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Internal Hexagon vs Conical Implant–Abutment Connections: Evaluation of 3-Year Postloading Outcomes

Sorin Gheorghe Mihali, PhD, DMD; Hom-Lay Wang, PhD, MSD, DDS; Olimpiu Karancsi, PhD, DMD; Emanuel Adrian Bratu, PhD, DMD

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Different types of internal implant–abutment connections, namely hexagon and conical, have been used for implant restoration. However, data regarding the benefits of these internal connections in terms of clinical outcomes are scarce. Accordingly, the aim of this study was to compare radiographic marginal bone loss (RMBL) and associated implant complications between implants with internal hexagon (IH) connections and those with internal conical (IC) connections. Forty-nine patients with 98 implants (2 per patient) placed in the posterior mandible were recruited. All implants were inserted in pairs into solid D2 bone according to a randomized sequence; the first patient received an IH connection implant on the mesial side, while the second patient received an IC connection implant on the mesial side. Each patient received 1 implant with an IH connection and 1 with an IC connection, placed side by side. Four months after placement, all implants were loaded with single screw-retained ceramic restorations with IH or IC connections. RMBL and complications, including implant/prosthesis failure, were recorded at the time of implant loading (baseline) and at 6, 12, and 36 months after loading. The results revealed no significant between-group differences in RMBL ($P = .74$), gingival bleeding on probing ($P = .29$), and complications ($P = .32$). Thus, the type of internal implant–abutment connection did not affect clinical outcomes, including RMBL and implant/prosthesis failure. Future studies should additionally evaluate long-term prosthesis-related complications, such as screw loosening and fracture, between the 2 types of internal connections.

dental implant–abutment connection, screw-retained restorations, conical connection, hexagon connection, bone remodeling

Introduction

Oral implantology is an evolving field with continuously developing designs, concepts, and materials. Every year, millions of dental implants are inserted and loaded with prosthetic superstructures, and, as observed in any therapeutic technique, biological and biomechanical complications may occur.[1] Currently, most dental implants have different abutment connections to minimize the risk of abutment movement and loosening of the inner screws. With screw-retained restorations (SCRs), the abutment can be removed if necessary. Sherif et al[2] showed that there was no significant difference between cement-retained restorations and SCRs in terms of clinical outcomes. This suggests that SCRs are as reliable as cement-retained restorations, although the latter are more popular in current clinical practice.

Another abutment modification is the so-called platform switching, which involves placing an abutment of smaller diameter into an implant of larger diameter. However, research has demonstrated that platform switching alone does not prevent crestal bone loss, regardless of mucosal thickness.[3,4] Nonetheless, one study reported a small positive effect of platform switching in terms of minimizing marginal bone loss (approximately 0.3 mm) 1 year after loading.[5] Similar results were reported in another study.[6]

The implant–abutment microgap and its relationship with crestal bone loss have also been evaluated. The microgap traps bacteria and can function as a reservoir for them; this often triggers inflammatory responses and infection around implants.[6] Interestingly, one study compared implants with screw-retained internal hexagon (IH) abutments and implants with a cone-morse internal connection and found no detectable separation or microgap between the implants and the abutments around the conical connection.[7] In contrast, numerous gaps and voids were present between the implant and the screw-retained IH abutment.[7]

In a study on the biomechanical behavior of multiple implant-supported prostheses, Borie et al[8] showed minimum stress in the bone surrounding implants with internal conical (IC) connections. In another study that evaluated fracture resistance under oblique compressive forces for IH and IC connection implants, the maximum deformation force for IC connection implants was significantly higher than that for IH connection implants.[9] The friction-locking mechanics and the solid design of the IC connection have been shown to provide greater resistance to deformation and to fracture under oblique compressive loading.

To our knowledge, data on the benefits of IH and IC connections in terms of clinical outcomes are scarce. Therefore, the aim of this study is to compare radiographic marginal bone loss (RMBL) and associated implant complications between implants with identical surface treatments but with different internal connections, namely, IH and IC connections.

Materials and Methods

Subjects

This clinical study was approved by the appropriate ethical committee, and written informed consent was obtained from all human participants. The study was conducted at the Department of Implant Supported Restorations from March 1, 2013, to May 31, 2017. Patients aged ≥21 years who could understand and sign a written informed consent form, who required a 2-implant–supported prostheses (excluding overdentures) in a free-end zone of the posterior mandible, and who exhibited adequate bone in the treatment area (width ≥ 6.75 mm; height ≥ 12 mm) were considered eligible. Additional inclusion criteria were as follows: presence of D2 bone, good oral health, no smoking history, and presence of a thick gingival biotype (ie, ≥2 mm of tissue thickness measured at the implant insertion site using cone-beam computed tomography [CBCT] and a periodontal probe). Bone density was assessed on the basis of computed tomography–derived Hounsfield units.[10] Preoperative radiographs and CBCT scans, as well as clinical examinations, were used to determine soft tissue and bone volumes. No hard or soft tissue grafting procedures were permitted for the included patients.

The exclusion criteria were as follows: medical conditions requiring prolonged steroid treatment and/or medications that could interfere with bone metabolism, irradiation of the head and neck area, autoimmune diseases requiring medical treatment, intravenous bisphosphonate or oral bisphosphonate for >3 years, local inflammation and untreated periodontitis, acute or purulent infection in the area of implant placement, poor oral hygiene and motivation (O'Leary plaque index ≥ 30%),[11] uncontrolled diabetes (HbA1c > 8%), pregnancy or nursing, psychiatric problems, absence of an antagonistic occlusal surface for the implant-supported prosthesis at the time of implant loading, any type of bone augmentation performed at the implant insertion site with a healing period of <6 months, bruxism, alcoholism or chronic drug abuse, and inability to commit to the follow-up schedule.

The exclusion criteria during surgery were as follows: lack of primary stability of at least 25 N-cm, need for bone augmentation procedures during implant insertion, and inability to place the implant in a correct position from a prosthetic point of view.

Implants with IH (SEVEN, MIS) or with IC (C1, MIS) connections were used (Figure 1). For the IC connection, the type of conical connection was a 6-degree, which ensures a secure fit between abutment and implant with minimal micromovements. A single operator performed all the surgeries to minimize bias. All implants were inserted in pairs into solid D2 bone according to a randomized sequence; the first patient received the IH connection implant on the mesial side, while the second patient received the IC

connection implant on the mesial side. Each patient received 1 implant with an IH connection and 1 with an IC connection, placed side by side. The diameter and the length of the inserted implants were 3.75 or 4.20 mm and 10 or 11.50 mm, respectively. The diameter and the length of the 2 implants were the same for each patient.

Figures 1 and 2.

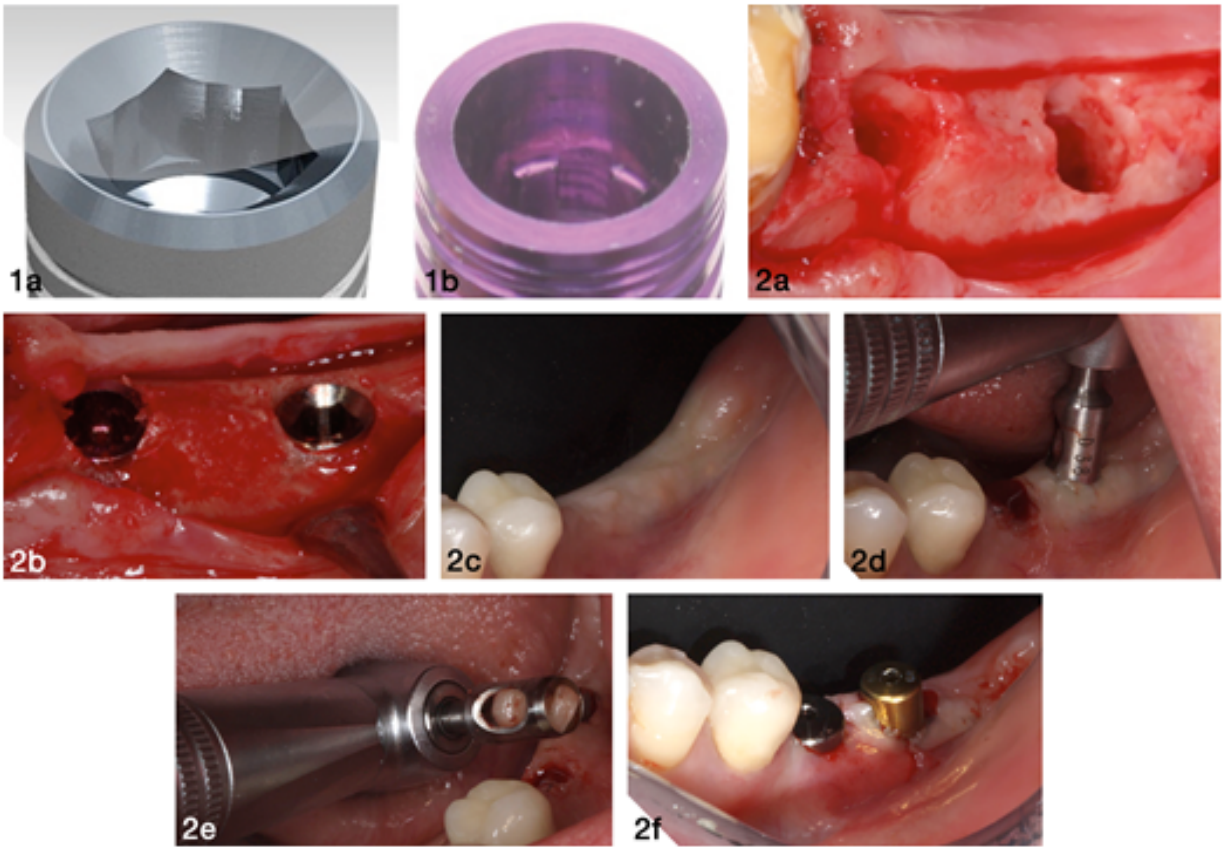

Figure 1. The 2 types of internal implant–abutment connections used in this study. (a) Internal hexagon connection. (b) Internal conical connection.
Figure 2. Illustration of implant insertion and uncovering procedures for implants with internal hexagon or conical connections. (a) Site after completion of the short-drilling protocol. (b) Implants with internal hexagon or conical connections are inserted to manage the free-end situation in the posterior mandible. (c) Clinical appearance of the crest during the 3-month osteointegration period. (d) Uncovered implant after the osteointegration period. (e) Gingival tissue in the tissue punch. (f) Healing screws.

Measurement

Peri-implant marginal bone remodeling was analyzed on intraoral radiographs obtained using the parallel cone technique at the time of implant loading (baseline) and at 6, 12, and 36 months after loading (Figure 4). To standardize the intraoral periapical radiographs, a silicone holder was used to maintain parallelism and minimize errors, and the X-ray (ProX, Planmeca) was directed perpendicular to the implant. The holder included a minimum of 3–4 teeth adjacent to the edentulous space. The radiographic sensor surface was retained in the mount to ensure reproducibility.

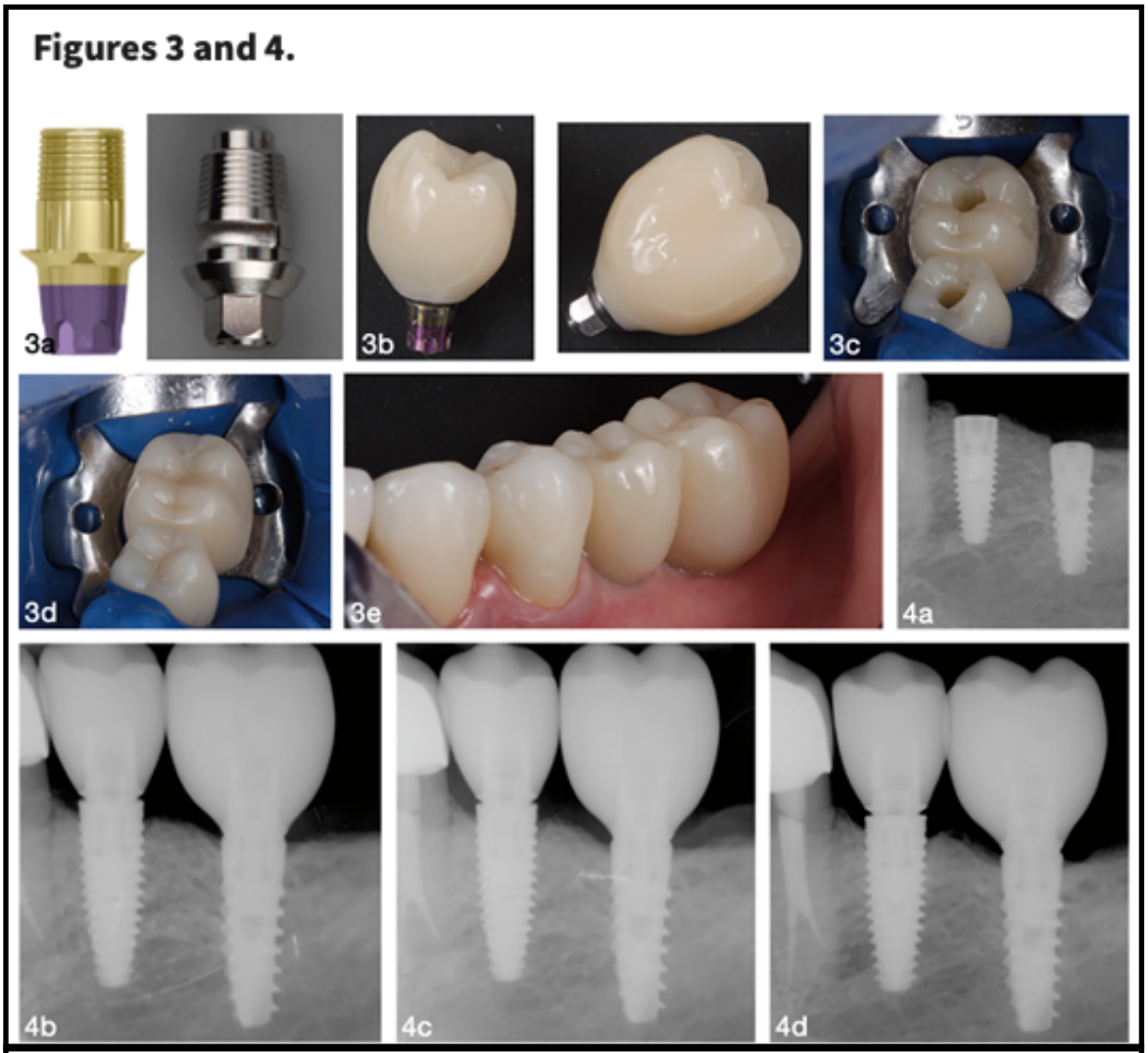

Figure 3. Illustration of implant restoration procedures. (a) Prefabricated titanium abutment connections. (b) All-ceramic screw-retained restorations. (c and d) Adhesive cementation of inlays for secure sealing of access holes. (e) Clinical aspects of the final fixed restorations.
Figure 4. Radiographs of implants with internal hexagon or conical connections at (a)

The peri-implant marginal bone level was evaluated by measuring the difference between implant–bone contact and implant–abutment junction using ImageJ 1.50e software (National Institutes of Health). All radiographs were registered on a 1:1 scale (Figure 5) according to the length (in mm) of the implant from the neck to the apex. The most common and reliable method used to assess marginal bone loss at the patient level involves determination of mesial/distal bone loss followed by calculation of the average of these measurements. Data were obtained by measuring the parallel axis of the implant, and results were determined by using 2 points: a reference point on the neck of the implant and another on the bone–implant contact.

Clinical preference regarding connection type was recorded at 6, 12, and 36 months after implant loading. Any complications, including implant/prosthesis failure, were recorded for both connection types.

Figures 5 and 6.

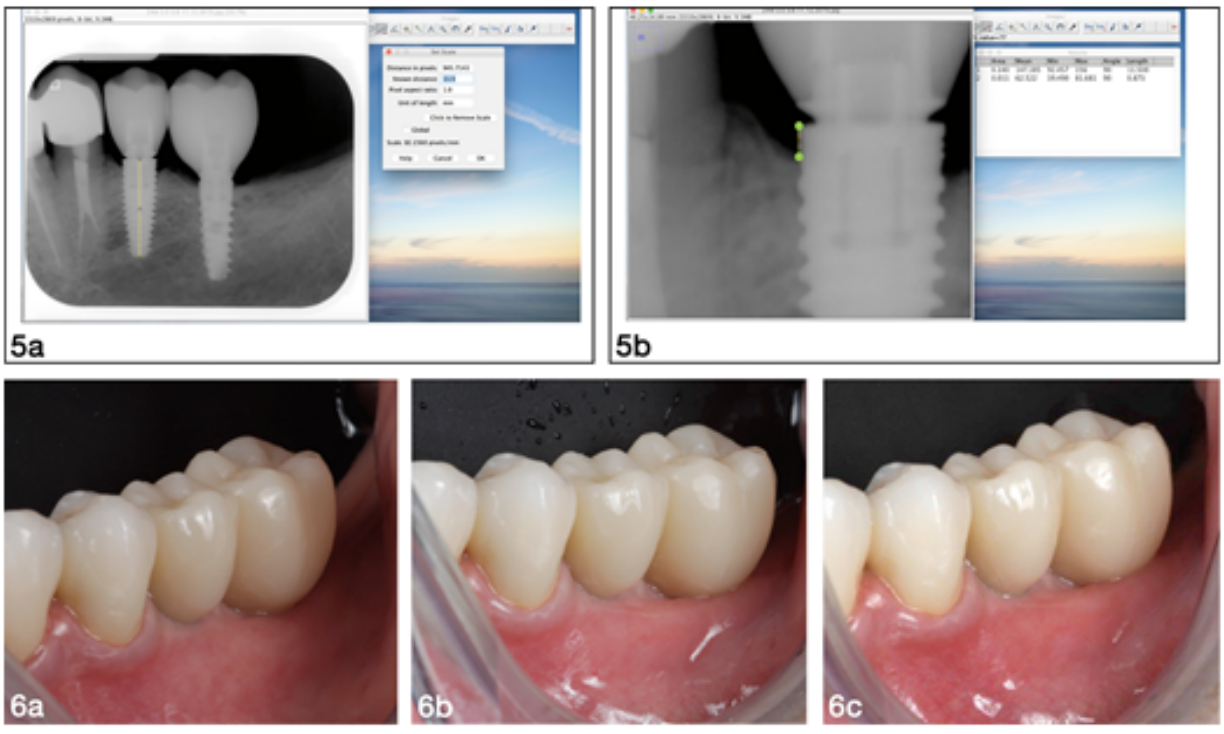

Figure 5. Radiographic analysis of bone level changes after the insertion of implants with internal hexagon or conical connections. (a) Calibration (in mm) with the known implant length using Image J software. (b) Measurement of bone level changes on the mesial aspect of the implant, from the platform to the implant bone level.
Figure 6. Clinical aspects of prostheses fitted on implants with internal hexagon or conical connections at (a) 6 months, (b) 12 months, and (c) 36 months.

Materials/Procedures

All patients received a prophylactic oral antibiotic 1 hour before surgery (2 g amoxicillin or 600 mg clindamycin in case of allergy to penicillin) and were instructed to rinse their oral cavities with a 0.2% chlorhexidine mouth rinse for 1 minute. All patients were treated under local anesthesia.

A gingival flap was elevated for implant insertion. The implant site was prepared using a short-drilling protocol,[12] and all implants were inserted with an insertion torque of <50 N-cm. During implant site preparation, the operator also subjectively assessed bone quality. Once the implant site was prepared, the operator inserted the 2 implants as per the randomization sequence. Saline irrigation was applied during the entire site preparation and implant insertion procedure. At least 3 mm of bone was left between each implant. The torque was measured using an insertion ratchet for the last 3–4 rotations. After insertion, all implants embedded at the crestal bone level received cover screws provided by the manufacturer of each type of implant. All implants were submerged for the healing process.

After surgery, the patients were prescribed 200 mg Ketoprofen (1–3 times a day as needed) and an antibiotic (1 g amoxicillin twice a day for 5 days or, in case of penicillin allergy, 300 mg clindamycin twice a day for 5 days). Follow-up assessments were performed within 1 week, and sutures were removed after 10 days.

Three months after implant insertion, a second surgery was performed to uncover the implants and place healing screws. The implant insertion and uncovering procedures are depicted in Figure 2.

Four weeks after implant uncovering, impressions were recorded using the direct transfer technique, and prosthetic restorations were delivered 1 week later. All patients received single screw-retained implant-supported monolithic lithium disilicate (e.max Press, Ivoclar Vivadent, Schaan, Liechtenstein) crowns. Either IH (Ti Base Kit, Single Tooth Restoration, MIS) or IC (Ti Base Kit, Single Tooth Restoration, MIS) prefabricated titanium implant–abutment connections were selected. All single-crown restorations were extraorally cemented on the titanium abutments using an adhesive cement (Multilink Hybrid Abutment, Ivoclar Vivadent). All SCRs with IH or IC connections were fixed to the implants using a torque of 25 N-cm. The screw access holes were closed with ceramic inlays.[13] A rubber dam was used during inlay cementation to minimize humidity from the oral cavity and peri-implant sulcus. The restorative procedures are depicted in Figure 3.

In this study, determination of a sample size was not attempted. Forty-nine patients were included, and each received 2 implants. Two Excel spreadsheets were generated: 1 for the IH connection and 1 for the IC connection. An independent statistician analyzed all data.

All statistical analyses were performed using OS X El Capitan version 10.11.3 software (Apple Inc). The significance of the differences observed was evaluated using 1-way analysis of variance. A P value of ≤.05 was considered statistically significant. All statistical calculations are described in the tables, and the results are presented as mean ± SD with minimum and maximum values. The rate of complication, including implant/prosthesis failure, was compared between groups using the Fisher exact test. The measurements taken at each follow-up visit (6, 12, and 36 months) were compared to the baseline measurements for evaluation of remodeling at the marginal bone level. The Scheffé method was used to analyze the mean radiographic values at 6, 12, and 36 months after loading, with baseline values as covariates.

Results

In total, 80 patients were screened for eligibility; from these, 17 who were unable to commit to the 3-year follow-up schedule, 3 with bruxism, 8 who required bone augmentation because of insufficient bone <6 months before implant insertion, 1 who had received irradiation, and 2 with poor oral hygiene were excluded (n = 31). Finally, 49 patients (28 men, 21 women) were included. Each patient received 2 implants, yielding a total of 98 implants analyzed. The patient and intervention characteristics according to type of connection are presented in Table 1. Two of the 49 patients (a total of 4 implants) were excluded from the analysis due to not completing the 36-month follow-up (1 died during the first year in a car accident and the other could not be contacted after 12 months). The 47 remaining patients completed all follow-up evaluations, and their implants exhibited stable osseointegration.

Table 1

Patient characteristics and implant specifications

	Hexagon	Conical
Implant diameter (mm)		
3.75	29	30
4.20	19	20
Implant length (mm)		
10.0	21	22
11.5	27	28
Site		
Premolar	21	20
Molar	29	28
Sex		
Male	28	28
Female	21	21

No implant presented with clinically or radiographically evident complications during the 3-year follow-up, and there was no statistically significant difference with regard to prosthesis failure between the IH and the IC connection groups (P = .32; difference = –0.08; 95% CI, –0.25–0.08). In addition, the 2 groups showed no statistically significant differences in terms of gingival bleeding or pathologies involving the peri-implant tissue (P = .29; difference = 0.12; 95% CI, –10–0.35).

With regard to the radiographic bone level changes, there was no significant difference between groups from baseline to the 3-year follow-up (P = .73; difference = –0.03; 95% CI, –0.25–0.17). The average RMBL in the IH and the IC connection groups was 0.42 and 0.35 mm, respectively, at 6 months (Table 2); 0.58 and 0.70 mm, respectively, at 1 year; and 0.68 and 0.64 mm, respectively, at 3 years (Table 2).

Table 2

Changes in the peri-implant marginal bone level for implants with internal hexagon or conical connections*

	Internal Hexagon Connection				Internal Conical Connection			
Implant Placement	Mean ± SD	Min	Max	95% CI	Mean ± SD	Min	Max	95% CI
6-mo follow-up	0.42 ± 0.40	0.01	1.4	−0.22–0.08	0.35 ± 0.34	0.01	1.2	−0.25–0.08
P value		.38				.38		
12-mo follow-up	0.58 ± 0.44	0.01	1.6	−0.09–0.33	0.70 ± 0.52	0.01	1.94	−0.10–0.35
P value		.25				.25		
36-mo follow-up	0.68 ± 0.50	0.01	1.92	−0.25–0.17	0.64 ± 0.45	0.01	1.68	−0.26–0.19
P value		.73				.73		

*CI indicates confidence interval; Max, maximum; Min, minimum.Mean, SD, Min, and Max values are reported in millimeters.

The Fisher least significant difference test confirmed that bone level changes did not differ significantly between the 2 groups at any time point (P > .5; Table 3). However, there was a significant difference between baseline and 36 months in the IH connection group (P < .05) and between baseline and 12 (P < .001) and 36 months (P < .01) in the IC connection group.

Table 3

Comparison of *P* values of bone level changes between internal hexagon connections and internal conical connections in implants (Fisher least significant difference test)

	Hexagon Versus Conical	Hexagon	Conical
6-mo follow-up	$P = .38$	$P = .41$	$P > .50$
12-mo follow-up	$P = .25$	$P = .13$	$P < .001$
36-mo follow-up	$P = .73$	$P < .05$	$P < .01$

Discussion

Several factors, including but not limited to abutment type, mucosa biotype, alveolar bone thickness, and oral hygiene, have been shown to influence the peri-implant marginal bone level. The results of this study showed that 3 years after loading, there were no statistically significant differences between IH and IC implant–abutment connections in terms of RMBL and complications (including implant/prosthesis failure). This is consistent with the outcome reported in a systematic review that compared conical and nonconical implant–abutment connections in vitro and in vivo.[4] The authors of that review concluded that both abutment connections exhibited sufficient resistance to maximal bending forces and to fatigue loading.[4]

For the analysis of marginal bone loss, most studies[14,15] recommend mesial and distal measures obtained from a conventional periapical radiograph. From a statistical point of view, there are no differences between mesial and distal radiographic measurements. One in vitro study examined the accuracy of interproximal peri-implant bone defect detection with titanium (Ti) and zirconium dioxide (ZrO_2) implants using digital periapical radiography and CBCT. The results of the above-mentioned study indicate that the assessment of interproximal peri-implant defect width in both Ti and ZrO_2 implants was more accurate with periapical radiography compared to CBCT. CBCT measurements always led to an overestimation of the defect width, which reached clinical relevance in ZrO_2 implants.[16]

Meetal et al,[17] in a study comparing CBCT and conventional periapical radiography, found that digital long-cone periapical radiographs are a reliable and valid method for the detection of circumferential peri-implant bone defects and that conventional periapical radiography performs significantly better than CBCT. Conversely, another study[18] reported that CBCT and conventional periapical radiography produce similar results in the evaluation of radicular changes. However, it indicates the use of conventional periapical radiography because CBCT implies a higher radiation dose. Periapical radiography is a reliable method[19,20] and in our study it was also more accurate than CBCT-3D evaluation, although we did use a silicone holder for reproducibility on the first technique.

In the present study, RMBL was similar between the 2 connection types, even though the IC connection implants were designed to allow platform switching. Thus, there appeared to be no added benefit of platform switching, consistent with the findings of a study by Esposito et al,[3] who found no statistically significant differences in clinical outcomes between internal and external connections. Our results are also consistent with those of another systematic review that found similarities between platform-switched and regular-platform implants placed in the molar region.[21] In another study, however, conical abutments did show some superiority in terms of seal performance,

microgap formation, torque maintenance, and abutment stability.[22] Other in vivo studies (human and animal) have also indicated that conical and nonconical systems are comparable in terms of implant success and survival rates. However, some have argued that a conical implant–abutment connection provides better abutment fit, stability, and seal performance than a nonconical abutment connection.[22]

Regarding bacterial microleakage from the human saliva to the implant–abutment connection, some studies have demonstrated that Morse taper connections and conical implant–abutment connections lead to significantly less bacterial species than IH and external hexagon connections.[23,24] In the current study, the results regarding peri-implant soft tissue loss and bone loss indicated a slight bone loss around the IH implant–abutment connections.

In the present study, a delayed loading approach was applied to minimize any potential influencing variables and promote uneventful healing. Because no bone or tissue grafting procedures were performed, the conditions were uniform and permitted a fair evaluation of the influence of connection type.

Another factor that should be taken into consideration is the initial gingival tissue thickness at the crest level. Generally, thick bony plates are associated with thick tissue biotypes, while thin bony plates are associated with thin tissue biotypes that are more prone to fenestration and dehiscence after dental extractions and implant placement. In the present study, patients with thick mucosa (≥2 mm) generally exhibited a normal architecture and a stable contour at the follow-up examinations. During the 3-year follow-up period, the peri-implant soft tissues showed normal physiological characteristics (Figure 6).

Future studies should consider the use of optical coherence tomography (OCT) for the analysis of bone-implant contact. One article[25] has reported that the implant-bone interface can be successfully investigated through a noninvasive method. Compared to conventional dental imaging, OCT is safer and can achieve the best depth resolution of all known methods. In a pilot study, Sanda et al[26] demonstrated that OCT is an effective diagnostic imaging tool only if the mucosa covering the implant body is thinner than 1 mm. On the other hand, some reports indicate that OCT imaging of implants is useful up to mucosa thicknesses of 3 mm. In another study,[27] OCT was used for the visualization and identification of peri-implant bone defects, and quantitative measurements of defect depth were obtained. It was concluded that OCT can be successfully used to determine peri-implant bone levels and to identify bone defects and that it produces quantitative noninvasive measurements of bone loss.

Conclusion

This study found no statistically significant differences in marginal bone remodeling or complications (including implant/prosthesis failure) between implants with IH connections and those with IC connections 3 years after loading. Thus, the type of internal implant–abutment connection did not influence clinical outcomes, including RMBL and implant/prosthesis failure. Future studies should address long-term prosthesis-related complications, such as screw loosening and fracture.

Acknowledgments

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Note

The authors do not have any financial interests, either direct or indirect, in the products or information listed in the manuscript.

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