Influence of Placement Depth on Bone Remodeling Around Tapered Internal Connection Implant: A Clinical and Radiographic Study in Dogs

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Background: The aim of this study is to evaluate the influence of placement depth on bone remodeling around implants with two different types of tapered internal implant–abutment interface (IAI): tapped-in (TI) tapered internal IAI and screwed-in (SI) tapered internal IAI in dogs.

Methods: The second, third, and fourth premolars and the first molar in mandibles of six beagle dogs were extracted. After 8 weeks, two SI implants and two TI implants were placed in one side of the mandible. There were four experimental groups: 1) SI placed crestally (SIC); 2) TI placed crestally (TIC); 3) SI placed 1.5 mm subcrestally (SIS); and 4) TI placed 1.5 mm subcrestally (TIS). Healing abutments were connected 12 weeks after implant surgery. Implants and teeth were brushed every second day during the healing period. Clinical and radiographic parameters were recorded at 4, 10, and 16 weeks after second-stage surgery.

Results: Differences between SI and TI implants inserted in the same vertical position were not significant for peri-implant probing depth (PD), clinical attachment level (CAL), or bone resorption ($P > 0.05$). Subcrestal placement of both implants had greater PD and CAL compared to crestal groups. However, distance from IAI to the first bone–implant contact was lower in subcrestal groups compared to crestal groups (1.27 ± 0.42 mm for SIC versus 0.46 ± 0.26 mm for SIS, $P < 0.05$; 1.36 ± 0.31 mm for TIC versus 0.78 ± 0.42 mm for TIS, $P < 0.05$).

Conclusions: Tapered internal IAI configuration had no significant effect on crestal bone resorption. Moreover, subcrestal placement of tapered internal IAI had a positive impact on crestal bone preservation around the cervix of the implant. *J Periodontol 2012;83:1164-1171.*

KEY WORDS

Animals; bone resorption; comparative study; dental implants; dental implant-abutment design; radiography.

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Subcrestal placement of two-stage implants in esthetic areas has been recommended to obtain an ideal emergence profile.[1,2] In addition, data from biomechanical analysis have shown that strain levels in peri-implant bone were reduced as the insertion depth of the implant was increased.[3] However, microgap of implant–abutment interface (IAI) was implicated as a key factor contributing to peri-implant bone remodeling.

In the past 15 years, microleakage at the IAI has been widely evaluated.[4-8] Bacteria, fluid, and small molecules were capable of passing through the IAI.[4-6] Results from a clinical study revealed that periodontopathic microbes inhabited the IAI of two-stage implants.[9] Furthermore, an animal study showed that crestal bone was located ≈1.5 to 2 mm below the IAI.[10] Subcrestal placement of IAI resulted in a significantly greater maximum density of inflammatory reaction correlated with bone loss than supracrestal interfaces did.[11,12] In addition, lower levels of peri-implant crevicular fluid, interleukin-1β, and tumor necrosis factor-α were recently reported around implants placed supercrestally compared to those placed crestally.[13] Therefore, supercrestal implants have been recommended, and pure interference–fit connections or one-piece implants may be suitable alternatives.[12]

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Conversely, animal studies using commercially-available two-part implants indicated that subcrestal implants may not increase bone loss or jeopardize the position of soft peri-implant tissue.[14,15] In recent years, studies using implants with a tapered internal connection showed conflicting results about the influence of IAI on bone loss around implants.[16-19] Jung et al.[16] reported that the greatest bone loss occurred at implants placed 1 mm below the bone crest. In contrast, some studies showed a positive impact on crestal bone preservation with subcrestal implant placement.[18,19] It is important to mention that different types of IAI might result in different patterns of bone loss. Narrower "dish-shaped" defects were observed in implants with tapered internal connections compared to implants with butt-joint connections of IAI.[20,21]

Freestanding single-tooth implant restoration using implants with tapped-in (TI) tapered internal (locking-taper) IAI, which showed excellent microbial sealing ability in an in vitro study,[7] seemed a reliable solution to treating posterior edentulism.[22] Unlike implants with screwed-in (SI) tapered internal IAI, the manufacturer recommended inserting implants 2 to 3 mm subcrestally in clinical practice. However, no data are available as to whether different placement depths cause different physiologic responses around this IAI configuration. Moreover, it is unclear whether TI implants would be more favorably placed subcrestally compared to SI implants.[3,23]

The aim of the present study is to evaluate the bone remodeling around TI implants placed crestally and subcrestally compared to SI implants in the canine model.

MATERIALS AND METHODS

Animals

The experimental protocol was approved by the Medical Ethical Committee for Animal Investigations of Peking University Health Science Center, Beijing, China (number LA2010-032). Six male beagle dogs (1 to 2 years old; weighing 10 to 12.5 kg) were included. The dogs were housed individually and fed once daily with soft food and water. All surgical and clinical procedures were performed under general anesthesia, using intravenous sodium pentobarbital (30 mg/kg).

Surgical Protocol

At the first stage of the study, the mandibular second, third, and fourth premolars and the first molars were carefully extracted. Before extraction, the surgical sites were disinfected with 0.12% chlorhexidine solution. Subsequently, 2% lidocaine hydrochloride with epinephrine at 1:100,000 was administered as local anesthesia. The teeth were sectioned in the buccolingual direction, and the roots were individually extracted to reduce trauma to the bony walls. The flaps were sutured with resorbable 4-0 sutures.[†] After extraction, antibiotic (penicillin G procaine 40,000 IU/kg, intramuscular) and analgesic were administered once every 24 hours for 7 days. During the first week after surgery, the wound area was carefully cleaned with 0.12% chlorhexidine solution.

After a healing period of 8 weeks, implant surgery was performed. Two SI implants[‡] and two TI implants[§] were placed on one side of the mandible of each dog (total, 24). Anterior and posterior positions between implant systems were alternated. There were four experimental groups: 1) SI placed crestally (SIC); 2) TI placed crestally (TIC); 3) SI placed 1.5 mm subcrestally (SIS); and 4) TI placed 1.5 mm subcrestally (TIS).

One week before implant surgery, scaling was performed to remove supragingival calculus. For implant placement, horizontal crestal incisions were made from the distal region of the first premolar to the mesial region of the second molar. Mucoperiosteal flaps were elevated to expose the alveolar bone. The edentulous osseous ridge was carefully flattened with surgical burs under copious irrigation with chilled sterile physiologic saline. Osteotomies for implants were drilled according to manufacturers' recommendations. A distance of $\approx$10 mm between dental implant centers was maintained to avoid contact among the bone defects. The implants were then inserted. After placement of the cover screws and/or plug inserters, flaps were sutured with 4-0 nylon sutures to submerge all implants. Antibiotic and analgesic were administered as before. The sutures were removed after 10 days of healing.

After 12 weeks of healing, the implants were surgically uncovered. The second-stage surgery was performed using a minimal invasion technique. Small crestal incisions were performed so that the cover screws or plug insertions could be removed and replaced by healing abutments and/or temporary abutments. The heights of healing abutments and temporary abutments were selected according to commercial availability. For the SI groups, 4.5×4 and 4.5×6 mm were used, respectively, in the crestal and subcrestal groups. For the TI groups, 4.0×4.5 and 4.0×6.5 mm were used, respectively, in the crestal and subcrestal groups. Special attention was taken to avoid occlusal contact. Chlorhexidine digluconate (0.12%) rinses were applied every second day for the first 10 days after surgery. After that, oral hygiene procedures using a soft toothbrush were performed every second day until the end of the experiment.

† VICRYL, Ethicon, Johnson & Johnson, Langhome, PA.
‡ OsseoSpeed, 3.5×8 mm, Astra Tech Dental, Mölndal, Sweden.
§ Integra-CP, 3.5×8mm, Bicon Dental Implants, Boston, MA.

Clinical Evaluations

Clinical parameters were recorded at 4, 10, and 16 weeks after second-stage surgery. The distance from the gingival margin to the bottom of the sulcus/pocket (peri-implant probing depth [PD]) and the distance from the fixed point in the abutment shoulder to the bottom of the sulcus/pocket (clinical attachment level [CAL]) were measured to the nearest 0.5 mm using a periodontal probe‖ at mesial and distal sites of each implant. CAL was adjusted by different length of abutment and different distances from abutment shoulder to ridge among groups at the time of implant placement. Clinical measurements, including the modified plaque index (PI)[24] and bleeding index (BI),[25] were recorded. All clinical measurements were done by one calibrated examiner (MP).

Radiography

Radiographic templates were fabricated before radiographic evaluation similar to the methods described by Hermann et al.[26] Customized light-polymerizing acrylic resin fix at the cusps of the canine and second molars, respectively, were attached to the individual acrylic resin plane to allow for precise repositioning and stabilization of the radiographic template. A commercially-available film holder was rigid to customized plane to obtain a reproducible and parallel image. Then, an optimum parallel and perpendicular standardized radiographic technique was used to minimize errors of angulation and distortion.

Standardized periapical radiographs were taken with a digital image system¶ at 10 days after implant placement and at 0, 4, 10, and 16 weeks after second-stage surgery (Fig. 1). Exposure parameters were 60 kV, 7 mA, and 0.16 seconds at a focus-film distance of 37 cm. The following measurements were performed at mesial and distal sites of each implant (Fig. 2): 1) vertical measurement from the IAI to the first bone–implant contact (fBIC). In situations in which the marginal hard tissue was above the IAI, it was recorded as 0 to avoid introducing any bias in the results; 2) vertical measurement from IAI to the ridge (IAI-Ridge); 3) horizontal bone loss (HBL), horizontal measurement from the ridge to the implant body; 4) peri-implant bone slope (SLO), angle between a vertical line along the outer implant surface and a line extending along the peri-implant bone defect; and 5) ridge loss, vertical measurement from ridge to IAI at 10 days after implant placement (original ridge) minus follow-up measurement from ridge to IAI. Measurements were adjusted for distortion using the total length of the implant. A software program# was used to analyze each calibrated image. Radiographic image alignment and analysis were performed by one calibrated examiner (BH).

Statistical Analyses

Standard error of measurement (SE) and Spearman correlation coefficient (CC) for clinical (SE = 0.31 mm; CC = 0.889) and radiographic (SE = 0.11 mm; CC = 0.983) measurements were calculated to determine intra-examiner reliability.[27]

The mean values and standard deviations were calculated for all the parameters. Experimental data rows were examined with the Shapiro-Wilk test for normal distribution. If data were not distributed normally, it would be analyzed using the Friedman test and the Wilcoxon test. For the statistical evaluation of the changes within groups over time and the changes among groups, analysis of variance (ANOVA) and Bonferroni correction for multiple comparisons were used, with all results adjusted for any dog effect. Subsequently, for comparisons between groups, data at the last evaluation was used because this represented the final result during the full course of healing. ANOVA was reapplied and comparisons of interest were performed using Bonferroni-adjusted Student t tests. P values <0.05 were considered significant. All statistical analyses were performed using statistical software.**

RESULTS

Healing was uneventful in all implants. Clinically healthy peri-implant mucosa was observed around implants at follow-up examinations (Fig. 1). Although oral hygiene was performed every second day, mean modified PI was 1.5 and mean BI was 2.0 at the end of experiment, with no statistically significant differences among the four groups.

Clinical Findings

PD and CAL among the four groups at 4 weeks, after second-stage surgery, were comparable with the 16 weeks evaluation (P >0.05) (Figs. 3A and 3B; Table 1). At 16 weeks after second-stage surgery, PD was deeper in subcrestal groups, and PD difference between the SIC and the SIS groups was significant (P = 0.042) (Table 2). CAL of subcrestal groups was also greater than crestal groups but only showed significant difference in the TI groups (4.3 ± 0.5 mm for TIC versus 5.3 ± 0.9 mm for TIS, P = 0.023). Differences of PD and CAL between TI groups and SI groups inserted in the same position were not significant (P >0.05) (Table 2).

Radiographic Findings

Ridge loss and IAI-fBIC were increased for all four groups over time (Figs. 3C and 3D; Table 1). A statistical significance was observed for IAI-fBIC at the end of experiment compared to second-stage surgery

‖ UNC, Hu-Friedy, Chicago, IL.
¶ Digora, Soredex, Helsinki, Finland.
\# NIH Image J v.1.44n, National Institutes of Health, Bethesda, MD.
** SPSS v.11.5, IBM, Chicago, IL.

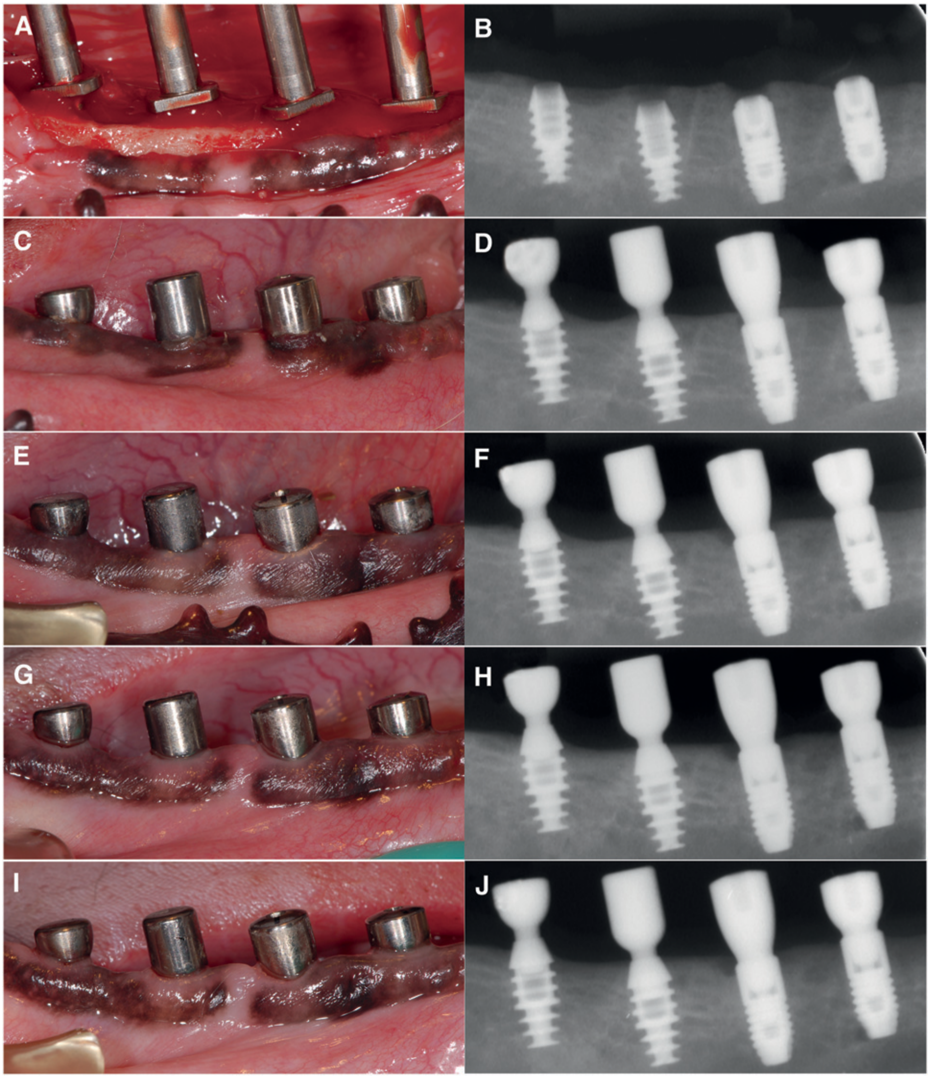

Figure 1.
***A** and **B)** Clinical and radiographic images of the four groups at implant placement; **C** and **D)** second-stage surgery; **E** and **F)** 4 weeks after second-stage surgery; **G** and **H)** 10 weeks after second-stage surgery; and **I** and **J)** 16 weeks after second-stage surgery.*

within all groups except the TIC group (P <0.05) (Table 1). No statistical differences were observed for IAI-fBIC from 10 to 16 weeks after second-stage surgery within all groups (P >0.05). The changes in IAI-fBIC were not significantly different among groups (P >0.05). At the end of the experiment, IAI-fBIC in the subcrestal groups was significantly lower than the crestal groups (P <0.05) (Table 2). IAIs in the crestal groups were located at the coronal position of the ridge, and at the apical position in the subcrestal groups; the differences between crestal and subcrestal groups were significant (P <0.05) (Table 2). The HBL and SLO in the TI groups seemed to be lower than the SI groups; however, these differences were not statistically significant among groups (P>0.05) (Table 2).

DISCUSSION

The purpose of the present study is to detect the influence of implant depth and IAI configuration on clinical and radiographic parameters around dental implants. There were several previous studies evaluating the influence of subcrestal placement of tapered internal implants on crestal bone loss,[16-21] but only limited information is available on whether different IAI configurations result in different peri-implant bone reactions,[20,21] and no comparative data exist between SI and TI from a side-by-side comparison when placing implants with their IAI crestally or subcrestally. The results of the present study demonstrate that there was no significant difference in PD, CAL, ridge loss, IAI-fBIC, and HBL between SI implants and TI implants when placed crestally or subcrestally under the unloading condition. Subcrestal groups had lower IAI-fBIC and higher PD compared to the crestal groups.

In the present study, the subcrestal groups had a low value of IAI-fBIC (0.46 mm for SI, 0.78 mm for TI) as seen in Table 1. The bone loss encountered in the implants with SI was comparable to that encountered in a previous animal study by Welander et al.,[17] who placed the IAI of the same implant system 2 mm subcrestally and found that IAI-fBIC of the control implant was 0.37 mm. A low value of IAI-fBIC in the subcrestal groups was also comparable to previous studies using SI implants under loading and immediately loaded conditions.[16,18] However, the higher amount of bone resorption ≈1.26 mm in the subcrestal tapered internal implant group was reported by Weng et al.[21] This discrepancy could be due to the influence of implant surface. The tapered internal implant used in the study by Weng et al. had a 1.5 mm smooth collar design, whereas implants with a rough collar design were used in the present study. It has been reported that bone tissue favors rough implant surfaces compared to relatively smooth titanium surfaces.[28,29]

The reason for the low IAI-fBIC value in subcrestal groups may be partially explained by the sealing ability of tapered internal connection that prevents or minimizes the bacterial leakage along the conical interface. In the studies of Broggini et al.,[11,12] a microgap of IAI ≈50 μm, which acted as a bacterial reservoir, was responsible for the bone loss.[12] In contrast, the capacity of the TI to prevent the invasion of oral microorganisms was evaluated by Dibart et al.,[7] who concluded that the conical contact between implant and abutment provided by the locking-taper design was hermetic with regard to bacterial invasion (24 hours for outside-in experiment and 72 hours for inside-out experiment) but there was a microgap (less then 0.5μm) at the prosthetic interface. Another in vitro study was conducted by Aloise et al.[8], in which *Streptococcus sanguinis* II was inoculated in TI and SI implants under anaerobic conditions for a longer period (14 days), showed that the frequency of bacterial leakage along IAI was only 20% for each type of IAI. This finding may also be attributed to the IAI design with platform switching. The concept of platform switching (abutment with narrower diameter connected to the implant),[30] suggests a decrease in crestal bone loss by shifting the IAI away from bone crest to reduce the influence of bacterial leakage from IAI and by shifting the stress concentration away from the dense cortical bone around the bone–implant interface. Limited bone remodeling around implants with platform switching placed subcrestally has also been reported in clinical studies.[19,31]

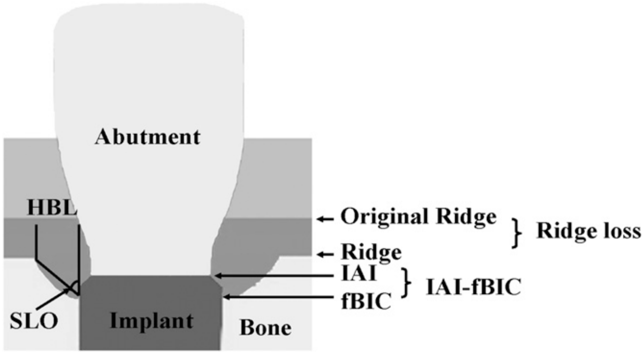

Figure 2.
Schematic representation of the landmarks for radiographic parameters measured: 1) original ridge, ridge at the time of implant placement; 2) ridge, ridge at the time of evaluation; 3) IAI; 4) fBIC; 5) HBL; and 6) SLO.

In this study, IAI-fBIC in implants of the crestal group were 1.27 and 1.36 mm for the SI group and the TI group, respectively (Table 2). This was also lower than the bone loss obtained by Weng et al.,[21] who reported 2.08 mm for the same parameter in their crestal tapered internal implant. However, better IAI-fBIC of ≈0.85 mm for their crestally submerged implants with SI was found by Abrahamsson et al.[32] The reasonable explanation is that several factors, such as IAI, implant surface, formation of biologic width, and surgical trauma may contribute to bone remodeling around a crestally placed implant.[33,34] In the present study, ridge loss during implant placement to second-stage surgery, which might be chiefly caused by surgical trauma, is 0.38 to 0.78 mm (Fig. 3C). A high value of IAI-fBIC in the crestal groups was established at the time of second-stage surgery, and the change of IAI-fBIC from second-stage surgery to 16 weeks later among the four groups was not significantly different (Fig. 3D; Table 1).

The clinical implications of the present study should be noted. Although different clinical recommendations were given by manufacturers for the two implant systems, the results demonstrate that the two IAI configurations had no significant differences in clinical and radiographic parameters.

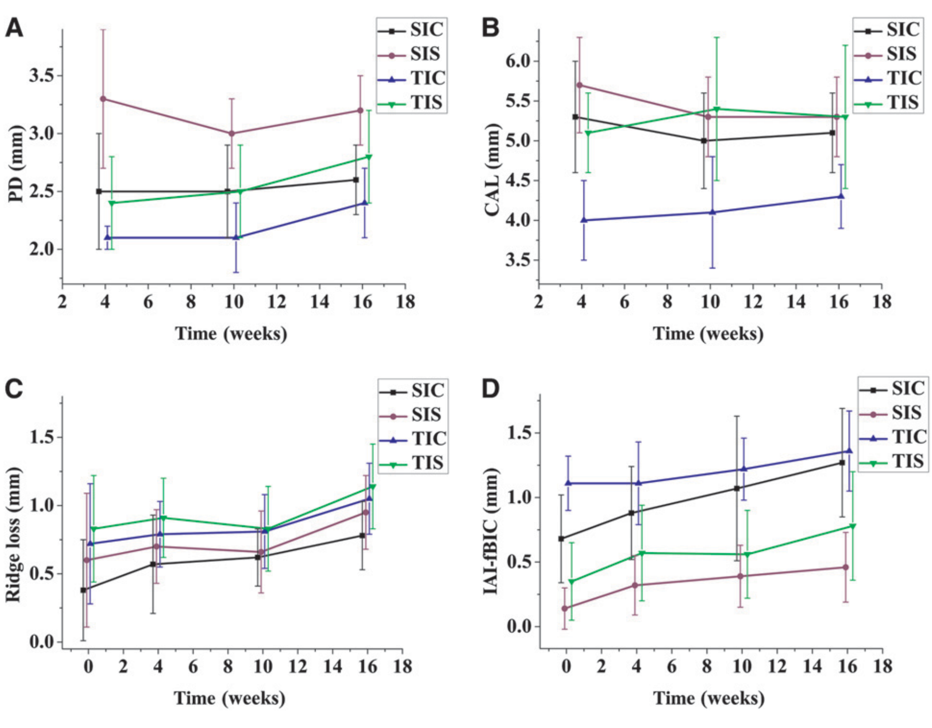

Figure 3.
*Plotting of means (n = 6) of PD **(A)**, CAL **(B)**, ridge loss **(C)**, and IAI-fBIC **(D)** for all groups after second-stage surgery.*

Table 1.

Data (mm; mean ± SD) From the Clinical and Radiographic Analysis of Implants After Second-Stage Surgery

Parameters	0 Weeks	4 Weeks	10 Weeks	16 Weeks	Change†	*P*
PD					16 – 4 weeks	
SIC	—	2.5 ± 0.5	2.5 ± 0.4	2.6 ± 0.3	0.0 ± 0.5	NS
SIS	—	3.3 ± 0.6	3.0 ± 0.3	3.2 ± 0.3	–0.1 ± 0.7	NS
TIC*	—	2.1 ± 0.1	2.1 ± 0.3[a]	2.4 ± 0.3[a]	0.4 ± 0.3	*a*
TIS	—	2.4 ± 0.4	2.5 ± 0.4	2.8 ± 0.4	0.4 ± 0.5	NS
P					NS	
CAL					16 – 4 weeks	
SIC	—	5.3 ± 0.7	5.0 ± 0.6	5.0 ± 0.5	–0.3 ± 0.4	NS
SIS	—	5.7 ± 0.6	5.3 ± 0.5	5.3 ± 0.5	–0.5 ± 0.7	NS
TIC	—	4.0 ± 0.5	4.1 ± 0.7	4.3 ± 0.5	0.3 ± 0.6	NS
TIS	—	5.1 ± 0.5	5.4 ± 0.9	5.3 ± 0.9	0.2 ± 0.8	NS
P					NS	
Ridge loss					16 – 0 weeks	
SIC	0.38 ± 0.37[b]	0.60 ± 0.49	0.72 ± 0.44	0.83 ± 0.39[b]	0.46 ± 0.43	*b*
SIS	0.57 ± 0.36[c]	0.70 ± 0.27	0.79 ± 0.24	0.90 ± 0.29[c]	0.34 ± 0.29	*c*
TIC*	0.62 ± 0.21[d]	0.66 ± 0.30[e]	0.81 ± 0.27[d,e]	0.83 ± 0.31	0.21 ± 0.29	*d, e*
TIS	0.78 ± 0.25[f,g]	0.95 ± 0.27	1.05 ± 0.26[f]	1.13 ± 0.31[g]	0.36 ± 0.21	*f, g*
P					NS	
IAI-fBIC					16 – 0 weeks	
SIC	0.68 ± 0.34[h,i]	0.88 ± 0.36[j]	1.07 ± 0.56[h]	1.27 ± 0.42[i,j]	0.60 ± 0.32	*h, i, j*
SIS	0.14 ± 0.16[k]	0.32 ± 0.23	0.39 ± 0.24	0.46 ± 0.26[k]	0.32 ± 0.34	*k*
TIC	1.11 ± 0.21	1.11 ± 0.32	1.22 ± 0.24	1.36 ± 0.31	0.25 ± 0.29	NS
TIS	0.35 ± 0.30[l]	0.57 ± 0.37	0.56 ± 0.34	0.78 ± 0.42[l]	0.44 ± 0.22	*l*
P					NS	

ANOVA test was used to analyze data that were distributed normally. Pairwise comparisons were performed using Bonferroni-adjusted Student *t* tests. Letters indicate statistically significant differences ($P < 0.05$).
— = without examination; NS = not significantly different.
* Data were not distributed normally. Significant differences was obtained by Friedman test ($P < 0.05$); Wilcoxon test was used for comparison to each other.
† Changes of PD and CAL observed from 4 weeks to 16 weeks, and changes of ridge loss and IAI-fBIC observed from 0 weeks to 16 weeks.

Limited IAI-fBIC in the subcrestal group might not be a key factor in the success of the regular implant, but for short implants, improvement of bone–implant contact might be important for obtaining predictable long-term results. Furthermore, IAI in the subcrestal groups were located at the apical position of the ridge, which was beneficial for avoiding metal exposure. Therefore, according to the present results, appropriate subcrestal placement of implants with tapered internal IAI is recommended. However, the optimal position related to the crest when the implant is subcrestally placed needs additional evaluation.

Although a low value of IAI-fBIC around the subcrestal implant was also mentioned in several aforementioned studies,[16,18,19,31] different recommendations were reported. For instance, in the study by Jung et al.,[16] bone loss was measured from the reference line representing the ridge at the time of implant placement to fBIC at the end of the experiment, and the result showed that the greatest bone loss occurred at implants placed 1 mm below the bone crest. Another report by Barros et al.,[18] who measured the value of IAI-ridge and regarded it as crestal bone resorption, showed that the crestal bone resorptions of subcrestal groups were significantly lower than those of the crestal groups. However, other studies proposed that crestal bone loss around the subcrestal implant was identified as IAI-fBIC.[19,31] The apparent discrepancies might be partially explained by the difference in measurement techniques. It seems that a single parameter cannot totally represent bone response around subcrestal implants, and three major parameters are suggested for evaluating the bone morphology around the subcrestal implants: 1) IAI-fBIC, representing bone-to-implant contact around implants; 2) IAI-ridge, revealing the related position between the top of implant and ridge, which is critical to avoid metal exposure; and 3) HBL, reflecting the width of intrabony defect, which is important for additional ridge prevention.

Table 2.

Data (mm; mean ± SD) From the Clinical and Radiographic Analysis of Implants 16 Weeks After Second-Stage Surgery

Parameters	Crestal	Subcrestal	*P*
PD*			
SI	2.6 ± 0.3	3.2 ± 0.3	0.042
TI	2.4 ± 0.3	2.8 ± 0.4	NS
P	NS	NS	
CAL			
SI	5.0 ± 0.5	5.3 ± 0.5	NS
TI	4.3 ± 0.5	5.3 ± 0.9	0.023
P	NS	NS	
Ridge Loss			
SI	0.83 ± 0.39	0.90 ± 0.29	NS
TI	0.83 ± 0.31	1.13 ± 0.31	NS
P	NS	NS	
IAI-Ridge†			
SI	–0.80 ± 0.51	0.61 ± 0.21	<0.001
TI	–0.89 ± 0.44	0.25 ± 0.41	<0.001
P	NS	NS	
IAI-fBIC			
SI	1.27 ± 0.42	0.46 ± 0.26	0.001
TI	1.36 ± 0.31	0.78 ± 0.42	0.020
P	NS	NS	
HBL			
SI	0.70 ± 0.29	0.87 ± 0.28	NS
TI	0.43 ± 0.40	0.54 ± 0.36	NS
P	NS	NS	
SLO (°)*			
SI	41.42 ± 15.40	40.46 ± 9.03	NS
TI	27.47 ± 15.58	30.67 ± 17.32	NS
P	NS	NS	

ANOVA test was used to analyze data that were distributed normally. Pairwise comparisons were performed using Bonferroni-adjusted Student *t* tests.
NS = not significant different.
* Data were not distributed normally. Friedman test and Wilcoxon test were used.
† Negative value means ridge at the apical position of IAI.

Another interesting result in the present study is that greater PD and CAL levels were recorded in subcrestal groups than in crestal groups (Table 2). A similar result was reported by Pontes et al.,[15] in which implants with butt-joint connection of IAI were used. This was in accordance with the results of an animal study by Todescan et al.,[14] who reported a longer epithelium and connective tissue around implants placed 1 mm below crestal bone compared to those placed at the crestal bone level. Moreover, in the present study, PD and CAL values were stable from 4 weeks after second-stage surgery to the end of the experiment (Figs. 3A and 3B). These clinical findings suggest that the absolute values of PD and CAL might not be treated as a single parameter for evaluating the clinical status of implants, because they were influenced by implant depth and not correlated with bone loss (IAI-fBIC). The establishment of baseline PD and CAL values is important for allowing comparison to future examinations. The stability of these results should be determined over a longer period.

It should be mentioned that the soft- and hard-tissue change around implants in the present study was evaluated under unloading conditions. Although no crestal bone loss after normal loading was reported in a previous study,[35] variations in micromechanical stability of IAI and stress distribution patterns might cause different bone remodeling around implants. Clinical studies with longer healing periods and under loading conditions should be conducted to confirm the present results and evaluate their clinical significance.

CONCLUSIONS

Within the limits of this study, it is concluded that tapered internal IAI configurations had no significant effect on crestal bone resorption. Moreover, absolute values of PD and CAL might increase after placing implants subcrestally, which implies the importance of establishing baseline PD and CAL for evaluating the clinical status of implants. Furthermore, subcrestal placement of tapered internal IAI had a positive impact on crestal bone preservation around the cervix of the implant.

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