

Conical Versus Internal Hex Implant–Abutment Connections: A Randomized Controlled CBCT (Cone Beam Computed Tomography) -Based Evaluation of Peri-Implant Crestal Bone Loss

Abstract

Background

Preservation of peri-implant crestal bone is a critical determinant of long-term implant success. The implant–abutment connection plays an important role in maintaining peri-implant tissue stability by influencing force distribution, micromovement, and microleakage at the implant interface. Conical connections have been proposed to provide superior mechanical stability and enhanced crestal bone preservation compared with internal hex connections.

Aim

To evaluate and compare peri-implant crestal bone loss around implants with conical and internal hex implant–abutment connections using cone-beam computed tomography (CBCT).

Materials and Methods

This prospective randomized controlled clinical trial included 20 systemically healthy patients requiring replacement of a single missing posterior tooth. Participants were randomly allocated into two groups (n=10 each). Group A received implants with a conical connection (S-Fix®), while Group B received implants with an internal hex connection (i-Fix®). Clinical and radiographic evaluations were performed at baseline and af-

ter 9 months. Crestal bone loss was assessed using CBCT, with the implant–abutment junction serving as the reference point. Data were analyzed using paired and unpaired t-tests, with statistical significance set at $p \leq 0.05$.

Results

All implants demonstrated successful osseointegration, resulting in a survival rate of 100% at 9 months. Mean crestal bone loss in the conical connection group was 0.86 ± 0.09 mm, whereas the internal hex connection group exhibited a mean crestal bone loss of 0.93 ± 0.08 mm. Although the conical connection group showed lower crestal bone loss, intergroup comparison revealed no statistically significant difference ($p = 0.071$).

Conclusion

Within the limitations of the present study, both conical and internal hex implant–abutment connections demonstrated favorable clinical and radiographic outcomes. Implants with conical connections exhibited a trend toward reduced crestal bone loss; however, the difference was not statistically significant. Further long-term studies with larger sample sizes are required to validate these findings.

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INTRODUCTION

In contemporary dentistry, dental implants are widely regarded as a reliable and routinely performed treatment for the rehabilitation of missing teeth. Ongoing innovations in implant macrodesign, surface engineering, and restorative components have significantly improved treatment outcomes, allowing successful rehabilitation of patients with partial or complete tooth loss. These advances have contributed to enhanced implant survival, functional efficiency, esthetic outcomes, and patient satisfaction (1). The pioneering work of Brånemark on osseointegration transformed implant dentistry by providing scientific evidence for the stable integration of titanium implants with living bone, thereby establishing endosseous implants as a dependable treatment modality for long-term oral rehabilitation (1).

Although achieving osseointegration is indispensable for implant stability, the success of dental implants is equally dependent on maintaining healthy tissues around the implants, particularly the marginal crestal bone. Preservation of crestal bone supports both the functional integrity and esthetic upshot of implant therapy. Traditionally, success of implant treatment was associated with marginal bone loss not exceeding 1.5 mm during the first year after loading, followed by an annual loss of no more than 0.2 mm thereafter (2). The literature consistently reports favorable survival rates for dental implants. However, achieving clinical success requires the continued health of the peri-implant tissues. In particular, preservation of the marginal crestal bone plays a vital role in maintaining implant function, esthetics, and long-term stability. Progressive bone loss around an implant can adversely affect its prognosis and increase the risk of biological or mechanical complications (3). Peri-implant bone remodelling is influenced by multiple interacting factors, such as the extent of surgical trauma, three-dimensional implant placement, establishment of the peri-implant soft tissue seal (biologic width), surgical approach, and implant design characteristics. Among these variables, the implant–abutment connection has gained considerable attention because it affects both mechanical load distribution and bacterial microleakage, thereby influencing the stability of the surrounding hard and soft tissues (4). Abutment micromotion, stress distribution, and microbial colonization within microgaps are influenced by the type of implant–abutment screw connection. These mechanical and biological factors may contribute to screw loosening, implant instability, and peri-implant crestal bone resorption (5). The transmucosal pathway through which the prosthetic connection emerges from the implant represents a constant anatomical feature of implant-prosthetic rehabilitation (6). Irrespective of the connection design, a microscopic gap may exist at the implant–abutment interface. This microgap can serve

as a niche for bacterial accumulation and may facilitate the diffusion of bacterial products and inflammatory mediators into the surrounding peri-implant tissues, potentially contributing to peri-implant inflammation and subsequent crestal bone remodeling (4).

In response to these concerns, implant manufacturers have developed different connection geometries aimed at improving the biological seal and mechanical stability of the implant–abutment complex. These designs are commonly grouped into three categories: external connections, internal parallel connections, and conical connections.

The external hexagonal implant–abutment connection, despite its long history of clinical use, has been reported to be more susceptible to rotational instability and screw loosening when subjected to functional occlusal forces. In comparison, internal connection designs provide a more stable implant–abutment interface, offering greater resistance to lateral loading and a more effective seal against bacterial penetration. Among the available internal connection systems, conical (Morse taper) connections have emerged as a preferred design because of their friction-locking mechanism, which limits micromovement at the interface and minimizes the size of the implant–abutment microgap. These biomechanical advantages have been linked to reduced bacterial microleakage, enhanced structural stability, and improved maintenance of peri-implant crestal bone over time (7).

Evaluating peri-implant bone changes is essential for determining the long-term clinical performance of dental implants and the effectiveness of their prosthetic connections. An accurate evaluation of marginal crestal bone is essential for identifying subtle bone remodeling that may influence implant prognosis. Cone-beam computed tomography (CBCT) has become an important diagnostic tool because it provides detailed three-dimensional images with greater accuracy than conventional radiographic methods for assessing peri-implant bone architecture and defects (8). Based on these considerations, this following study was carried out to compare crestal bone loss around implants with different implant–abutment connection designs through a combination of clinical examination and CBCT-based radiographic analysis.

MATERIALS AND METHODS

Ethical Considerations and Informed Consent

Prior to the commencement of the study, ethical clearance was obtained from the University Ethics Committee Medical (UECM), Swami Vivekanand Subharti University (Approval No. SMC/UECM/2024/886/362). The committee reviewed the study protocol and confirmed that it complied with the prescribed ethical principles for research involving human participants.

All eligible participants received detailed information regarding the objectives of the study, the treatment procedures, anticipated benefits, and potential risks before enrolment. Written informed consent was obtained from each participant before any study-related procedures were initiated. In addition, the trial was prospectively registered with the Clinical Trials Registry–India (CTRI) under the registration number CTRI/2024/10/075944.

Sample Size Estimation

As per discussion with the statistician, the sample size was calculated using the formula as mentioned below:

$$\text{Sample Size per group} = 2 \text{ SD}^2 (Z_{\alpha/2} + Z_{\beta})^2 / d^2$$

Based on the 85 percent power of the study and 5 percent type I error and effect size of 1.40 (effect size for the significant difference between the groups) the minimum sample size came out to be 18 i.e. 09 samples in each group. The sample size was increased to 20 i.e. 10 samples per group.

- SD – Standard deviation
- $Z_{\alpha/2} = 1.96$ (From Z table) at type 1 error of 5%

- $Z_{\beta} = 0.842$ (From Z table) at 80% power, 1.282 at 90% power
- d = effect size = difference between mean values

The mean and standard deviation for the clinical and radiographic variables were determined at baseline and at the 9-month follow-up using the following equations.

Participants & Study Design

This investigation was conducted as a prospective, parallel-arm, randomised controlled clinical trial at the Department of Periodontology and Implantology. The conduct and reporting of this study adhered to the CONSORT guidelines. (Fig. 1)

Study Population

Twenty systemically healthy individuals, aged 18–50 years, who required implant-supported replacement of a single missing posterior tooth were recruited for the study.

Inclusion Criteria

Participants were considered eligible if they met the following criteria:

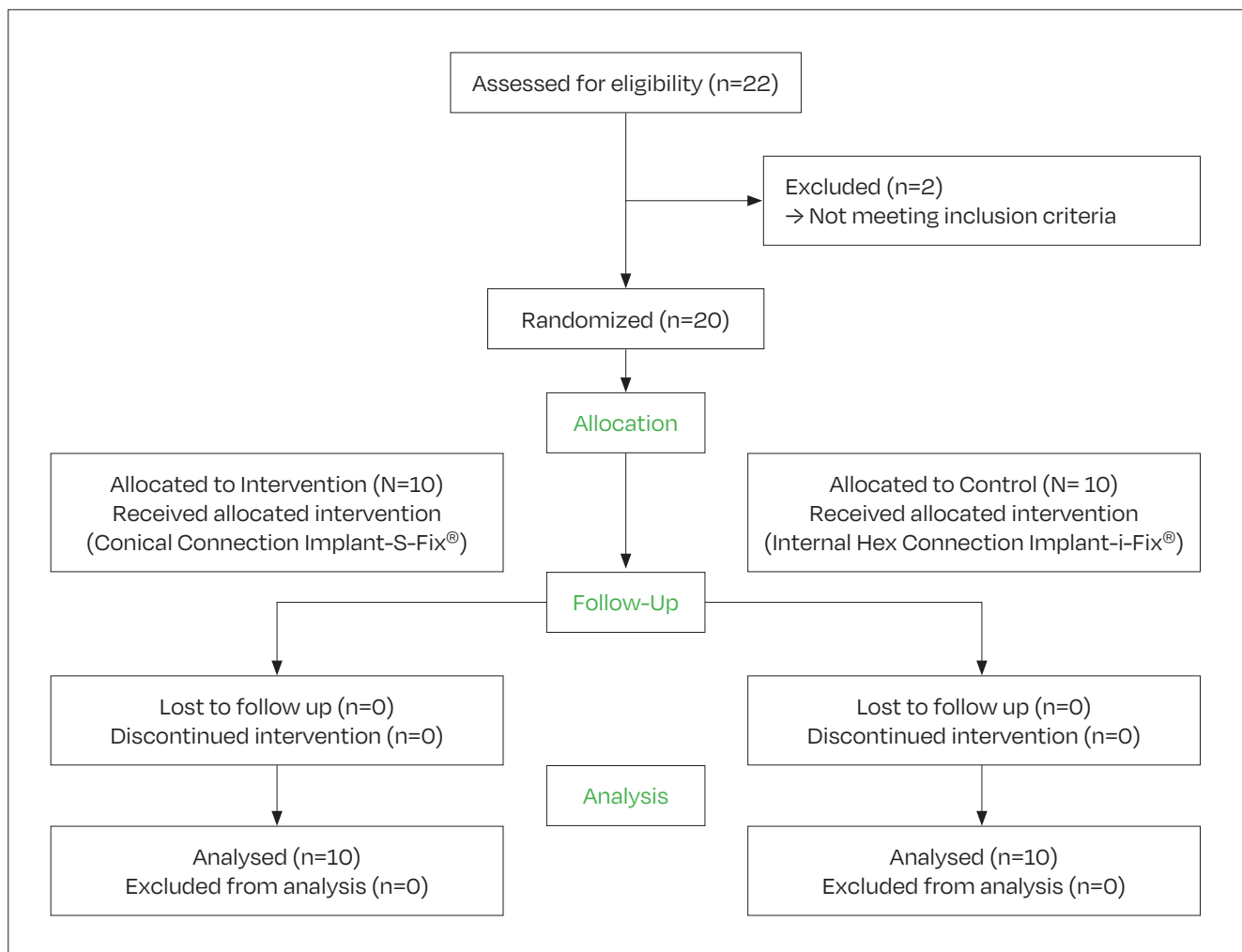


Fig. 1 Consort flow diagram.

- Presence of a single missing tooth in the posterior maxillary or mandibular region.
- Availability of adequate mesiodistal space and sufficient alveolar bone width and height to facilitate implant placement.
- Adjacent teeth that were either intact or restored with functionally and esthetically acceptable restorations.
- Adjacent prosthetic restorations that did not interfere with implant-supported replacement of the missing tooth.
- Good periodontal status and satisfactory general systemic health.

Exclusion Criteria

Individuals were excluded if they met any of the following conditions:

- Inability or unwillingness to maintain satisfactory oral hygiene.
- Current or previous history of tobacco smoking.
- Presence of temporomandibular joint (TMJ) disorders.
- History of bruxism, other parafunctional oral habits, or deep bite.
- History of alcohol or substance abuse.
- Inadequate vertical interocclusal space for the planned implant-supported prosthetic restoration.
- Uncontrolled diabetes mellitus.
- Absence of functional opposing dentition (lack of opposing occlusion).

Patient preparation

After the preliminary clinical assessment and treatment planning, Phase I periodontal therapy was carried out for all patients. Comprehensive oral hygiene instructions were provided, highlighting the importance of effective plaque control for the maintenance and long-term success of dental implants. Two weeks later, patients were re-evaluated, and only those who achieved adequate oral hygiene were included in the study. These participants were then randomly assigned to one of the two study groups, and this time point was considered the baseline for the study.

Randomization and blinding

Participants were randomly assigned to the test or control group in a 1:1 allocation ratio using a computer-generated randomization sequence. Allocation concealment was ensured through sequentially numbered, opaque, sealed envelopes (SNOSE) prepared by an independent investigator who was not involved in participant recruitment, surgery, or outcome assessment. Owing to the nature of the intervention, blinding of the operating surgeon was not feasible. However, the radiographic evaluator and the statistician responsible for data analysis were blinded to the group allocation

to minimize assessment and analytical bias.

Patients were given one capsule of Augmentin® 625 mg 24 hrs before and one capsule of Augmentin® 625 mg 1 hr prior to the procedure.

Surgical technique

Surgical Procedure

Group A (Conical Connection Implant [S-Fix®])

After evaluation of the preoperative records and identification of the relevant anatomical landmarks, local anesthesia was administered, a subcrestal incision was made and a full-thickness mucoperiosteal flap was reflected to expose the implant site. The osteotomy was initiated using a lance drill to penetrate the cortical bone to the predetermined implant length. Sequential intermediate drills corresponding to the selected implant diameter and length were then used to prepare the osteotomy.

The Conical Connection implant (S-Fix®) was inserted into the prepared osteotomy using gentle digital pressure until initial resistance was achieved, followed by final seating with a beam-type torque ratchet. The attached cover screw was secured using a hex driver. The flap was repositioned and sutured using polyglycolic acid/poly-lactic acid (PGA/PLA) sutures. (Fig. 2A, 2B, 2C)



Fig. 2A

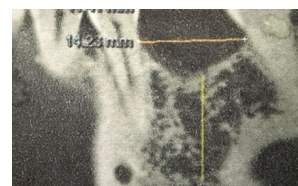


Fig. 2B

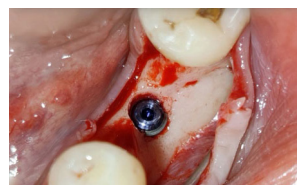


Fig. 2C



Fig. 2D



Fig. 2E



Fig. 2F

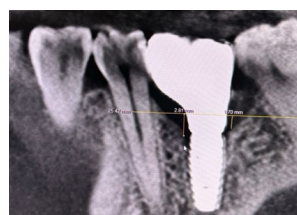


Fig. 2G

Fig. 2A Pre-OP view. **Fig. 2B** Pre-OP CBCT (tangential view). **Fig. 2C** S-Fix® implant placed with cover screw placed. **Fig. 2D** Baseline CBCT. **Fig. 2E** Gingival former placed after 3 months. **Fig. 2F** Crown delivered. **Fig. 2G** 9 months post-OP CBCT.

Group B (Internal Hex Connection Implant [i-Fix®])

After evaluation of the preoperative records and identification of the relevant anatomical landmarks, the implant site was exposed by reflecting a full-thickness mucoperiosteal flap. The osteotomy was initiated with a lance drill to the planned implant depth, followed by sequential twist drills of increasing diameter according to the implant dimensions.

The Internal Hex Connection implant (i-Fix®) was inserted into the prepared osteotomy using gentle digital pressure until resistance was encountered. Final seating was achieved using a torque ratchet, after which the cover screw was placed. The surgical flap was repositioned and sutured in a routine manner. (Fig. 3A, 3B, 3C)

Second-Stage Surgery (Groups A and B)

After a successful healing phase of 3–4 months, second-stage surgery was performed. An incision was made over the implant site, and the soft tissues were reflected sufficiently to expose the cover screw, which was subsequently removed. A healing abutment was connected to the implant, and the surrounding soft tissues were sutured around it (Fig. 2E, 3E). The healing abutment remained in place for approximately 10 days to facilitate soft tissue maturation.

Following adequate healing, implant impressions were made in the Department of Prosthodontics, and definitive prosthetic crowns were subsequently delivered (Fig. 2F, 3F).

Outcome Assessment

The following primary and secondary outcomes were measured:

a. Cone-Beam Computed Tomography (CBCT)

CBCT scans were obtained at baseline (immediately after implant placement) and at 9 months to evaluate peri-implant crestal bone changes (Fig. 2D, 2G, 3D, 3G).

b. Radiovisiography (RVG)

RVG images were recorded preoperatively, immediately after implant placement, and at 9 months to assess mesial and distal peri-implant bone levels.

c. Clinical Parameters

Clinical parameters were recorded at baseline and at 3 months and 9 months following implant placement. Oral hygiene instructions were reinforced at each follow-up visit to ensure optimal plaque control and maintenance of peri-implant health.

Primary outcomes

It included Crestal Bone Loss (CBL) (mm) measured using CBCT.

Secondary outcomes

These included:



Fig. 3A

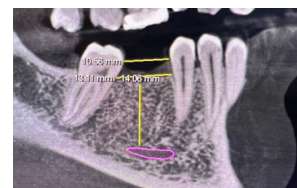


Fig. 3B



Fig. 3C



Fig. 3D

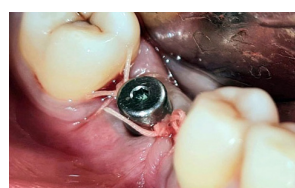


Fig. 3E



Fig. 3F



Fig. 3G

Fig. 3A Pre-OP view. **Fig. 3B** Pre-OP CBCT (tangential view). **Fig. 3C** i-FIX® implant placed with cover screw placed. **Fig. 3D** Baseline CBCT. **Fig. 3E** Gingival former placed after 3 months. **Fig. 3F** Crown delivered. **Fig. 3G** 9 months post-OP CBCT.

a) Clinical peri-implant parameters

b) Implant survival rate

The implant–abutment junction served as the reference point for all measurements.

Patients were followed for a period of 9 months after implant placement (6 months after loading). CBCT scans were obtained at baseline and at the end of the follow-up period for assessment of CBL bone loss and PIBD.

The study data were collected at baseline (implant placement) and at 9 months after implant insertion were entered into a spreadsheet, tabulated, and subjected to statistical analysis.

Descriptive statistics, including mean and standard deviation (SD), were calculated for all study variables. Intragroup comparisons between baseline and 9-month measurements were performed using the paired t-test, while intergroup comparisons between the two implant systems were carried out using the unpaired t-test.

Data analysis was performed by a biostatistician experienced in dental research who was blinded to the group allocation to minimize analytical bias. A P value of ≤ 0.05 was considered statistically significant. Statistical analyses were performed using IBM SPSS Statistics for Windows, Version 20.0 (IBM Corp., Armonk, NY, USA).

RESULTS

Crestal Bone Loss Assessed by CBCT

Cone-beam computed tomography (CBCT) scans (Galileos-Sirona, CS 9300 Scanner®) were obtained to assess peri-implant crestal bone loss. To ensure consistency in measurements, each CBCT image was aligned along the long axis of the implant. The implant–abutment junction (IAJ) was used as the reference landmark, and the vertical distance from the IAJ to the first point of bone-to-implant contact was measured to quantify crestal bone loss.

In Group A (Conical Connection implants), no crestal bone loss was observed at baseline. At the 9-month follow-up, the mean crestal bone loss was 0.86 ± 0.09 mm, representing an average increase of 0.86 mm over the study period. Similarly, Group B (Internal Hex Connection implants) showed no bone loss at baseline, while the mean crestal bone loss at 9 months was 0.93 ± 0.08 mm, corresponding to a mean increase of 0.93 mm.

A comparison between the two groups at the 9-month follow-up was performed using an unpaired t-test. Although the conical connection group demonstrated slightly lower mean crestal bone loss than the internal hex connection group, the observed difference was not statistically significant ($p = 0.071$; $p > 0.05$). These findings indicate that both implant–abutment connection designs exhibited comparable peri-implant crestal bone changes during the 9-month evaluation period (Table 1A, 1B; Fig. 4).

DISCUSSION

Conical implant–abutment connections, also known as Morse taper connections, have become increasingly popular in implant dentistry because of their favorable biomechanical properties. In contrast to conventional butt-joint or internal hex designs, these connections incorporate a tapered interface that allows the implant and abutment to engage through a friction-fit mechanism. During abutment tightening, compressive forces develop at the interface, producing a self-locking effect, often referred to as cold welding. This intimate contact minimizes movement between the components and creates a highly stable implant–abutment assembly that functions as a unified structure rather than as separate parts. Owing to these characteristics, conical connections have been associated with improved mechanical performance and long-term stability. Supporting these observations, Schmitt et al[9] demonstrated that conical implant–abutment connections provide better mechanical stability, a more precise fit, and fewer prosthetic complications than conventional connection designs.

In addition to providing a secure implant–abutment interface, the conical connection design offers greater resistance to rotational stresses, bending forces, and lateral occlusal loads. The close adaptation between the implant and abutment minimizes micromovement during function, thereby reducing mechanical stress trans-

Interval	Group A	Group A
	mean difference	mean difference
baseline vs 9 months	-0.86	-0.93

Tab. 1A Intra-group comparison of bone loss for both the groups.

S.No.	Time - Differences	P-Value
1	0-9	0.071**
*shows no significant difference between time-points at .05 level of significance. $p > 0.05$		

Tab. 1B Inter-group comparison of bone loss using unpaired 't' test for both the groups.

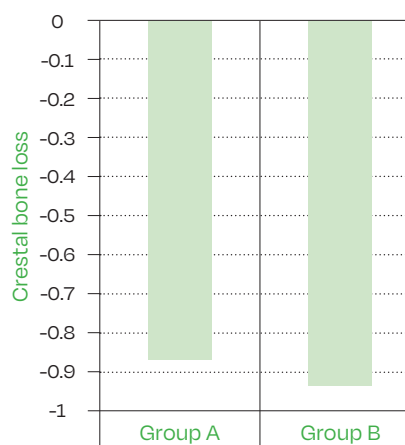


Fig. 4

The bar diagram of intergroup comparison of crestal bone loss in group A and group B.

mitted to the surrounding crestal bone. This improved mechanical stability may decrease stress concentration in the crestal region and help maintain peri-implant bone integrity. Finite element studies have also shown that tapered implant–abutment connections promote a more uniform distribution of occlusal forces along the implant body, thereby limiting excessive stress at the cortical crest. Such a biomechanical advantage is believed to reduce overload-related bone remodeling and contribute to the preservation of marginal bone levels. Consistent with these findings, the systematic review and meta-analysis by Yu et al[10] reported that implants with internal tapered (conical) connections exhibited significantly less marginal bone loss and better peri-implant tissue stability than implants with non-tapered connection designs. An additional benefit of conical implant–abutment connections is their compatibility with the platform-switching concept. By positioning the implant–abutment interface slightly inward from the implant platform, the microgap and the associated inflammatory cell infiltrate are displaced away from the crestal bone. This horizontal offset is thought to limit crestal bone remodeling and support the long-term maintenance of peri-implant soft tissue contours. The combined effect of a conical (Morse taper) connection and platform switching creates a more favorable biologic and biomechanical environment around the implant. Supporting this concept, Macedo et al[11] reported that the use of Morse taper connec-

tions together with platform switching contributes to the preservation of both peri-implant hard and soft tissues, resulting in improved peri-implant tissue stability.

In the present study, crestal bone loss was evaluated and compared between implants with internal hex and conical implant–abutment connections. Although the difference between the two groups was not statistically significant, the conical connection group exhibited slightly lower crestal bone loss than the internal hex group. Similar observations have been reported by Pozzi et al [12], who compared internal conical and external hex implant connections and found significantly less marginal bone loss around implants with internal conical connections (0.51 mm) than around those with external hex connections (1.10 mm). These findings suggest that conical connection designs may provide a biomechanical advantage in preserving peri-implant crestal bone.

The findings of the present study are also in agreement with those of Pessoa et al [13], who reported significantly greater peri-implant bone loss one year after loading in implants with external abutment connections (1.14 mm) compared with those having internal abutment connections (0.24 mm). Their results further support the role of internal implant–abutment connection designs in maintaining peri-implant crestal bone stability.

In contrast to the findings of the present study, Esposito et al [14] reported no statistically significant difference in marginal peri-implant bone loss between implants with external hex and internal connection designs. In their comparative study of tapered titanium screw-shaped implants, both implant systems exhibited progressive marginal bone loss following functional loading. Although the internal connection group showed slightly greater mean peri-implant bone loss (1.21 mm) than the external hex group (1.13 mm), the difference was minimal, indicating that both implant connection designs achieved similar clinical outcomes in terms of marginal bone preservation.

Limitations

- The study included a relatively small sample size of 20 participants with 20 implant sites, which may have limited the statistical power of the findings. Future studies with larger sample sizes are required to provide more robust and generalizable evidence.
- The follow-up period was limited to 9 months. Although CBCT was used to evaluate peri-implant bone changes, longer-term follow-up through well-designed prospective, randomized, and multicenter clinical trials is necessary to better assess crestal bone stability and peri-implant bone density over time.
- Histological evaluation was not performed because of ethical considerations associated with obtaining human tissue samples. Inclusion of histological analysis in future experimental studies could provide a

more comprehensive understanding of the biological response at the bone–implant interface.

CONCLUSION

The following conclusions can be drawn–

- 1) All implants survived at the end of 9-months period showing a survival rate of 100%.
- 2) Although implants with a conical connection demonstrated comparatively lower marginal bone loss, the results of the present study were not statistically significant.

Within the limitations of the present study, it can be concluded that implants with an internal hex connection demonstrated slightly greater crestal bone loss than those with a conical connection. However, the difference between the two implant–abutment connection designs was not statistically significant, suggesting comparable clinical performance over the study period.

Clinical significance

Every degree matters at the implant–abutment interface. Although both internal hex and conical connections demonstrated comparable peri-implant crestal bone preservation, conical connections exhibited a tendency toward reduced crestal bone loss, highlighting their potential biomechanical advantage in maintaining long-term peri-implant tissue stability.

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