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COMPARATIVE EVALUATION OF CRESTAL BONE LOSS IN AN ACTIVE AND PASSIVE IMPLANTS WITH VARIOUS DESIGNS: AN IN VIVO STUDY

Dental Science

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ABSTRACT

Background: Crestal bone loss is a critical determinant of dental implant success, with implant macro-design a major biomechanical influence on early marginal bone remodeling. Active (self-tapping, aggressive-thread) and passive (parallel-walled, minimally tapered) implants differ in insertion mechanics and load transfer, but comparative in vivo evidence on how specific thread geometries affect early crestal bone behaviour is limited. **Aim:** To compare crestal bone loss around active implants with double-thread design, active implants with double-thread back-tapered design, and passive implants with cylindrical thread design over three months. **Materials and Methods:** Fifteen partially edentulous subjects (25–60 years) received three implants each — Group A (active, double-thread), Group B (active, double-thread back-tapered), and Group C (passive, cylindrical thread). Standardized periapical radiographs at baseline, 1 month, and 3 months were used to measure mesial and distal crestal bone height via calibrated pixel analysis (ImageJ). One-way ANOVA (inter-group) and paired t-test (intra-group) were applied, with $p < 0.05$ as significant.**Results:** All groups showed significant bone height reduction from baseline to 3 months ($p < 0.001$). Inter-group differences were non-significant at baseline ($p > 0.01$) but highly significant at 1 and 3 months ($p < 0.001$). Group B showed the least crestal bone loss, followed by Group A, while Group C showed the greatest loss on both mesial and distal aspects.**Conclusion:** Implant macro-design significantly influences early crestal bone remodeling. Double-thread back-tapered active implants preserved crestal bone better than conventional double-thread active implants and cylindrical-thread passive implants, likely due to more favourable stress distribution and reduced crestal compression.

KEYWORDS

Crestal Bone Loss; Dental Implants; Active Implants; Passive Implants; Implant Design; Osseointegration; Back-tapered Implant.

INTRODUCTION

Dental implant therapy is now a predictable, widely accepted modality for replacing missing teeth, with long-term success rates exceeding 90%. Despite advances in materials, surface modification, and prosthetic design, crestal bone loss remains a persistent biological challenge and a key determinant of implant success[1]. Preserving crestal bone maintains peri-implant soft tissue architecture, supports long-term osseointegration, and favours esthetic outcomes, particularly in the anterior maxilla[1,4].

Crestal bone loss is multifactorial, driven by biological factors (surgical trauma, inflammation, microbial colonization at the implant–abutment microgap) and biomechanical factors (occlusal overload, crestal stress concentration, implant macro- and micro-design)[1,2]. Implant macro-design-thread geometry, pitch, body shape, taper, collar, and platform configuration-directly affects stress distribution, insertion torque, primary stability, and micromovement during loading[3,21,23].

Implants are broadly classified as active implants (tapered, aggressive self-tapping threads that compress bone for high primary stability) and passive implants (parallel-walled or minimally tapered, relying on a passive osteotomy fit to minimize crestal compression)[16]. Active designs suit compromised bone and immediate-loading protocols but may induce crestal microdamage from higher insertion torque; passive designs may better preserve crestal bone despite lower primary stability in soft bone[22,24].

While many studies have examined individual factors such as platform switching[4,20], connection type[10], and collar texture[8,12,25], comparative in vivo evidence on active versus passive designs with varied macro-geometry remains limited. This study compares crestal bone loss among active double-thread, active double-thread back-tapered, and passive cylindrical-thread implants.

AIMS AND OBJECTIVES

Aim

To compare and evaluate crestal bone loss in active and passive implants with various designs.

Objectives

1. To evaluate crestal bone loss in active implants with double-thread design.
2. To evaluate crestal bone loss in active implants with double-thread back-tapered design.
3. To evaluate crestal bone loss in passive implants with cylindrical thread design.

MATERIALS AND METHODS

Sample Selection

Inclusion criteria: age 25–60 years; partially edentulous, requiring posterior implant-supported rehabilitation; ≥3 edentulous sites suitable for implant placement without augmentation; systemically healthy; adequate bone volume (≥10 mm height, ≥4 mm width) on CBCT; OHI-S ≤ 1.5.

Exclusion criteria:

Uncontrolled systemic disease; active smoking; history of head-and-neck radiotherapy; bruxism; pregnancy/lactation; periodontal disease in adjacent teeth.

Fifteen subjects meeting these criteria were enrolled after clinical and radiographic screening. Each patient received three implants, one per study group, distributed by clinical need and bone availability.

Group	Implant Type	Design
Group A	Active implant	Double-thread design
Group B	Active implant	Double-thread with back-tapered design
Group C	Passive implant	Cylindrical thread design

Preoperative Evaluation and Implant Specifications

Medical/dental history, intraoral examination, periodontal probing, and OHI-S assessment were recorded. Preoperative CBCT assessed bone quality per the Lekholm and Zarb classification, and standardized periapical radiographs were taken using the long-cone paralleling technique. Titanium alloy (Ti-6Al-4V), sandblasted, acid-etched implants were used: self-tapping double-thread (Group A); double-thread back-tapered (Group B); and cylindrical-thread, non-self-tapping (Group C). Implant length and diameter were selected per available bone height and density.

Surgical Protocol

Pre-surgical preparation included full-mouth prophylaxis, a 0.12% chlorhexidine rinse, and antibiotic prophylaxis (amoxicillin 500 mg tid × 5 days, or clindamycin 300 mg if penicillin-allergic). Local anaesthesia used 2% lidocaine with 1:100,000 epinephrine. A full-thickness mucoperiosteal flap was reflected and sequential osteotomies prepared under saline irrigation at 800–1200 rpm.

Implants were placed with a controlled insertion torque of 35–45 Ncm (Groups A, B) or 25–35 Ncm (Group C), measured with a digital torque wrench; primary stability was recorded via resonance frequency analysis (Osstell ISQ). Flaps were closed with interrupted 3-0 silk sutures, and implants healed submerged for 3–4 months.

CASE REPORT

A partially edentulous patient presenting with missing teeth in relation to 45, 47, and 36 was selected for simultaneous placement of all three study implant designs — a double-thread active implant (Group A) at 45, a double-thread back-tapered active implant (Group B) at 36, and a cylindrical-thread passive implant (Group C) at 47 — enabling direct intra-patient comparison of crestal bone response.

Pre-Operative and surgical sequence

Fig. 1. Osteotomy sites prepared i.r.t. 45, 47, 36.

Fig. 2. Implants placed-cylindrical-thread design i.r.t. 47, double-thread design i.r.t. 45, and double-thread back-tapered design i.r.t. 36.

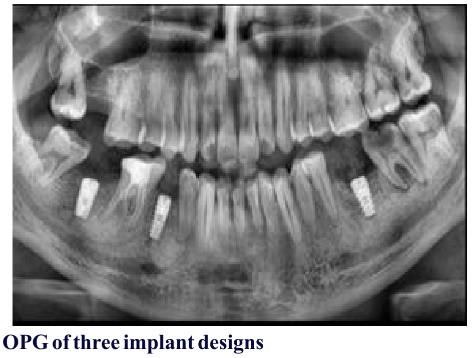

Fig. 3. OPG of three implant designs

Radiographic Evaluation

Standardized periapical radiographs at baseline, 1 month, and 3 months were digitized and analysed in ImageJ using a calibrated grid to measure mesial and distal crestal bone height in pixels. Data were tested for normality via one-way ANOVA; inter-group comparisons used one-way ANOVA, and intra-group comparisons (baseline vs. 1 and 3 months) used the paired t-test, with $p < 0.05$ considered significant.

H_0: No difference in crestal bone level among the three implant design groups. H : A difference exists among groups.

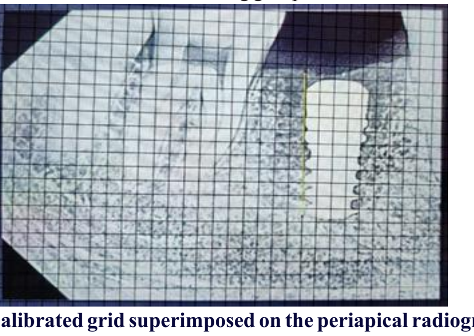

Fig. 4. Calibrated grid superimposed on the periapical radiograph using ImageJ software for standardized measurement.

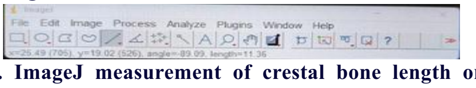

Fig. 5. ImageJ measurement of crestal bone length on the periapical radiograph.

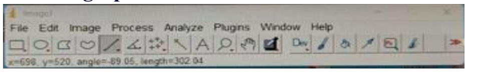

Fig. 6. ImageJ measurement of the corresponding pixel length used for calibration and bone-loss calculation.

OBSERVATIONS AND RESULTS

Crestal bone height (mean ± SD, pixels) was recorded at baseline, 1 month, and 3 months for the mesial and distal aspects of each group. All three groups showed a progressive decrease over time, indicating measurable early bone remodeling.

Table 1. Comparison of Crestal Bone Level (Mean ± SD, pixels) — Mesial Side

Group	Baseline	1 Month	3 Months	Relative Bone Loss
Group A (Double thread)	521.6 ± 221.4	515.4 ± 220.2	506.2 ± 218.6	Moderate
Group B (Double thread, back-tapered)	521.6 ± 221.4*	515.4 ± 220.2*	506.2 ± 218.6*	Least
Group C (Cylindrical thread)	564.8 ± 229.6	557.1 ± 228.4	546.2 ± 226.9	Maximum

Table 2. Comparison of Crestal Bone Level (Mean ± SD, pixels) — Distal Side

Group	Baseline	1 Month	3 Months	Relative Bone Loss
Group A (Double thread)	506.4 ± 208.1	500.2 ± 207.0	491.6 ± 205.5	Moderate
Group B (Double thread, back-tapered)	506.4 ± 208.1*	500.2 ± 207.0*	491.6 ± 205.5*	Least
Group C (Cylindrical thread)	566.2 ± 232.8	557.4 ± 231.6	544.1 ± 229.4	Maximum

Group B (back-tapered) showed the least crestal bone loss, Group A (double-thread) moderate loss, and Group C (cylindrical) the greatest loss on both mesial and distal aspects — consistent with reduced crestal stress and better load distribution for the back-tapered design versus higher stress concentration for the cylindrical design.

Table 3. Inter-Group Comparison-One-Way ANOVA (Mesial Side)

Time Interval	F-value	p-value	Inference
Baseline	0.742	> 0.01	Not significant
1 Month	18.63	< 0.001	Highly significant
3 Months	27.12	< 0.001	Highly significant

Table 4. Inter-Group Comparison-One-Way ANOVA (Distal Side)

Time Interval	F-value	p-value	Inference
Baseline	0.801	> 0.01	Not significant
1 Month	20.44	< 0.001	Highly significant
3 Months	31.08	< 0.001	Highly significant

One-way ANOVA showed no significant baseline difference ($p > 0.01$), confirming comparable starting bone levels, but highly significant differences at 1 and 3 months ($p < 0.001$) on both aspects, with back-tapered implants showing significantly less bone loss.

Table 5. Intra-Group Comparison-Paired t-test, Baseline vs. 1 Month / 3 Months (Mesial Side)

Group	Comparison	t-value	p-value	Inference
Group A	Baseline vs 1 Month	4.12	< 0.01	Significant
Group A	Baseline vs 3 Months	6.85	< 0.001	Highly significant
Group B	Baseline vs 1 Month	3.78	< 0.01	Significant
Group B	Baseline vs 3 Months	6.21	< 0.001	Highly significant
Group C	Baseline vs 1 Month	5.46	< 0.001	Highly significant
Group C	Baseline vs 3 Months	8.92	< 0.001	Highly significant

Table 6. Intra-Group Comparison - Paired t-test, Baseline vs. 1 Month / 3 Months (Distal Side)

Group	Comparison	t-value	p-value	Inference
Group A	Baseline vs 1 Month	4.35	< 0.01	Significant
Group A	Baseline vs 3 Months	7.14	< 0.001	Highly significant
Group B	Baseline vs 1 Month	3.96	< 0.01	Significant
Group B	Baseline vs 3 Months	6.64	< 0.001	Highly significant
Group C	Baseline vs 1 Month	6.08	< 0.001	Highly significant
Group C	Baseline vs 3 Months	9.21	< 0.001	Highly significant

Within each group, bone height decreased significantly from baseline to both 1 and 3 months ($p < 0.01$), confirming early remodeling in all designs, though to markedly different degrees.

DISCUSSION

This study compared early crestal bone changes among double-thread, double-thread back-tapered, and cylindrical-thread implants using calibrated pixel analysis at baseline, 1, and 3 months. Significant differences within and between groups indicate that implant macro-design meaningfully influences early marginal bone remodeling, consistent with the broader literature identifying macrogeometry as a key determinant of peri-implant bone behaviour[3,7,21].

Group A (double-thread) showed moderate bone loss, greater than the back-tapered design but less than the cylindrical design. The double-thread configuration improves primary stability and load transfer through deeper bone engagement, but residual crestal stress concentration likely accounts for the moderate remodeling observed, consistent with prior biomechanical analyses of dual-thread systems[21,22,24].

Group B (back-tapered) exhibited the least crestal bone loss, in line with literature on the biomechanical benefits of tapered geometries - improved stress distribution, reduced cortical microfracture, and better marginal bone preservation than parallel-walled designs[7,23,24]. The significant inter-group differences ($p < 0.01$) confirm that implant geometry can meaningfully mitigate early bone loss, a finding of particular relevance in esthetic zones[9,13].

Group C (cylindrical) showed the greatest bone loss on both aspects. Implants lacking a stress-relieving taper concentrate mechanical forces at the crest during loading, promoting microdamage and remodeling[21,22]. The consistently greater distal versus mesial loss across all designs is consistent with higher functional loading at the distal crestal region, particularly in posterior sites[9,17].

Albrektsson's classic success criteria permitted up to 1.5 mm marginal bone loss in the first year, while recent evidence favours keeping early loss below 1 mm by 3–6 months[5,18]. Bone-loss magnitudes in this study fall within clinically acceptable limits across all groups but clearly favour the back-tapered design, supporting implant macro-design as a key consideration in esthetic zones, poor-quality (Type III/IV) bone, immediate-loading protocols[6,19], and load-bearing posterior regions[9,17].

LIMITATIONS

The small sample size (15 subjects) and short follow-up (3 months) capture early remodeling but not long-term stability. Pixel-based radiographic measurements, though calibrated, may not fully represent three-dimensional bone changes[14,15]. Longer follow-up with CBCT-based volumetric assessment is warranted to confirm these findings.

CONCLUSION

Within this study's limitations, implant macro-design significantly influenced early crestal bone loss. Double-thread back-tapered active implants provided superior bone preservation, likely from favourable stress distribution and reduced crestal compression. Conventional double-thread implants showed moderate change, while cylindrical-thread passive implants showed the greatest remodeling — reinforcing macro-geometry as a key consideration in implant selection for optimal early bone stability.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

SOURCE OF FUNDING

Nil.

ETHICAL CLEARANCE

Obtained from the Institutional Ethics Committee prior to commencement of the study. Written informed consent was obtained from all participants.

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