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A Study of 42 Partially Edentulous Patients with Single-Crown Restorations and Implants to Compare Bone Loss Between Crestal and Subcrestal Endosseous Implant Placement

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Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
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Background: The purpose of the study was to evaluate the influence of dental implant placement at different bone levels upon the resultant postoperative peri-implant bone loss.

Material/Methods: Forty-two partially edentulous patients seeking implant-supported single-crown restorations were screened followed by segregation into 2 groups (GP), GP E (equicrestal) and GP S (subcrestal) (n=21 each). Sixty endosseous implants (30 each) (Adin Tourage-S, Israel), size 3.5/8 and 4/10 mm for mandible, were placed using a 2-stage surgical procedure. At 4 to 6 months, straight abutments were attached followed by restoration (Vita Zahnfabrik, Germany). Crestal bone levels (mesial/distal) of implant fixtures were assessed at 5 time intervals (after surgery, and at 3, 6, 9, and 12 months) using digital radiography. Means and standard deviations were calculated, following which the differences were statistically analyzed using ANOVA at *P* value of <0.05.

Results: The mean annual bone loss for GP S (1.96 mm) was higher than GP E (1.10 mm). At all studied time intervals, the bone loss for implants in GP S was higher than in GP E ($P<0.05$). Between time intervals, lowest bone loss was observed on the distal side in GP E (0.11 mm/6-9 month) and the highest bone loss was observed on the distal side of GP S (0.6 mm/9-12 month). Differences in the means between the 2 groups on mesial and distal sides were statistically significant at all time intervals ($P<0.05$).

Conclusions: Subcrestal implant placement was associated with more bone loss than when implants are placed at the crestal level.

Keywords: Alveolar Bone Loss • Dental Implant-Abutment Design • Dental Implants, Single-Tooth • Osseointegration • Peri-Implantitis

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Background

Loss of natural teeth initiates an imbalance within orofacial structures, which subsequently can progress into inefficient masticatory dynamics, thereby causing occlusal discrepancy that may further deteriorate to compromised esthetics. However, restoring the missing teeth reduces these adverse effects. Within the last 2 decades, available prosthetic treatment options for replacing lost teeth have witnessed a prodigious change, especially with introduction of dental implants, which in turn have improved quality of the patient's life [1]. Formerly, removable partial dentures (RPD) were commonly used to substitute missing teeth, which changed with the advent of fixed partial dentures (FPD) (tooth-supported). FPDs are still used widely, as they improve masticatory function, esthetics, and comfort. As science and technology progressed, newer options to replace teeth came into effect. Presently, implants as a treatment preference are being widely advocated for replacing teeth and lost structures, the biological basis of which is osseointegration, a concept introduced in 1969 [2]. A major advantage of dental implants over conventional tooth-supported FPD is that it is independent of the adjacent natural teeth, thus preserving and fulfilling the basic principle of tooth preservation. During the last few decades of clinical advances in material science and design for endosseous implants, replacement of the tooth/teeth has evolved, which has increased prosthetic treatment options within implant dentistry [3]. Osseointegration as per Branemark's theoretical concept implies that a titanium screw could be drilled into a viable, vital bone and permitted to integrate with the bone, which in time could support the dental prosthesis [2]. With the advent and support of precise computer-aided diagnosis and computer-aided machining (CAD/CAM), implant-supported restorations have developed to be a commonly used treatment modality for restoring lost dentition, as it satisfies the psychological, functional, and esthetic needs of partially edentulous patients [4]. Dental implants have progressed in shape, size, surface treatment, and clinical loading, thus making it one of the most desired treatment options for replacing partially or completely edentulous arches.

Osseointegration is the basis of dental implant success, and depends largely on the quality and quantity of the surrounding bone [5]. Conservation of crestal bone in and around the submerged implant fixture is a vital clinical criterion to be considered for successful implant therapy. The bone loss around an implant also influences the esthetic outcome of the prescribed treatment. Consequently, estimation of the crestal bone levels in patients treated with implants is crucial for the final outcome of the prosthesis. Various modalities have been proposed for measuring crestal bone loss and all of these are well documented in the scientific literature [6]. Radiographic assessment using intra-oral peri-apical radiographs (long-cone paralleling technique) has been widely used for its simplicity, availability, and safety. Orthopantomograph and digital radiography have been found to be reliable methods (tools) to evaluate the clinical crestal bone changes [6]. The benchmark for implant success (long-term) as proposed by Alberktsson demands that the bone loss (vertical) around implant fixtures should be less than 0.2 mm per year after the first year of implant loading, which is still the standard [7]. The indicator for implant success remains the same for all prosthetic implant treatment options, whether implants are restoring a complete or a partial edentulous situation [8], or whether one uses a fixed or a removable implant prosthetic option. The collective configuration of bone loss observed generally is from the alveolar crest, which progresses toward the apical region. The cause of loss of bone around the implant could be either from local or systemic causes. While systemically compromised patients are relatively contraindicated for implant treatments, it is the local factors like infections and mechanical stresses (offset occlusal load) that play more significant roles in developing or preventing peri-implantitis. To achieve less bone loss, various investigators have proposed different implant placement positions in relation to the crestal bone. Two positions – equicrestal and subcrestal – have been reported, with conflicting results. Most studies have been used a mixed methodology in terms of implant numbers, implant-specific treatment option, and implant placement within the arch (anterior or posterior) and within the mouth (maxillary or mandibular). Since bone types are different within each arch, no study has been conducted exclusively studying the bone loss pattern in a specific area of the mouth. Furthermore, the follow-up evaluation period of presence/absence of crestal bone loss in and around the implant has been debated, and different authors have evaluated bone around implants at 6 months [9] and at 12 months [10]. Others have supported these views and have stated that follow-up of the patient at 6 and 9 months is appropriate for evaluating post-surgical and post-loading changes. However, an overall 10% of implants (n=10,000 implants) have been reported to still fail in clinically ideal conditions from multiple studies [11]. A retrospective study of 8,528 patients treated with 39,077 implants over a period of 27 years reported that the incidence of failure was higher within the first year of surgery (69%) (n=857), especially for the maxillary arch [12]. Implant site inflammation during the first year of implant placement was found to be a high risk for late implant failure [12]. Implant failures have been found to be associated with multiple patient, surgery, and prosthesis-related risk factors. Within the first year after surgery, poor patient compliance (eg, maintaining improper oral hygiene, smoking, not attending follow-up visits) has been reported to be a risk factor for implant treatment outcome. However, clinical study (n=84 implants) that assessed the effect of various predictor variables (demographic, health status, anatomic variables, implant-specific, and operative factors) found no significant

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differences of these variables that would increase the risk of crestal bone loss within 1 year after placement [13]. Studies have also investigated placing implants at various levels in relation to the clinically visible crest of the bone (crestal and subcrestal). While the crestal implant placement has been shown to have greater stability within the first year [14], subcrestal implant placement has been found to be associated with greater stability and less bone loss in the long term [15].

In the context of these 2 backgrounds, we conducted this study to evaluate two different implant placement positions (equicrestal and subcrestal). We recorded marginal bone loss in a specific area of the arch (mandibular posterior) with strict inclusion/exclusion criteria, thereby minimizing the effect of other variables observed in most previous studies. To assess the need for extra follow-up for implant restoration, we also added 2 additional follow-up visits (at 3 and 9 months). These time periods are significant in evaluating the initiation or absence of initiation of bone loss irrespective of implant placement positions. We hypothesized that subcrestal implant placement provides an ideal environment for bacterial growth, especially in the mandibular arch; therefore, more bone loss will be observed after second-stage surgery. Therefore, this study included 42 partially edentulous patients with single-crown restorations and implants and aimed to compare bone loss between crestal and subcrestal endosseous implants. Evaluating the differences in bone loss at 4 different intervals of time within the first year would fulfill the objective of the study, which is to recommend increased follow-up visits for all patients receiving implants.

Material and Methods

Ethics

The proposed study was conceptualized after reviewing the current literature and a research proposal was submitted to the Ethics Approval Committee of the college and its affiliated university. After approval from the Ethics Committee (approval number SU/SDS/74-A/2019/02), an informed consent form was customized as per the need of this study.

Study Design

This clinical study was conducted in one of the recognized postgraduate institutes of North India, between the second quarter of 2019 and the first quarter of 2021. The study design was that of a prospective study in which intervention in the form of dental implants was performed at 2 different clinical depths in the posterior mandibular arch, followed by the radiographic evaluation of bone loss around implants at 4 different time intervals, excluding baseline.

Sample Preparation, Selection, and Grouping

The patient sample for the study was cross-sectional, which was standardized by following strict inclusion and exclusion criteria. Patients who were included had to be 18 to 40 years (single implant restorations), any gender, willing and consenting for implant placement, practicing good oral hygiene, partially edentulous with well-healed mandibular edentulous posterior areas (to exclude the need for bone augmentation), sufficient bone width and height to accommodate a 3.5- or 4-mm by 8- or 10-mm implant, and did not have any type of occlusal problem. Any patient with a history of smoking, alcohol or drug consumption, medically compromised, evidence of parafunctional habit, inaccessible posterior area, or other absolute or relative contraindications for implant placement were excluded from the study. An additional criterion for exclusion of females was currently being pregnant. All patients were registered in the study after a detailed clinical and radiographic examination, assessment of diagnostic casts, bone mapping, orthopantomograph evaluation, and patient education and motivation – 42 patients (31 males and 11 females) were finalized to receive 60 endosseous implants in the mandibular posterior area. These patients were allotted (convenience sampling) to 2 equal groups (GP) – GP E (Equicrestal placement) and GP S (Subcrestal placement) – based on implant fixture relation to the adjacent bone. A total of 30 implants were placed on either right, left, or same/both sides of the mandibular arch. Allotment was done by convenience sampling, so that a uniform distribution of implants on either side was achieved. For each GP, a total of 22 implants in the distribution of 15 and 7 implants on either right or left side was achieved with equal distribution of 4 patients with 8 implants (2 on the same side/1 on the right and 1 on the left). The position of implant placement in the subcrestal group was 2 mm below the level of visible clinical bone crest. Patients were thoroughly informed about the significance of the study and possible risks during the surgical procedure. Written informed consent from each patient was obtained at this stage of the study.

Surgical Placement of Implants

For all patients in both groups, a thorough diagnostic evaluation for the feasibility of placing an implant in terms of determining tentative implant size, position, alignment, and relation to crestal bone was performed using a combination of digital intra-oral peri-apical radiographs (IOPA) (Kodak Carestream, IOPA2 Size Q, XJAM530), orthopantomography (OPG) (Gendex GXDP-700 Series OPG System, KaVo, Germany), (**Figure 1A**) cone beam computed tomography (CBCT) (Vera view epocs 3D R100; J. Morita, Kyoto, Japan) (**Figure 1B, 1C**), mounted diagnostic casts on programmed semi-adjustable articulator (Whip Mix series 3000; Elite Dental Services, Inc., Orlando, FL), and customized diagnostic splints. A standard 2-stage surgical

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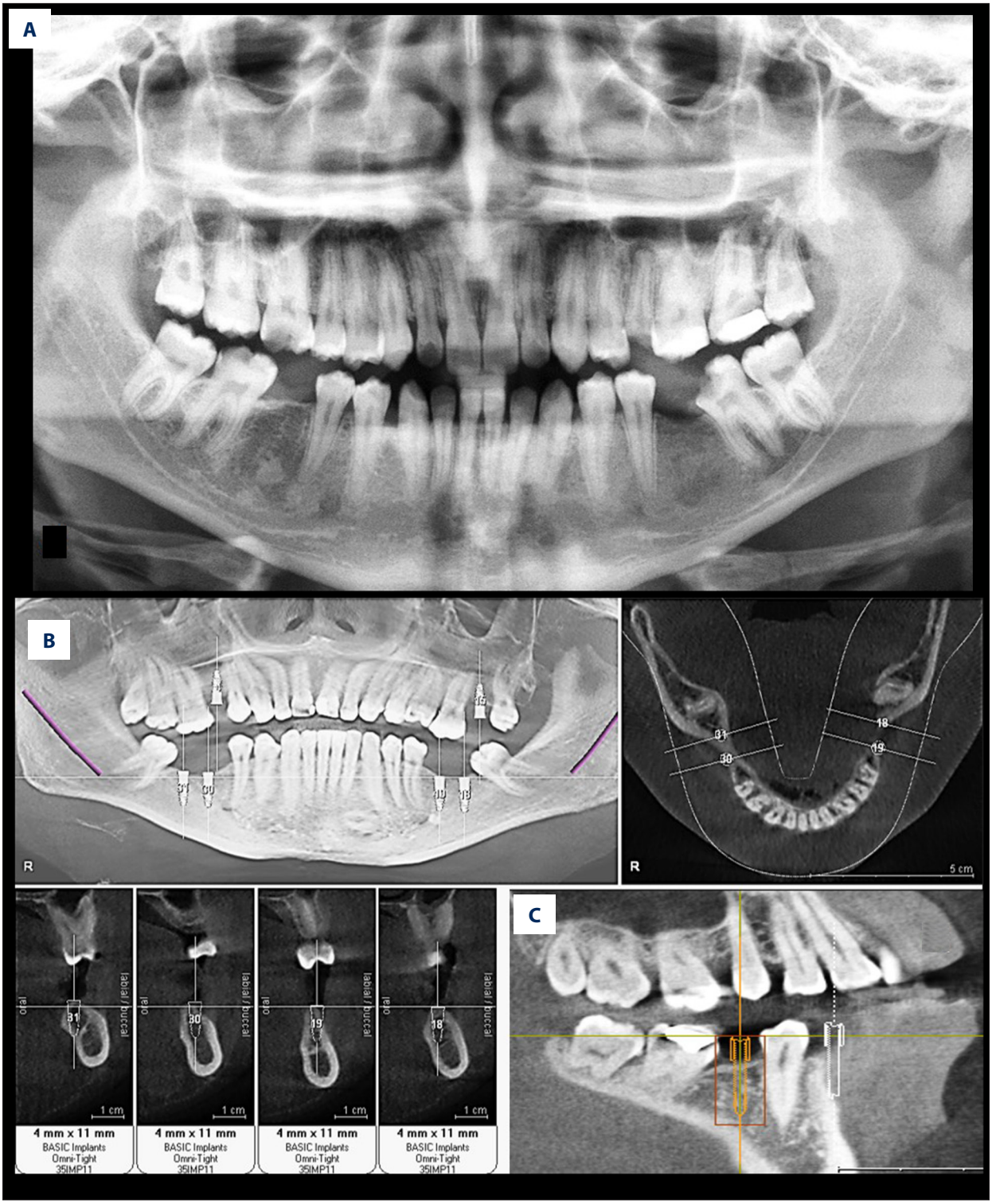

Figure 1. Diagnostic evaluation for implant selection using conventional digital orthopantomograph (**A**) and cone beam computed tomography (CBCT) (**B**) and (**C**). *Figure created using MS PowerPoint, version 20H2 (OS build 19042,1466), Windows 11 Pro, Microsoft corporation).*

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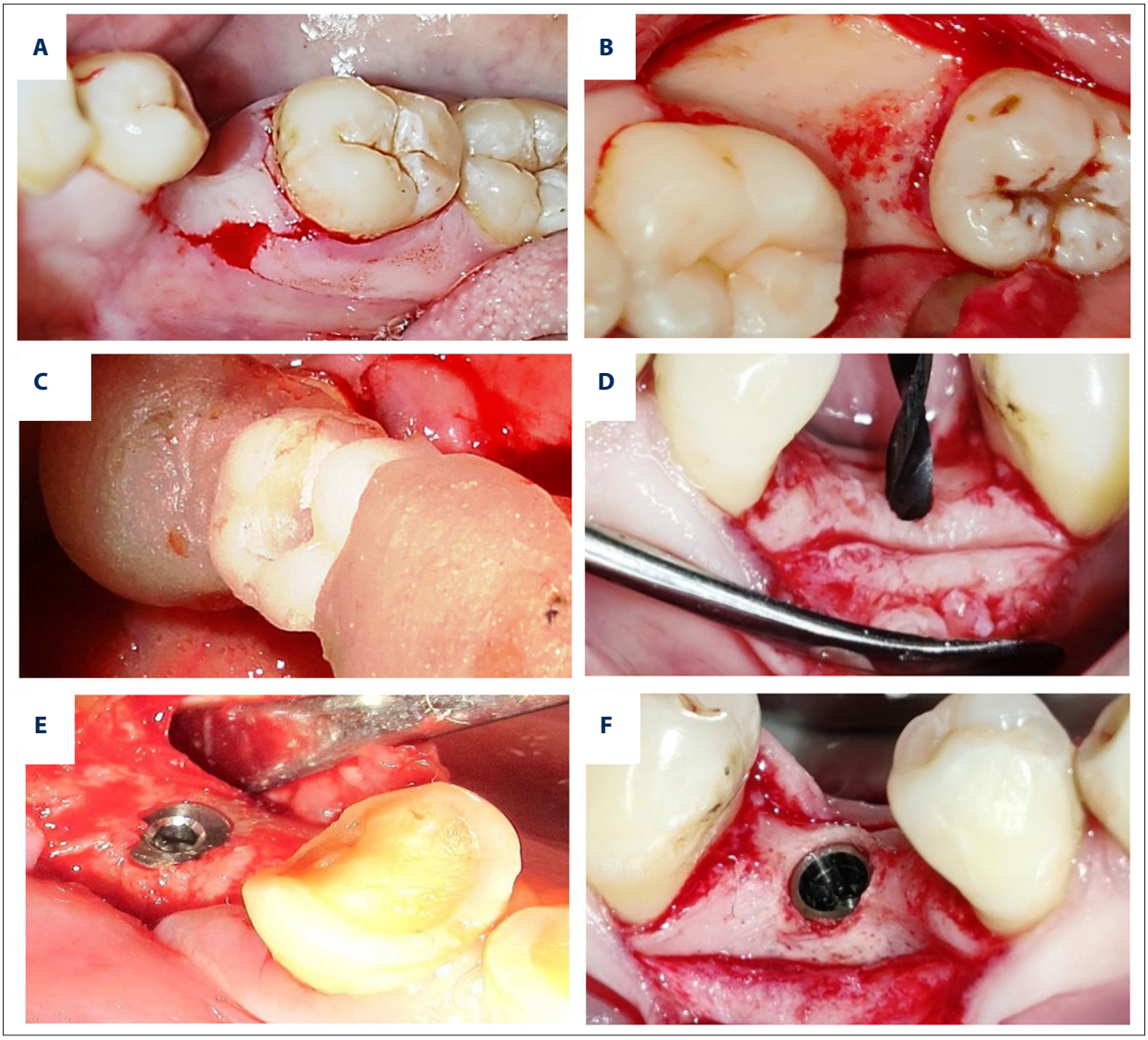

Figure 2. Sequence of implant placement showing crestal incision (**A**), flap reflection (**B**), surgical guide placement (**C**), pilot drilling (**D**), equicrestal implant fixture placement (**E**), and Subcrestal implant placement (**F**). *Photographs taken using* a d*igital single-lens reflex (DSLR) (Canon EOS 700D) with 100 mm macro lens) with/without ring flash. Compiled figure created using MS PowerPoint, version 20H2 (OS build 19042,1466), Windows 11 Pro, Microsoft corporation).*

protocol was followed for all patients. All patients were supervised by a 3-member multidisciplinary team (prosthodontist, oral surgeon, and periodontist), with more than 8 years of experience in implant treatment. A local anesthetic agent (Lox 2%, Neon Pharmaceuticals, India) was administered and verified for numbness. A mid-crestal incision was made (**Figure 2A**) and a full-thickness flap was elevated buccally and lingually to the level of the mucogingival junction (**Figure 2B**), exposing the alveolar ridge. The customized surgical stent/guide was placed intraorally, which aided in proper orientation of the implant (**Figure 2C**). An initial pilot drill was used, which corresponded to 0.5 mm more than the final length of the chosen implant (**Figure 2D**). Then, osteotomy was done as per the standard operating protocol for bone type (soft, medium, hard) using different drill types (D1-2 for hard bone and D3-4 for soft and medium bone). After the drilling protocols, the implants (Touareg STM, Adin Dental Implants System Ltd., Afula, Israel) were placed in their predesignated group positions and torque in accordance with the manufacturer's guidelines. Implants in GP E were placed at the level of the clinically visible bone crest (**Figure 2E**), while implants in the GP S were placed 2 mm below the clinically visible alveolar bone crest (**Figure 2F**). Primary stability was achieved up to 25 Ncm (verified and measured by Osstell) in all the subjects, and cover screws were placed (using a 0.05" hex driver) over the implants and the flap was advanced for the primary closure using

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interrupted sutures (Ethicon, nonabsorbable surgical suture, Johnson and Johnson). Intra-oral peri-apical radiographs were taken for all patients immediately after placement of implants using the parallel-cone technique with the help of a sensor-positioning device (Rinn XCP, Dentsply). Postoperative care instructions and possible complications were explained to the patients and each patient received written instructions for enhancing patient compliance. Medications prescribed included routinely administering antibiotics and analgesics (5 days for all patients) that were individualized for each patient according to the clinical situation and demand. Patients were also recommended to use chlorhexidine mouthwash twice daily until the next appointment. All patients were recalled after 1 week for suture removal. No postoperative complications were reported by any patients in either group.

Prosthetic Phase

All patients were respectively recalled for second-stage surgery after 4 months, when the cover screws were exposed and removed. Gingival formers of the appropriate height were chosen according to the clinical situation and placed on the implant for 2 weeks in all patients. For all patients, the implants were used as abutments that supported a single-crown restoration in the posterior mandibular area. Once a satisfactory gingival collar was obtained, the gingival formers were removed and an implant-level impression was made with the help of closed-tray impression copings. The impression material of choice was addition polyvinyl siloxane material (Reprosil, Dentsply/Caulk; Milford, DE, USA), and a dual-mix technique was employed. The implant analogs were screwed and master casts were poured with die stone (Ultrarock, Kalabhai Dental, India). The casts were retrieved from their respective impressions, following which the abutments were chosen and fitted onto the implant analog. The final feldspathic porcelain (VMK-95 Metall Keramik; Vita Zahnfabrik, Bad Sackingen, Germany) restorations were fabricated and were cemented with zinc phosphate cement (Harvard, Germany) onto the implant abutments.

Measurements and Data Evaluation, Collection, and Analysis

All measurements were made through radiographic evaluation at various follow-up time intervals (3, 6, 9, and 12 months). A digital radiographic sensor (Sopix, Action India) was used, where the exposure parameters were kept standardized at 60 KVp, 10 MA, and 0.05 seconds. The radiographic technique used for IOPA was a parallel-cone technique with the help of a sensor-positioning device (Rinn XCP, Dentsply) [16]. All images were calibrated before measuring on the computer using dental imaging software (6.14.7.3, Carestream Health, Inc., 2014). Metric analysis was performed on a millimeter scale using the measuring tool available in the software. The radiographic evaluation of patients in GP E and GP S was conducted at 5 different intervals of time: after placement (baseline) (**Figures 3A, 4A**), 3rd month (**Figures 3B, 4B**), 6th month (**Figures 3C, 4C**), 9th month (**Figures 3D, 4D**), and 12th month (**Figures 3E, 4E**). Following the exposure, images were captured using the software and stored. The 2 reference points (A and B) for the measurement were selected as the most coronal portion of the implant abutment of the measurable marginal bone level of the mesial and distal ends [17]. The determined values of each fixture were collected and compared over the follow-up period of 1 year separately for the mesial and the distal aspects.

Statistical Analysis

The collected data were first curated and then formally analyzed for normality, then means and standard deviations were calculated and tested (parametric). Analysis of variance (ANOVA) was used to assess statistically significant differences between the groups. Differences between 2 parameters and or groups were considered to be statistically significant if the value (*P*) was less than or equal (≤) to 0.05, with a power of 80% and confidence interval of 95%. Statistical analysis was done using GraphPad open software (Prism 6 GraphPad, LA, USA).

Results

Demographic characteristics

Group characteristics of patients are presented in **Table 1**, showing that the participants in each group in terms of gender, implant site and implant numbers (gender and site) were homogenous in distribution and did not have any significant differences that would confound the effect on the study results.

Distribution of Bone Loss Over Observed Time Intervals

In GP E, the mean difference of the crestal bone loss was between 1.02 mm (1.02 mm at 12 months minus 0.00 after placement) on the medial side and 1.10 mm (1.10 mm at 12 months minus 0.00 after placement) on the distal side, while for GP S the mean difference was between 1.96 mm (2 mm/0.04 mm at baseline minus 0.04 at 12 months) on both sides (**Table 2**). For GP S, the mean difference was calculated by subtracting the bone level at 12 months from the bone level at placement. There was relatively more bone loss observed in implants belonging to GP S at the 3rd month (mean 0.48 mm on both sides), 6th month (mean 0.45 mm-mesial, 0.44 mm – distal), 9th month (mean 0.45 mm – mesial, 0.44 – distal), and 12 months (mean 0.58 mm – mesial; 0.60 mm – distal) than in implants belonging to GP E, at all intervals of time (**Table 2**). The highest amount of bone loss (mean 0.60mm) was observed on the distal side

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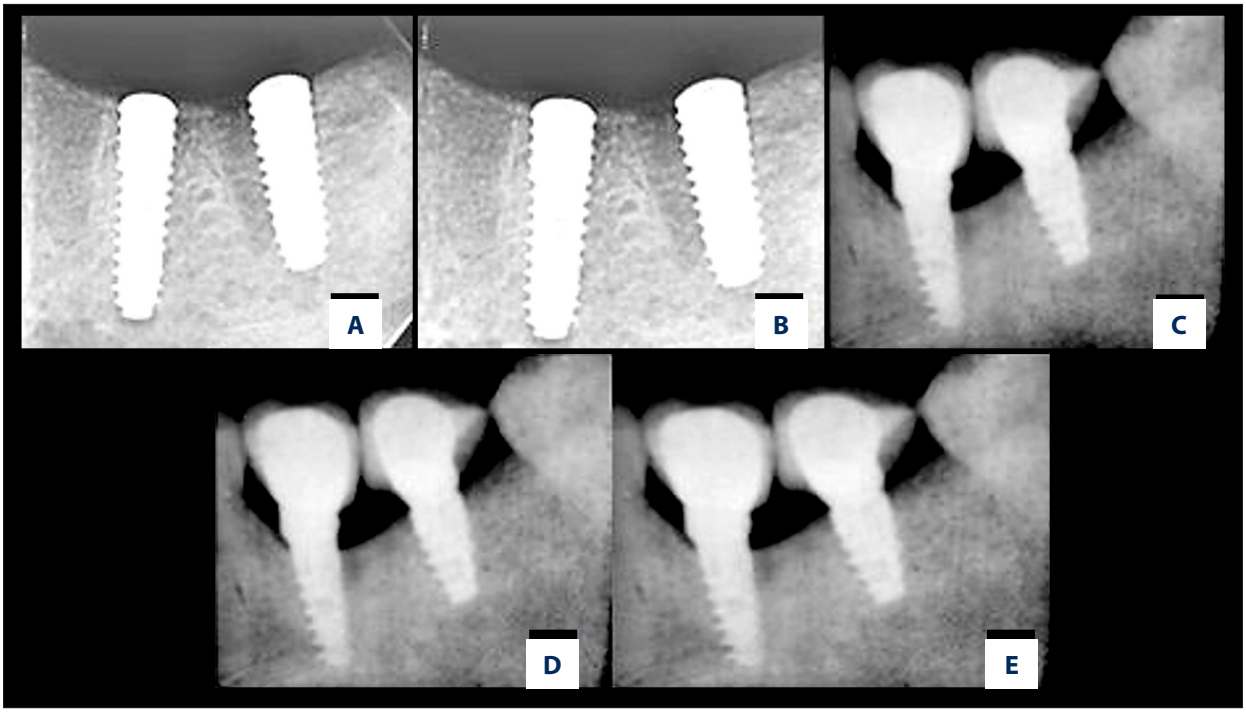

Figure 3. Radiographic interpretation of equicrestal implant placement (**A**) At the time of placement (**B**) At 3 months (**C**) At 6 months (**D**) At 9 months (**E**) At 12 months. *Figure created using MS PowerPoint, version 20H2 (OS build 19042,1466), Windows 11 Pro, Microsoft corporation).*

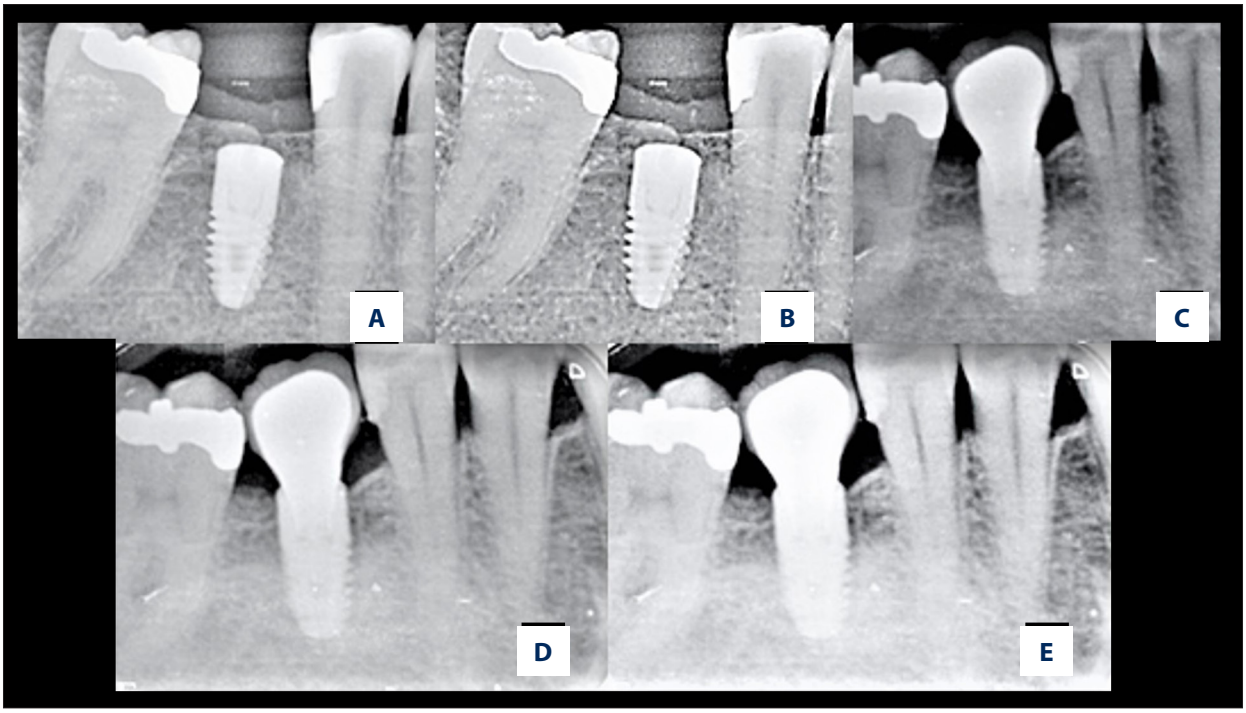

Figure 4. Radiographic interpretation of subcrestal implant placement (**A**) At the time of placement (**B**) At 3 months (**C**) At 6 months (**D**) At 9 months (**E**), At 12 months. *Figure created using MS PowerPoint, version 20H2 (OS build 19042,1466), Windows 11 Pro, Microsoft corporation).*

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Table 1. Demographic characteristics of study participants and their distribution status between the groups.

Parameter	Divisions	GP E (equicrestal) (n=21)	GP S (subcrestal) (n=21)	Total	Chi square test
		n (%)	n (%)		P-value
Average age	Male (n=31)	32.9	32.1	32.29 (n=31)	N.A
	Female (n=11)	34.2	35.1	34.72 (n=11)	
Gender	Male (n=31)	16 (76.2%)	15 (71.4%)	31 (73.8%)	χ^2=0.1232. (NS) P=.72562
	Female (n=11)	5 (23.8%)	6 (28.60%)	11 (26.2%)	
Implant site distribution (n=42)	Right mandible	11 (52.4%) (n=21)	6 (28.5%) (n=21)	17 (40.5%) (n=42)	χ^2=2.9412 (NS) P=.22979
	Left mandible	6 (28.5%) (n=21)	11 (52.4%) (n=21)	17 (40.5%) (n=42)	
	Others (same or both sides)	4 (19%) (n=21)	4 (n=19%) (n=21)	8 (19%) (n=42)	
Implant numbers (n=60)	Male	23 (76.7%) (n=30)	20 (66.7%) (n=30)	43 (71.7%) (n=60)	χ^2=0.7387 (NS) P=.39007
	Female	7 (23.3%) (n=30)	10 (33.3%) (n=30)	17 (28.3%) (n=60)	
	Right mandible	15 (50%) (n=30)	7 (23.3%) (n=30)	22 (36.7%) (n=60)	χ^2=3.5303 (NS) P=.171163
	Left mandible	7 (23.3%) (n=30)	15 (50%) (n=30)	22 (36.7%) (n=60)	
	Others (same or both sides)	8 (26.7%) (n=30)	8 (26.7%) (n=30)	16 (26.6%) (n=60)	

GP – group; n – number. Level of significance: NS (non-significant) = P≥0.05; * Significant = P<0.05.

of subcrestal implants between 9 and 12 months, while the least amount (mean 0.11mm) of bone loss was observed on the distal side of the implant in the equicrestal group between the 6th and 9th months (**Figure 5**).

Bone Loss Pattern

On average, the implants in subcrestal groups on both mesial and distal sides showed a consistent pattern in bone loss (mean range, 0.44 to 0.6 mm) at all studied time intervals (**Table 2, Figure 5**). In GP E, an inconsistent bone loss pattern was observed with periods of low bone loss in between [mean 0.28 (mesial) and 0.34 (distal) at 3rd month, mean 0.12 (mesial) and 0.36 (distal) at 6th month, mean 0.39 (mesial) and 0.11 (distal) at 9th month, mean 0.23 (mesial) and 0.29 (distal) at 12th month]. When compared with the baseline the implants in GP S showed higher bone loss on both mesial and distal sides (**Figure 6**). In GP S at the end of 12 months, 0.04 mm of bone were still present on both sides of the implants. Graphic representation of the amount of bone loss shows a consistent and regular bone loss pattern being observed with subcrestal implant placement, while there was a periodical bone loss pattern in equicrestal implant placement.

Differences Between the 2 Studied Groups

ANOVA was done to analyze the significance of differences in the means of bone loss observed at 4 different prospective time intervals from baseline. The differences between the 2 groups on mesial and distal sides were found to be statistically significant at the observed *P* value of <0.001, which was far less than the standard value (*P*<0.05). Within each group, no significant differences in bone loss were found between mesial and distal sides. When compared between the 2 groups, the differences on the mesial and the distal side were statistically significant (*P*<0.001). The results show that the bone loss observed in both groups was statistically significant, but the bone loss in GP E was less than in GP S.

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Table 2. Comparative means scores of clinical parameters among patients in various groups and the respective level of significance between various groups at different intervals of time.

Clinical parameters		Mesial crestal bone loss		Distal crestal bone loss	
		GP E	GP S	GP E	GP S
		Mean±SD	Mean±SD	Mean±SD	Mean±SD
Bone loss around implant	After placement	0.00±0.00	-2.00±-0.00	0.00±0.00	-2.00±0.00
	3rd month	0.28±0.04	-1.52±0.17	0.34±0.15	-1.52±0.15
	6th month	0.40±0.12	-1.07±0.36	0.70±0.82	-1.08±0.36
	9th month	0.79±0.0.72	-0.62±0.0.75	0.81±0.12	-0.64±0.19
	12th month	1.02±0.0.47	-0.04±0.39	1.10±0.29	-0.04±0.17
# Mean differences between various time intervals	0-3 M	0.28	0.48	0.34	0.48
	3-6 M	0.12	0.45	0.36	0.44
	6-9 M	0.39	0.45	0.11	0.44
	9-12 M	0.23	0.58	0.29	0.60
	0-12 M	1.02	1.96	1.10	1.96
Repeated measures ANOVA	F	183.54	179.37	12.250	185.399
	p-value	<0.001*	<0.001*	<0.001*	<0.001*

GP – group; M – month; E –equicarestal; S – subcrestal. Level of significance: NS (not-significant) = P≥0.05; * Significant = P≤0.05.
Formula: Mean difference calculated by z = [(x1 - x2) - (μ1 - μ2)]/sqrt (σ12/n1 + σ22/n2).

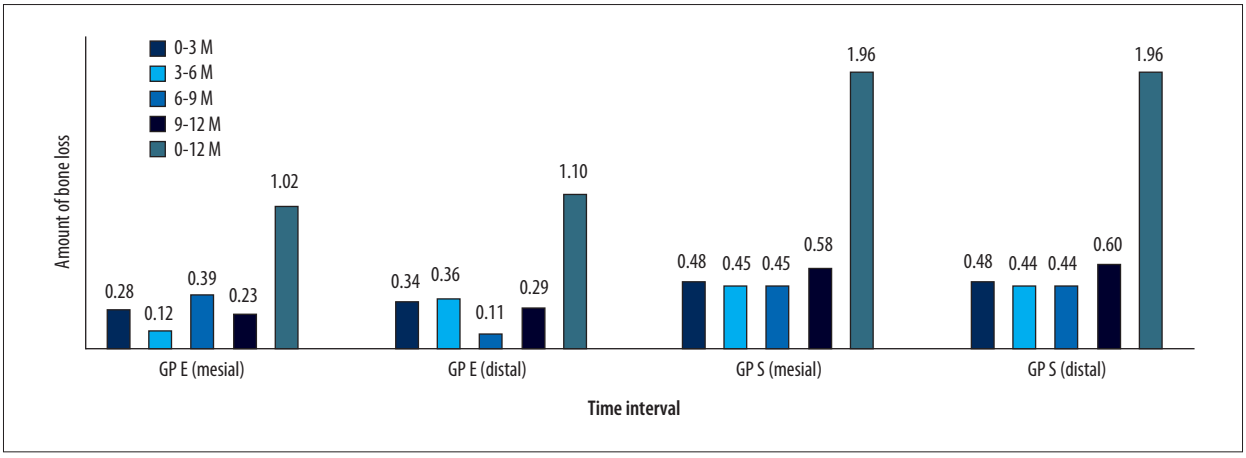

Figure 5. Graphical presentation showing comparative differences in crestal bone loss (millimeters) at different time intervals between equicrestal and subcrestal implant placement. *Figure created using MS Excel, version 20H2 (OS build 19042,1466), Windows 11 Pro, Microsoft corporation).*

Discussion

This study evaluated the effect of 2 different clinical depths in relation to the crestal bone in the posterior mandibular region upon the marginal or crestal bone remodeling. The study also intended to evaluate the need for increasing the follow-up visits during the first year based on the observed bone loss. The key finding of this study was that the subcrestal placement of implant was associated with increased bone loss during the first year and the bone loss was uniform throughout with no evidence of decrease during the first year. Equicrestal implant placement showed less bone resorption, with periods of decreased bone loss during healing and loading. From 6 to 9 months, the bone loss at the distal ridge crest was the lowest (0.11), while the maximum bone loss for distal subcrestal implants was at 9 to 12 months (0.6). In attempts to minimize crestal bone loss, studies have been conducted that focused on clinical procedures, biomechanical factors like implant design,

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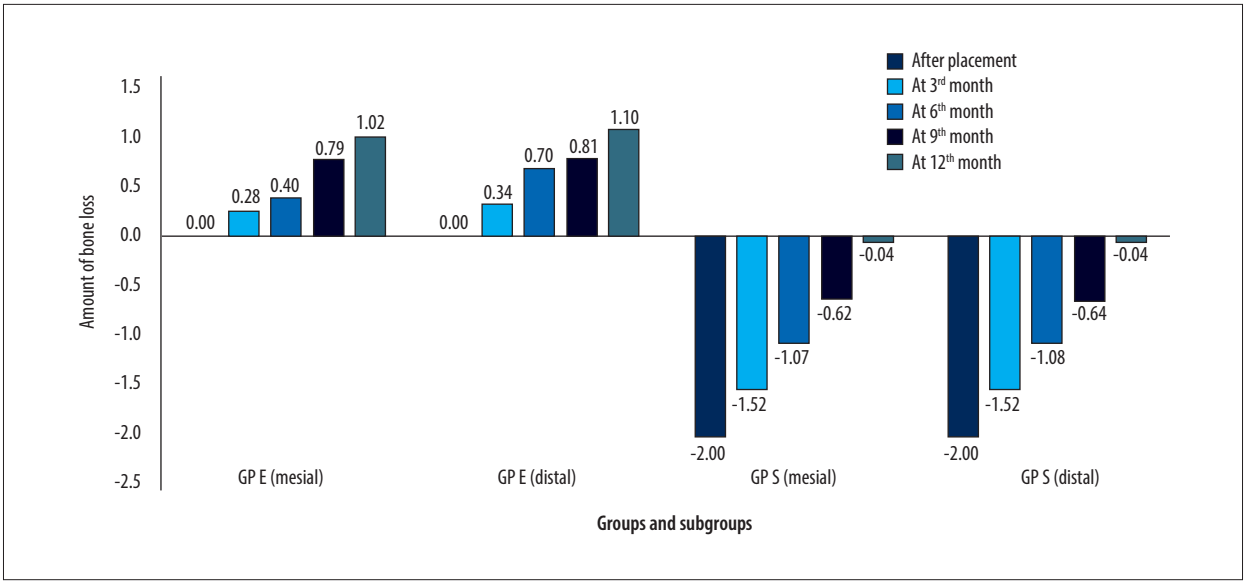

Figure 6. Graphical presentation of bone loss on either side of implants at 5 different time intervals between equicrestal and subcrestal implant placement. *Figure created using MS Excel, version 20H2 (OS build 19042,1466), Windows 11 Pro, Microsoft corporation).*

implant movement (micromovement) as a result of loading, platform switching, and implant coatings. There are few studies that evaluated implant placement depth as a factor affecting crestal bone loss around dental implants, which is why we conducted the present study. Most studies on implant placement depth have performed implant placement in both arches (maxillary and mandibular) and in both zones (anterior and posterior). The present study was exclusively designed to focus on the mandibular posterior region, where loading forces are maximized and there is a tendency for developing periimplantitis during the first year is high because of food accumulation. Moreover, studies have shown no differences in bone loss on mesial or distal sides of maxillary and mandibular implants [18]. The results of this study show that subcrestal implant placement caused a mean loss of 1.96 mm during the first year. The amount of bone loss is thus higher than that recommended by Albrektsson et al (≤1-1.5 mm) [19]. The equicrestal implant placement, however, fulfills the standards of Albrektsson et al and several other authors. Most implant failures after successful osseointegration have been either due to local inflammation or inappropriate occlusal loads [20]. In patients who ideally conform to implant treatment, customized occlusal design protects implant osseointegration [21].

Our results show that implant placement at subcrestal bone level increases crestal bone loss irrespective of the clinical status (healing and loading) of the implant fixture. These results are in agreement with those of studies by Gatti et al [14], Sunitha et al [22], and Hammerle et al [22,23]. Likewise, Balaji et al (24 implants) [24] and Rasouli Ghahroudi et al [25] (170 implants) showed no significant differences between crestal and subcrestal implant placement. In terms of the amount of bone loss, different authors have reported different findings. While Hobo et al in earlier studies reported mean bone loss of 1-1.5 mm for the first year, Johansson and Ekfeldt reported only 0.4 mm in the first year [26,27].

Contrary to our findings, various studies have favored subcrestal implant placement since they have been associated with decreased bone loss when observed during the first year and also long-term [15,28,29]. Tomas et al, in a 2-year follow-up, found subcrestal implant placement resulted in less bone loss (0.18±0.32 mm) than epicrestal (0.51±0.4 mm), along with a modified soft-tissue tenting technique [30]. A study by Chatterjee et al found less bone loss in the subcrestal position (mean, 0.27 mm) at 6 months as compared to the crestal position (mean, 0.39mm). However, their study differed from ours in that the final evaluation was 6 months and they loaded the implants within first 3 months as compared to the standard protocol that we followed. In a recent systematic review of 7 studies (rough-neck implants) between subcrestal and equicrestal implant placement, that studied 479 patients and 800 implant placements (243 crestal, 557 subcrestal) and followed up from 6 to 36 months, no evidence was found in terms of better clinical outcome between crestal and subcrestal implant placement [31]. However, all studies in the review included patients who were smokers and included evaluation that was clinical rather than radiographic. Three out of these 7 studies showed less bone loss in equicrestal implant placement. Most of these studies, however did not use strict inclusion criteria, as done in this study. It is well known that the prognosis of implant in terms of crestal bone loss is dependent on several clinical factors that have been

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linked to patient selection: patients maintain oral hygiene [32], implant location [33], implant design, surface, length, and diameter [34], bone quality and functional loading [35], and general health of the patient [26,31]. The reason for placing implants below the crest level is to decrease the risk of implant shoulder exposure at the bone tissue interface, which may be influenced by the oral environment and bacteria [22]. Others have also mentioned that bone loss is bound to decrease if the distance between the implant abutment junction and the crestal bone increases [36]. Bone remodeling is bound to occur whenever bone is drilled for placing implants. The increased bone loss observed in this study for the subcrestal group may be due to 2 reasons: natural bone remodeling and biological reaction of the implant bone interface. From the clinical point of view, the subcrestal placement of the implant allows the maintenance of crestal bone for a long period of time, thus increasing the longevity of the implant and the prosthesis [37].

Strength and Limitations

Our study shows that under stringent patient selection and in an exclusive posterior mandibular location, the equicrestal implant placement produces a significant reduction in bone loss as compared to subcrestal implant placement. This study could be the basis for developing a methodology approach for investigating implant prognosis in terms of bone loss. This study is, however, limited by the use of radiography for bone measurements, which are 2-dimensional images and a distortion factor is inherited in such an approach. These could be overcome by measurements done with CT scan or CBCT, which carry the risk of increased radiation exposure. Another limitation of the study is that the bone varies from individual to individual and from one population to another. This is particularly applicable to mandibular and maxillary posterior areas. The accessibility for oral hygiene maintenance tools such as brush and floss are also limited in mandibular posterior areas. The study does also possess the routine limitations of a cross-sectional study, including the smaller sample size.

Conclusions

The results of this study must be interpreted with caution and apply only to the selected patients and clinical conditions used during the study. In similar conditions, we conclude that equicrestal implant placement is better in terms of decreasing crestal bone loss during the first postoperative and post-loading year. We found that that subcrestal implant placement results in more bone loss than crestal implant placements during the first year. The bone loss did not follow a regular pattern, as compared to subcrestal implant placement, where there was increased and uniform bone loss observed at all time intervals.

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Declaration of Figures' Authenticity

All figures submitted have been created by the authors, who confirm that the images are original with no duplication and have not been previously published in whole or in part.

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