Original Article

Radiographic Comparison Of Crestal Bone Levels Around Unloaded Implants Placed In Different Regions Of Maxilla And Mandible: A Prospective Clinical Study

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Abstract

Purpose: The present study aimed to compare the crestal bone loss occurring around unloaded dental implants placed within various regions of maxilla and mandible using two-dimensional digital radiography with the help of image measurement software.

Methods: For this study, 47 participants receiving single spiral dental endosseous implants placed in partially edentulous spans in various regions of the maxilla and mandible were included. Digital radio-visuo-graphic (RVG) images of implants placed at baseline (0 months) and after 3 months were obtained. The crestal bone levels were measured by the image measurement software Image J and the values were compared for differences among various sites of implant placement.

Results: Overall, the mean and standard deviation of the mesial marginal bone level at unloaded implants was 1.4 ± 0.89mm (95% confidence interval [CI]) and that for the distal marginal bone level was 1.29 ± 0.89mm (95% confidence interval [CI]) at 3 months and their respective differences compared to baseline were statistically significant (p-value < 0.001). No significant difference was present with regard to bone loss in inter-arch and intra-arch comparisons.

Conclusion: Significant bone loss occurs during the initial healing period around unloaded implants which can be attributed to the physiologic differences in the quality of bone within various intra-oral sites. The clinician's choice of the implant must be dictated by its capability to preserve as much crestal bone as possible for a successful outcome.

Keywords: Bone remodeling; Crestal bone loss; Digital radiography; ImageJ; Osseointegration; Unloaded implants.

INTRODUCTION

In the field of oral rehabilitation for lost teeth, the implant-supported prosthesis has emerged as a dependable and predictable therapeutic option. The titanium implant undergoes integration with the surrounding osseous structure during its healing phase. The period of healing following dental implants is comparable to the normal healing process of bone tissue. Only when there is a sufficient amount of bone and peri-implant soft tissue, is the outcome of therapy surgically, aesthetically, and functionally predictable (1).

The amount of crestal bone loss occurring during the first year is likely to influence the peri-implant soft-tissue health and microbiological niche formed around it responsible for the longevity of the implant (2). It is therefore advised to utilise micro-threaded implants with a rough surface to preserve crestal bone levels (2–4). A rough surface and micro-threaded design at the implant facilitates early adaptation of the bone and reduces crestal bone loss as compared to smoother machined-neck implants (5) Submerged dental implants provide full mucosal coverage during the osseointegration phase which prevents injury and infection and creates ideal circumstances for smooth initial healing (6). If left untreated, early perforation and partial exposure of the cover screws are additional sites for plaque build-up causing inflammation, damage to the peri-implant mucosa, and even peri-implant bone loss.(7)

Clinical evidence suggests that the critical phase for dental implant failure is the initial healing period, when cover screw exposures may occur. Before the process of loading implants with prosthesis, general factors contributing towards the anchorage of implants are bone quality, implant type (design, length and diameter) and surgical skills of the clinician. Apart from these factors how bone reacts after the initial placement of implant till loading is very essential and often less understood. This study was envisioned to expedite the clinicians to understand the process of osseointegration and bone resorption through radiographs of implants during the initial unloaded healing phase. Currently we have very few studies to evaluate extent of bone resorption on unloaded implants. This study justifies in evaluating the phenomenon of crestal bone resorption around dental implants through radiographs; thus, facilitating clinicians to choose implant designs apt for the individual clinical scenario

MATERIALS AND METHODS

This study was approved by the Institutional Ethics Committee, All India Institute of Medical Sciences, Rishikesh (AIIMS/IEC/20/352) and conducted in the Department of Dentistry from January 2020 to December 2022. A total of 47 patients with individual implant sites meeting the inclusion and exclusion criteria were considered for the analysis. Of those, 28 were female and 19 were male and their ages ranged from 20 to 52 years.

The inclusion criteria was based on the current systemic condition of the patient deeming them healthy to undergo the implant placement, presence of sufficient bone quantity and quality assessed through the process of bone mapping at the single partially edentulous sites and the patient's capability to maintain adequate oral hygiene. Patients who reported with any systemic diseases such as uncontrolled diabetes, severe hypertension, osteoporosis or any pathological condition known to affect wound healing and bone physiology and those with known substance abuse (smokers, alcohol or drug abusers) were excluded from the study. Pregnant and lactating women were also excluded from the study. Proper consent from the patients was taken which informed the patient regarding the available treatment options and possible complications in the language understandable by the patient. Diameter and the length of the implant placed was decided after performing bone mapping of each implant site of the well-formed edentulous ridge and radiographic investigations. All patients underwent professional oral prophylaxis and were instructed for home-care oral hygiene habits. Routine blood investigations were performed to rule out any underlying systemic condition and those known to alter bone healing were excluded.

Surgical implant placement

A standard two-stage implant placement protocol was selected for all the patients. (8) After attaining profound anesthesia by means of local infiltration technique, a mid-crestal incision was placed at the desired implant site to raise a full-thickness mucoperiosteal flap buccally and lingually to get adequate access to the edentulous ridge. A round-bur was used to flatten the crest of the ridge. Following the principles of ideal implant placement, sequential drilling was performed such that the final osteotomy while preserving minimum of 1.5-2mm surrounding bone. Continuous and copious irrigation was maintained during the osteotomy preparation. When the desired osteotomy was obtained, a spiral dental implant (BioLine® SDI implant, BioLine, Germany) was placed with an insertion torque of suitable primary stability. Implants were placed equi-crestally and cover-screw was placed over the implant. The mucoperiosteal flap was repositioned and sutured into place using 3-0 PGLA resorbable sutures (Ethicon, Johnson & Johnson) (Fig1). Post-operative instructions included use of bi-daily oral rinse with 0.2% chlorhexidine digluconate solution for 15 days and prescription of analgesics and anti-biotics (400mg Ibuprofen BD and 625mg Amoxycilin-Clavulanate TDS) for 7 days. Patients were recalled for second stage surgery after 3 months. Using a conservative incision, the soft tissue over the cover screw was raised and healing abutment was placed followed by fabrication and delivery of prosthetic crown suitable for each case.

Radiographic assessment

Digital radio visuographic (RVG) images of the implant site were taken immediately on the day of surgery (baseline) and after 3 months. An image measurement software (ImageJ paper, National Institutes of Health) was used to measure the distance in the radiographic images. This software helps one to measure areas, perimeters, and lengths of selected surfaces in images. The scale was calibrated at 1:1 scale by assigning the values of known distances such as the length of the implant in the image. Measurements for mesial and distal portion were made from first thread of the implant to the apical (point- A) and coronal (point-C) portions of crestal bone respectively (Fig2) and mean of the coronal and apical measurements were calculated respectively. The means of the mesial and distal values were calculated for each implant site. The mean marginal bone change for each mesial and distal aspect was calculated as the difference between the values obtained at the time of placement and at 3 months. Percentage loss per length of implant was calculated as the difference in bone levels divided by the length of implant and multiplied by 100. The resulting values were analyzed.

STATISTICAL ANALYSIS

Data collected was analyzed with the IBM SPSS v.22 software. Descriptive statistics were applied for the group distribution and characteristics. Independent samples t-test was applied for bivariate comparison of bone changes between maxillary and mandibular implants and comparison of bone changes between anteriorly and posteriorly placed implants. Paired sample t-test was used for comparison of bone changes over the period of 3 months.

RESULTS

A total of 47 patients with individual implant sites meeting the inclusion and exclusion criteria were considered for analysis. Of those, 28 (59.6%) were female and 19 were male (40.4%). Table 1 shows the distribution of implant placement in various regions of the oral cavity and description of participants regarding gender, age and mean length of implant selected.

Mean mesial and distal bone loss were both higher in mandible than in maxilla, but the difference was not found to be significant. Mean mesial bone loss was higher in posterior teeth while mean distal bone loss was higher in anterior teeth with mean mesial bone loss being the highest for posterior mandible and mean distal bone loss being the highest for anterior mandible. Neither of these differences were statistically significant. (Table 2)

Table 3 shows comparison of bone changes at 0 months and at 3 months. Mean bone level at 3 months was significantly related to mean bone level at 0 months on both mesial and distal side. There was a significant mean marginal bone loss occurring at all sites after 3 months when compared to baseline (0 months).

Table 1: Distribution of implant placement in various regions of the oral cavity and demographic distribution of participants				
	Female (n)	Male (n)	Mean age (years)	Mean length of implant (mm)
Anterior maxilla (AMx)	6 (54.5%)	5 (45.5%)	30.73	11.23
Posterior maxilla (PMx)	6 (60.0%)	4 (40.0%)	34.90	10.70
Anterior mandible (AMd)	7 (63.6%)	4 (36.4%)	32.64	10.82
Posterior mandible (PMd)	9 (60.0%)	6 (40.0%)	35.07	11.30
All groups	28 (59.6%)	19 (40.4%)	33.45	11.04

Table 2: Mesial and distal marginal bone loss at study sites

REGION	n	MESIAL ASPECT				DISTAL ASPECT			
		Mean mesial marginal bone loss	Standard Deviation	Minimum percent bone loss per length of implant	Maximum percent bone loss per length of implant	Mean distal marginal bone loss	Standard Deviation	Minimum percent bone loss per length of implant	Maximum percent bone loss per length of implant
Anterior maxilla (AMx)	11	0.47	0.59	0.87	12.20	0.75	0.62	0.00	18.70
Posterior maxilla (PMx)	10	0.66	0.67	0.17	16.00	0.67	0.60	0.00	15.30
Anterior mandible (AMd)	11	0.61	0.76	0.00	20.40	0.91	0.64	0.00	16.00
Posterior mandible (PMd)	15	0.72	0.53	0.00	12.50	0.76	0.60	0.00	17.00
Mandible vs maxilla		p = 0.517				p=0.523			
Anterior vs posterior		p=0.399				p= 0.564			

Table 3: Comparison of bone changes at baseline (0 months) and 3 months

	Mean	Std. Deviation	t	Df	p-value
Mesial bone level at 0 month	0.7877	0.98882	-6.841	46	**<0.001**
Mesial bone level at 3 months	1.4128	0.89624			
Distal bone level at 0 month	0.6260	0.88997	-6.555	46	**<0.001**
Distal bone level at 3 months	1.2985	0.89795			

Fig 1: **Surgical implant placement** A) Maxillary anterior region B) Maxillary posterior region C) Mandibular posterior region

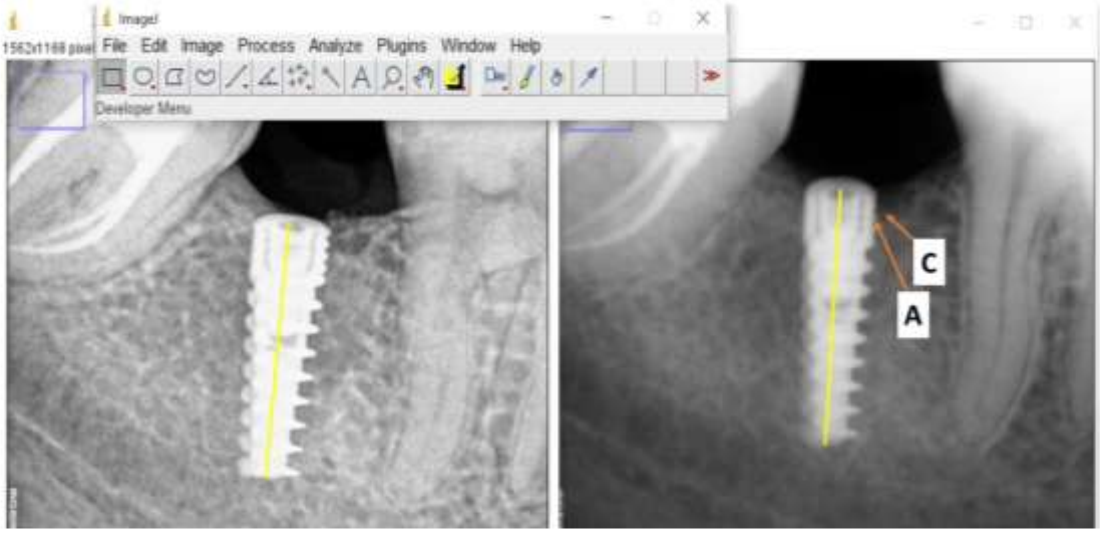

Fig 2: **Radiographic image analysis using Image J software**. 'A'- Apical-most point of crestal bone level 'C' – Coronal-most point of crestal bone level; both in relation to first thread of implant body. Yellow line- Length of implant used for calibration of image prior to measurements.

DISCUSSION

The stability of peri-implant bone levels and percentage of bone-implant contact (BIC) are considered as key factors in the success of dental implants. Although, even a minimum BIC (at least 50%) has resulted in clinically successful long-term service of the dental implant, stable crestal bone levels have shown to be less susceptible to both biomechanical and biological complications, and better aesthetics. (3,4) Marginal bone level changes in the first year following implant placement and loading should be less than 1-1.5 mm, and continuous annual bone loss should be less than 0.2 mm. (9). Alveolar bone is a dynamic tissue and it undergoes constant remodeling process which allows it to adapt to the local stresses. Frost has described how bone reacts to minimum and maximum threshold strains and mechanically adapts through trivial, physiologic, overload and pathological loading changes. (10) Remodeling is that process where in simultaneous resorption and deposition takes place so as to prevent the bone from accumulating micro-damages which are caused by repetitive loading.(11) The load bearing capacity of bone can be largely threatened if the bone remodeling is disturbed and micro-damages accumulate to cause bone fatigue. (12) However, loading alone does not result in specific osteoclast activation and resultant bone loss, as previously hypothesized, as bone loss has been recorded in unloaded implants as well (13) Most studies in the literature focus on bone loss occurring after mechanical loading of the functional implants. However, it is known that the bone undergoes a wide range of changes from the time of osteotomy preparation to complete osseointegration when the implant remains unloaded; mechanisms of which are still poorly understood. During this crucial period of healing, a multitude of factors, local as well as systemic, could influence the remodeling process.

Our study was an attempt to understand the factors influencing the crestal bone loss around unloaded implants and the correlation with the inherent site-specific quality of bone by using radiographic assessments. Radiographic evaluation is a reliable, non-invasive method to evaluate changes in crestal bone levels and can be easily incorporated in routine follow-up of patients with dental implant placement. In line with previous studies, our results showed significant marginal crestal bone loss during the period of first stage healing after placement of conventional implant. Mean mesial bone level at 0 months was 0.78 ± 0.98mm while that after 3 months of healing was 1.41 ± 0.89mm ($p<0.001$). Similarly, mean distal marginal bone level at 0 months was 0.62 ± 0.88mm and that after 3 months was 1.29 ± 0.89mm ($p<0.001$). This suggests that irrespective of loading, submerged conventionally placed endosseous implants display crestal bone loss. Histologic studies conducted on retrieved human dental implants validated for the fact that BIC in unloaded implants is lesser than that around loaded implants. Moreover, the BIC around loaded mandibular implants was found to be approximately 25% higher than that found around maxillary implants, 10% higher in the anterior as compared to posterior mandible and 25-30% higher in maxillary anterior regions. (4) Overall, loaded and even immediately loaded implants presented with 10-12% of higher BIC when compared with unloaded implants. (14–16) Traini et al and Mangano et al reported that implant loading seems to influence the orientation of collagen fibers and stimulation of functional osteocytes in the peri-implant bone resulting in abundance of transverse collagen fibers and functional osteocytes around loaded implants in comparison to the parallel collagen fibers around unloaded implants (3,17–20). This transverse orientation of collagen fibers facilitates increased resistance to compressive loads and stimulation of osteocytes in the formation of more regularly organized lamellar bone with greater bone density. On the contrary, the absence of any loading stimulus results in disuse atrophy of the bone around the implants and consequent bone loss.

Another important consideration in the early crestal bone loss of the unloaded implants is the design characteristics of the dental implant. Two-piece implants inherently possess a micro-gap at the implant abutment junction. Hermann et al. claim that the development of a micro-gap between the implant and abutment determines the amount of peri-implant bone loss. (21) Creation of a micro-gap favors bacterial growth and the bone adjacent to the gap resorbs up to a distance of this bacterial penetration, similar to the 'radius of action of bacteria' seen in bone loss in periodontal lesions. Callan et al. discovered in retrospective research that the location of implant-abutment micro-gap was partly responsible for the peri-implant bone loss. According to these authors, all implants with a micro-gap positioned in a subgingival position showed bone loss equivalent to or greater than 3 mm. A risk of losing supporting bone exists if the micro-gap is situated close to the bone (22). This also explains why one-piece implants present with minimal to zero bone loss when compared to two-piece implants. (23,24) This warrants the use of implant designs such as platform-switching in comparison with platform matching implants to reduce the crestal bone loss. According to some authors, conventional platforms result in greater marginal bone loss than platform switching implants and the protective function was greatly related to the extent of implant-abutment mismatching (25,26) Platform switching designs are known to shift the implant-abutment junction coronally and away from the crestal bone by allowing a thicker and more stable band of soft-tissue to form around the implant neck.(26,27) In our study, platform matched, spiral dental implants with coronal micro-thread design were placed. A comparative study with platform-switching design in future may help us to assess the effect of the design on bone level changes during the initial healing phase. Thus, if bone resorption observed between 2-3mm use of platform switching can help to prevent further resorption. (28) If bone resorption observed is more than 4 mm clinicians can modify implant designs into bioactive plasma coated or hydroxyapatite coated surfaces to promote rapid osseo-integration, especially in poor bone quality sites.(29) Finally, in regions of inadequate bone, grafting procedures may be undertaken such as use of hydroxyapatite particulate grafts, xenografts or allografts.(30)

Theoretically, the peri-implant mucosa must be a specific width in order for epithelial connective tissue to adhere properly. If this soft tissue dimension is not met, bone resorption will take place in order to guarantee the establishment of an attachment with the necessary biological width as seen in teeth (31). Although previous studies have reported no significant differences with regards to crestal bone loss in relation to submerged and non-submerged implants (15,32,33), none of the implants in our study showed any sign of early exposure, which is considered to be one of the influential factors for crestal bone loss.

Our study presented with the highest mean mesial marginal bone loss with posterior mandible (0.72mm) whereas the maximum mesial percent bone loss per length of implant was noted with mandibular anterior implants (20.4%). The mean distal marginal bone loss was found to be the highest in anterior mandible implants (0.91mm) and the maximum distal percent bone loss per length of implant was noted with maxillary anterior implants (18.7%). Measurements of bone loss in millimeters is more sensitive while percentage of bone loss per implant length can be considered to be more specific to individual implant. Therefore, both these values were considered in the site related comparisons. None of the site-specific comparisons, however, resulted in any statistically significant difference in the amount of crestal bone loss or percent bone loss per implant length. Ajanovic et al evaluated crestal bone loss around implants in different regions of maxilla and mandible after one year of functional loading and found no significant difference between the bone loss around maxillary and mandibular dental implants and bone loss was recorded to be higher in anterior as compared to posterior regions. (34) In contrary to the findings in a study by Boronat et al in their retrospective study, our study presented with more marginal bone loss in mandibular anterior as compared to posterior teeth. (35) This could be attributed to a longer osteolytic phase in osseointegration process to be occurring in anterior mandibular region owing to majorly cortical bone (D1/D2 type) and confined blood supply in the mandible as compared to the profusely vascularized maxillary bone. (36)

The findings in our study lead us into understanding that detecting marginal bone loss in radiographic assessment done at one point of time should not be considered as a sign of pathology since it could be the result of physiologic bone adaptation process.(37) Comparisons made over a period of time can signify an underlying pathologic process more reliably and thus radiographic investigations should be considered as a valid diagnostic tool for identifying potential implant fractures, screw loosening, osseo-disintegration, evaluation of cantilevered or overloaded implants.

Limitations of this study include the lack of three-dimensional or histo-morphometric assessment of the bone loss. Given the main purpose of the study to analyze the bone loss without any invasive interventions intra-oral periapical radiographs were considerably suitable for prospective evaluation. Further studies are required to assess how various designs of implant influence the bone morphology. However, from clinical stand-point, use of one-piece implants, bioactive implants or platform-switching implants in regions known to suffer greater marginal bone loss can help in reducing loss of supportive bone and promote healthy remodeling of the peri-implant bone.

CONCLUSION

Within the limits of this study it can be stated that there is a significant loss of marginal bone during the initial healing phase of three months which is affected by the inherent quality of bone and the remodeling process. While unloaded implants display crestal bone loss, it could correspond to the osteolytic phase of osseointegration or represent disuse atrophy due to lack of loading stimulus. The clinician must bear in mind that while some crestal bone loss is inevitable, choice of implant must be such that it is reduced to the minimum possible to ascertain successful outcomes.

ETHICAL APPROVAL

The study was approved by the Institutional Ethics Committee, All India Institute of Medical Sciences, Rishikesh (India) (AIIMS/IEC/20/352)

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Conceptualization, V.I. and A.D.; Methodology, R.K., K.P., H.A. and S.R.; Data curation, R.K.; Writing-original draft, R.K. and K.P.; Investigation, H.A. and S.R.; Writing- review and editing, A.D., S.D. and V.I.; Supervision, A.D. and S.D.