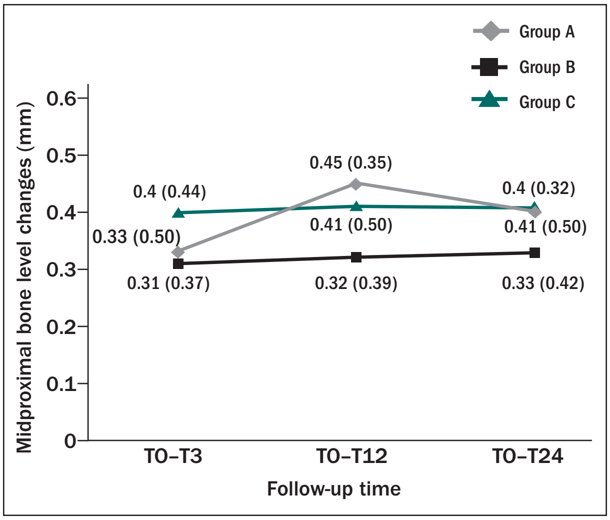


Fig 7 Mean (standard deviations) midproximal bone level changes over time according to treatment groups.

PMH was observed in all groups and all surfaces for the T3 to T12 and T3 to T24 intervals.

The mean MBL changes at different intervals are illustrated in Table 3 and Fig 6. Although group C implants exhibited greater MBL loss over time, differences with the groups were not statistically significant. The mean midproximal bone crest level changes over time are illustrated in Table 4 and Fig 7.

Similar to MBL, midproximal bone crest level changes over time were not significantly different between different treatment groups.

Pearson correlation analysis revealed a statistically significant correlation of the buccal bone wall thickness after the osteotomy with MBL change at 24 months (r = 0.33, P = .01) and a statistically significant correlation of midproximal bone level changes with MBL changes at proximal interimplant units at 24 months (r = 0.63, P = .0001, respectively).

DISCUSSION

The present study failed to demonstrate that interimplant distance significantly influences marginal and midproximal bone level changes in implants with internal conical connection and platform-switching characteristics. To evaluate the effect of interimplant distance on peri-implant bone and soft tissue dimensional changes, the authors aimed to identify cases that, as part of their treatment plan, had implants that needed to be placed at 2-mm, 3-mm, and > 4-mm interimplant distances. Radiography performed immediately after implant placement showed that the mean interimplant distances were 1.97 ± 0.44 mm (range, 1.2 to 2.6 mm) in group A implants, 3.12 ± 0.15 mm (range, 3 to 3.5 mm) in group B implants, and 5.3 ± 0.64 mm (range, 4.5 to 6.5 mm) in group C implants. Because of the study design, the group assignment was performed after radiographic and diagnostic survey, and no randomization was possible. The distribution of implant position is indicative of the study design, with more implants placed in single rooted teeth positions in groups A and B compared with group C (group A: 16 implants, group B: 11 implants, group C: 4 implants). To the authors' knowledge, this is the first prospective study that aimed implant placement at predetermined interimplant distances. However, the obvious drawback of this study is the lack of randomization and the clustering of implants to specific positions because of anatomical requirements.

Several clinical studies have evaluated the effect of interimplant distance on peri-implant bone topography changes.[6–11] Peri-implant bone topography has been described with parameters such as lateral bone loss,[6, 7] marginal bone loss,[7–11] and midproximal bone level changes.[7,10,11] A cross-sectional study reported a more apical position of the bone crest between implants with an interimplant distance of less than 3 mm.[6] This was attributed to the lateral bone loss observed in implants with external hex implant-abutment interface. This explanation was not supported by a retrospective study[7] with the same type of implants, in which lateral bone loss was not a significant factor in interimplant midproximal bone level changes. The current study did not include lateral bone loss to describe peri-implant bone topography changes. This was because a consistent and reproducible way to measure lateral bone loss was not identified in the current sample.

The present study failed to identify significant differences in midproximal bone level changes in implants placed at different interimplant distances. At the 2-year follow-up, implants in groups A, B, and C had midcrestal bone losses of 0.4, 0.33, and 0.41 mm, respectively, with the greatest amount of midproximal bone remodeling occurring at the interval between implant placement and crown delivery. This is in contrast to findings from other cross-sectional[6] and retrospective studies[7] that reported no influence of interimplant distance on interimplant bone crest levels. This difference in findings may be explained by the use of implants with different implant-abutment interface characteristics. A retrospective study evaluated implants of the same implant system over a 5-year time period and reported a borderline significant relationship between interimplant distance and midproximal bone level changes.[11] One major difference between the present study and that of Chang and Wennström[11] is the interval used for evaluating bone level changes. In the present study, the time of implant placement was considered as the baseline, whereas Chang and Wennström used the time of prosthesis placement as the baseline. In a more recent retrospective study[13] that evaluated the effect of interimplant distance on peri-implant bone levels in implants with various internal connection types and platform switching, no significant differences were observed in midproximal interimplant bone level change for implants with interimplant distances of ≤ 3 mm and >3 mm.

In the present study, similarly to midproximal interimplant bone level changes, no significant differences were found between the treatment groups in terms of MBL changes. At the 2-year follow-up, implants in groups A, B, and C had MBL losses of 0.27, 0.23, and 0.44 mm, respectively. In a retrospective study with external hexed implants, similar observations were made with the horizontal interimplant distance exhibiting a nonsignificant effect on bone level change over time.[7] In addition, Jo et al[13] reported a similar observation for implants with internal connection and platform switching. In the present study, even though no significant differences were noted between treatment groups, group C implants exhibited greater MBL loss than group A and group B implants. This increased bone loss might be caused by factors other than interimplant distance. The amount of marginal bone loss observed in the current study is consistent with that described in the literature for the specific implant system.[14–17]

Several animal studies have evaluated the effect of interimplant distance on peri-implant bone topography changes.[1–5] Studies using implants with internal conical connection and platform switching have shown that interimplant bone levels can be maintained at similar levels when implants are placed at 2- and 3-mm interimplant distances.[2–5] This concurs with findings from the present study.

Peri-implant mucosa dimensional changes took place primarily in the first 9 months after crown placement (T3–T12 interval). During the first 3 months after crown placement, an apical shift of buccal peri-implant mucosa was seen in all study groups in the present study. Three months after crown placement, a more coronal shift of peri-implant mucosa was observed for all implant surfaces in all implant groups, with no significant differences between the groups. Soft tissue changes in implant-supported fixed partial dentures have been described previously.[10] Thus, buccal soft tissue margin recession was observed during the first 2 months after implant placement with one-stage surgery, with no further changes seen in the subsequent 3-year follow-up period. Similarly, facial peri-implant marginal recession has been reported after crown placement in studies that used a two-stage surgical protocol for implant placement and delivered the prosthesis about 1 month after second-stage surgery.[17,18] Although it is difficult to compare results from different studies because of the differences in surgical protocols (one-stage vs two-stage) and baseline assignment (implant placement vs crown placement), small facial peri-implant soft tissue margin recession can occur as a result of biologic width establishment.[19,20]

Several studies have reported on interimplant soft tissue dimensions and the degree of interimplant papilla fill.[21–23] A cross-sectional study[21] reported a mean interimplant soft tissue height of 3.4 mm as assessed with transmucosal probing. Another cross-sectional study[23] using radiographic evaluation of interimplant soft tissue dimensions reported a 3.1-mm mean interimplant soft tissue height with no significant differences in implants with different implant-abutment connections and different interimplant distances. In addition, complete soft tissue fill of the embrasure space between two implants was observed when the distance from the bone crest to the contact point of the restorations was less than 4 mm.[22] The present study did not report on interimplant mucosal dimensions and papilla fill; thus, direct comparison with the previously mentioned studies is not possible. Because soft tissue fill of the embrasure space between two implants can be influenced by the prosthetic design of the crowns, in the present study, this variable was not considered to be of value when comparing implants placed at different interimplant distances.

Bivariate analysis showed a significant correlation between thickness of the buccal bone wall after the osteotomy and MBL changes at 24 months. The importance of the thickness of the buccal wall for evaluating bone level changes has been also identified in other studies.[24–26] Lastly, a significant correlation was observed herein of midproximal bone level changes with MBL changes at proximal interimplant units seen at 24 months, which is in agreement with the findings of Chang and Wennström.[11] Thus, the amount of interimplant midproximal bone loss is related to the amount of MBL changes at the proximal interimplant units, regardless of the interimplant distance.

CONCLUSIONS

The present 2-year prospective study of adjacent implants placed at different interimplant distances found that interimplant distance does not render an increased risk for bone loss during functional loading. This conclusion applies only to implants with internal conical connection and platform switching characteristics and is in contrast with the common belief that an interimplant distance of less than 3 mm is a risk for greater bone loss.

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REFERENCES

1. Scarano A, Assenza B, Piattelli M, et al. Interimplant distance and crestal bone resorption: A histologic study in the canine mandible. Clin Implant Dent Relat Res 2004;6:150–156.
2. de Oliveira RR, Novaes AB Jr, Papalexiou V, Muglia VA, Taba M Jr. Influence of interimplant distance on papilla formation and bone resorption: A clinical-radiographic study in dogs. J Oral Implantol 2006;32:218–227.
3. Novaes AB Jr, de Oliveira RR, Muglia VA, Papalexiou V, Taba M. The effects of interimplant distances on papilla formation and crestal resorption in implants with a morse cone connection and a platform switch: A histomorphometric study in dogs. J Periodontol 2006;77:1839–1849.
4. Elian N, Bloom M, Dard M, Cho SC, Trushkowsky RD, Tarnow D. Effect of interimplant distance (2 and 3 mm) on the height of interimplant bone crest: A histomorphometric evaluation. J Periodontol 2011;82: 1749–1756.
5. Elian N, Bloom M, Dard M, Cho SC, Trushkowsky RD, Tarnow D. Radiological and micro-computed tomography analysis of the bone at dental implants inserted 2, 3 and 4 mm apart in a minipig model with platform switching incorporated. Clin Oral Implants Res 2014;25:e22–29.
6. Tarnow DP, Cho SC, Wallace SS. The effect of inter-implant distance on the height of inter-implant bone crest. J Periodontol 2000;71: 546–549.

7 Cardaropoli G, Wennström JL, Lekholm U. Peri-implant bone alterations in relation to inter-unit distances. A 3-year retrospective study. Clin Oral Implants Res 2003;14:430–436.
8. Kupershmidt I, Levin L, Schwartz-Arad D. Inter-implant bone height changes in anterior maxillary immediate and non-immediate adjacent dental implants. J Periodontol 2007;78:991–996.
9. Degidi M, Novaes AB Jr, Nardi D, Piattelli A. Outcome analysis of immediately placed, immediately restored implants in the esthetic area: The clinical relevance of different interimplant distances. J Periodontol 2008;79:1056–1061.
10. Chang M, Wennström JL. Peri-implant soft tissue and bone crest alterations at fixed dental prostheses: A 3-year prospective study. Clin Oral Implants Res 2010;21:527–534.
11. Chang M, Wennström JL. Bone alterations at implant-supported FDPs in relation to inter-unit distances: A 5-year radiographic study. Clin Oral Implants Res 2010;21:735–740.
12. Annibali S, Bignozzi I, Cristalli MP, Graziani F, La Monaca G, Polimeni A. Peri-implant marginal bone level: A systematic review and meta-analysis of studies comparing platform switching versus conventionally restored implants. J Clin Periodontol 2012;39: 1097–1113.
13. Jo DW, Yi YJ, Kwon MJ, Kim YK. Correlation between interimplant distance and crestal bone loss in internal connection implants with platform switching. Int J Oral Maxillofac Implants 2014;29:296–302.
14. Wennström JL, Ekestubbe A, Grondahl K, Karlsson S, Lindhe J. Oral rehabilitation with implant-supported fixed partial dentures in periodontitis-susceptible subjects. A 5-year prospective study. J Clin Periodontol 2004;31:713–724.
15. Koutouzis T, Wennström JL. Bone level changes at axial and non-axial-positioned implants supporting fixed partial dentures. A 5-year retrospective longitudinal study. Clin Oral Implants Res 2007;18: 585–590.
16. Koutouzis T, Koutouzis G, Tomasi C, Lundgren T. Immediate loading of implants placed with the osteotome technique: One-year prospective case series. J Periodontol 2011;82:1556–1562.
17. Koutouzis T, Lundgren T. Crestal bone-level changes around implants placed in post-extraction sockets augmented with demineralized freeze-dried bone allograft: A retrospective radiographic study. J Periodontol 2010;81:1441–1448.
18. Bengazi F, Wennström JL, Lekholm U. Recession of the soft tissue margin at oral implants. A 2-year longitudinal prospective study. Clin Oral Implants Res 1996;7:303–310.
19. Small PN, Tarnow DP. Gingival recession around implants: A 1-year longitudinal prospective study. Int J Oral Maxillofac Implants 2000; 15:527–532.
20. Berglundh T, Lindhe J. Dimension of the periimplant mucosa. Biological width revisited. J Clin Periodontol 1996;23:971–973.
21. Tarnow D, Elian N, Fletcher P, et al. Vertical distance from the crest of bone to the height of the interproximal papilla between adjacent implants. J Periodontol 2003;74:1785–1788.
22. Gastaldo JF, Cury PR, Sendyk WR. Effect of the vertical and horizontal distances between adjacent implants and between a tooth and an implant on the incidence of interproximal papilla. J Periodontol 2004;75:1242–1246.
23. Lee DW, Park KH, Moon IS. Dimension of interproximal soft tissue between adjacent implants in two distinctive implant systems. J Periodontol 2006;77:1080–1084.
24. Spray JR, Black CG, Morris HF, Ochi S. The influence of bone thickness on facial marginal bone response: Stage 1 placement through stage 2 uncovering. Ann Periodontol 2000;5:119–128.
25. Koutouzis T, Neiva R, Nonhoff J, Lundgren T. Placement of implants with platform-switched Morse taper connections with the implant-abutment interface at different levels in relation to the alveolar crest: A short-term (1-year) randomized prospective controlled clinical trial. Int J Oral Maxillofac Implants 2013;28:1553–1563.
26. Koutouzis T, Neiva R, Nair M, Nonhoff J, Lundgren T. Cone beam computed tomographic evaluation of implants with platform-switched Morse taper connection with the implant-abutment interface at different levels in relation to the alveolar crest. Int J Oral Maxillofac Implants 2014;29:1157–1163.