Comparison of bone loss around implants using radiographs

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ABSTRACT
This article presents an original-research conducted at Pushpagiri College of Dental sciences, Thiruvalla, Kerala to compare and evaluate the vertical crestal bone changes around implants with different surface coatings and diameter using CBCT and RVG taken at the time of loading and one year after loading. Thirty-six samples were divided in 4 group; based on 3 parameters: implant surface coating, implant diameter, and single versus multiple implants supported bridges. Length of all implants is kept standardised at 10 mm. Data were statistically analyzed by Students paired t-test and comparison between CBCT and RVG is done using interclass correlation test. The mean crestal bone loss has increased statistically significant from the time of loading and after one year of loading. The average crestal bone loss on single implants were less compared to multiple implants supported bridges at both timings. CBCT shows more accurate and reliable values than RVG both clinically and statistically. It was concluded that crestal bone loss was less among single implants with calcium phosphate surface coating and wider diameter than alumina blasted and narrow diameter implants. Single implant shows less bone loss than multiple implants. The CBCT shows a reliable method of detecting circumferential peri-implant bone defects than RVG.
Keywords: dental implant, marginal bone loss, cone beam computed topography, radiovisiography, radiographic evaluation
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INTRODUCTION

The use of endosseous implants to restore lost dentition has proved to be a successful treatment modality, providing the patient with near natural replacement.[1] The success rate obtained with dental implants depends to a great extent on the quality of osseointegration. Early identification of signs and symptoms of bone loss is, therefore essential to prevent implant loss.[2]

Evaluation by radiographs is considered as a source of information for determining the amount of cervical bone loss around dental implants.[3] According to established criteria for the assessment of implant survival and success by Albrektsson et al,[4] marginal bone level changes in the first year should be less than 1-1.5 mm and ongoing annual bone loss should be less than 0.2 mm. Bone loss usually begins from the crest region of an osseointegrated implant and progresses apically. Possible cause of crestal bone loss could be a local inflammation and mechanical stresses acting on the crestal bone around the implant crest module.[5] Anatomic factors such as the quality and architectture of bone tissue, as well as implant features, example: length, surface area, coating, implant timing and occlusal load influence alveolar bone crest resorption.[6,7]

Implant success or failure is largely dependent on the macroscopic and microscopic design of implant. Macroscopics design features include body design thread geometry. Microscopic design, includes implant materials, surface morphology and surface coating.

Several investigations have reported that the crestal bone loss can be minimized by increasing the contact area of bone to implant interface and therefore reducing stress at the cortical alveolar crest.[8] Studies have showed that there is marginal bone loss initially after loading of dental implant with prosthesis. But how much marginal bone loss will be there before loading of delayed loading implants with respect to different diameter, surface coating and number of implants needs further assessment. Keeping this in mind, a study was undertaken to assess marginal bone loss occurring 6 months after the implant placement, but before loading of dental implant with prosthesis.[9]

The aim of the study was to evaluate the vertical crestal bone changes of delayed loading implants using cone beam computed tomography (CBCT) and radiovisiography (RVG); specifically to evaluate the crestal bone loss between the surface coatings of single implant system at the time of loading and after one year of loading, to assess the crestal bone loss between different diameter of single implant system at the time of loading and after one year of the loading, to measure the vertical crestal bone loss between single and multiple im-

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plant supported bridges, and to assess the comparison of measurement between CBCT and RVG.

METHODS

This study was conducted at the Department of Prosthodontics, Pushpagiri College of Dental Sciences, Thiruvalla, after receiving approval from the Institutional Ethics Committee (IEC) and the Review Board, Pushpagiri Institute of Medical Sciences and Research Center and clearance obtained for the same (No.PCDS/IEC/K10/11/15).

The present invivo study was designed to be of the quasi-experimental type. The selection of cases was purely based on the patients desires for a radiographical analysis of crestal bone around the implants. A total of 36 samples with 9 samples in each group was collected for the study based on the values from previous studies for a confidence level of 95% and power of study as 80%. According to the selection criteria, 36 patients were selected for the study, who have placed implant in the mandibular posterior right or left region with a minimum period of 3 months of healing were selected. The patients were selected based on the criteria of age group between 20 and 60 years, non-smoker, no relevant medical history, good oral hygiene, healthy remaining dentition, and adequate ridge width and height to place implants, wheras the patients with poor oral hygiene, medically compromised severe bruxism, untreated periodontitis or periapical pathology, heavy smoking and alcoholics were excluded from the study. Informed consent was taken from every patient.

This study was divided into groups based on 3 parameters ie. implant surface coating, implant diameter as well as single and multiple implant-supported bridges. The length of the implant was standardized and kept at 10 mm.

Patients who met the inclusion criteria were divided into 4 groups. Group A comprised of patients with single implant (ADIN [Osseofix] 3.75×10 mm. calcium phosphate); Group B comprised of patients with single implant (ADIN [Toureg] 3.75×10 mm alumina blasted; Group C comprised of patients with single implant (ADIN 4.2×10 mm, calcium phosphate; Group D comprised of patients with multiple implant (ADIN 4.2×10 mm, calcium phosphate.

The comparison is taken between 1) two implants with different surface coating (ADIN [Osseofix] 3.75×10 mm) and ADIN (alumina blasted, 3.75×10 mm), Group A & Group B; 2) two implants with different diameter (ADIN [Osseofix] 3.75×10 mm) and ADIN [Osseofix] 4.2×10 mm), Group B & Group C; and 3) single implant versus implant supported bridge (ADIN [Osseofix] 3.75×10 mm and ADIN [Osseofix] Implant supported bridges, 4.2×10 mm, Group 1 & Group 4).

Thyroid collar, lead apron, ADIN surgical kit, RVG x-ray cover, RVG sensor holder, Toureg™-S implant (ADIN dental implant system, Alon Tavor, Israel) and Osseofix™-OS implant resorbable blast medium (RBM) (ADIN Dental implant systems, Alon Tavor) are materials used to carry out this study; and CBCT-CS9300 3D Manual (Carestream Dental Atlanta, GA) and RVG)-6200, Carestream Dental Atlanta, GA) are the equipments used in this study.

Both radiographic techniques were explained to the patients and case history was taken. Preoperative radiographs were also examined to find out the position and angulation of implant or presence of any cyst or pathology. The RVG was taken using sensor plate of thickness 7.3 mm of size 1 sensor model. The radiographs were taken perpendicular to the long axis of the implants with a long-cone parallel technique. The patient position was standardized with the upper arch parallel to the floor and midsagittal plane parallel to the floor. X-ray was operated at 60 kVp with minimum source to skin distance at about 100 mm.

The CBCT was taken with 90 voxel size, 84kv, 6.3 Ma with exposure time 20 sec and area 753 mGy.cm^2. The image was taken in accordance with ALARA principle. The CBCT and RVG were taken immediately after loading which were taken as baseline reference and also after 1 year.

Measuring bone loss in RVG marginal bone loss was performed as follows: the marginal height of each fixture is measured mesially and distally by using the fixture thread as an internal dimensional reference with the help of a millimetric grid. Marginal bone loss is measured by measuring the distance from the shoulder on the implant fixture to the most coronal point on the mesial and distal alveolar bone crest respectively. Two perpendicular lines were dropped on the mesial and distal aspect of the implants to the first bone-to implant contact. Comparative measurements of mesial and distal crestal bone levels adjacent to implants were made to the nearest 0.1 mm. A minimum of 3 readings were made on mesial and distal side for each case and average values were used to calculate the amount of crestal bone loss. The crestal bone loss measured using Carestream viewer software to the accuracy of 0.2 mm. CBCT measurement were taken on mesial, distal, buccal and lingual side same as that of RVG. The marginal bone loss was defined as the difference between true crestal bone levels

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at the baseline and after one of loading. So, calculated crestal bone change is *crestal bone change (at given time) = bone level at base line - bone level at that time.*
Two investigators, a radiologist and a dentist performed the radiographic analysis.

Statistical analysis

The data analysed and presented as mean and SD for the outcome variable at different time periods (at the time of loading and after 1 year of loading). Comparison of effect of two implant diameters, 3.75 mm and 4.2 mm, at different time periods were done using Student t-test. Similarly, the effect of different surface coating and single verses multiple were also compared using the same test. The correlation between CBCT and RVG was also calculated using interclass correlation test.

RESULTS

Table 1 and Table 2 depicts the mean crestal bone loss values of 4 different types of implants using RVG and CBCT respectively, whereas Fig.1 and Fig.2 are the graphical representation of comparison of the average crestal bone loss occurring around 4 different types of implants at the time of loading and after one year using RVG and CBCT, respectively.

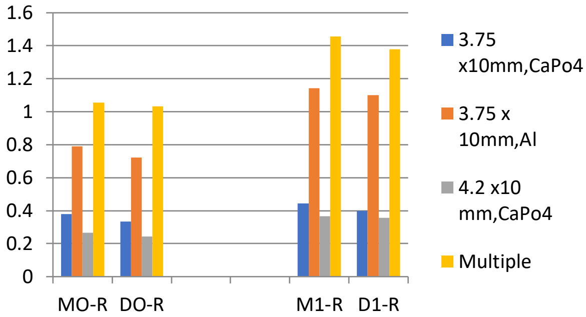
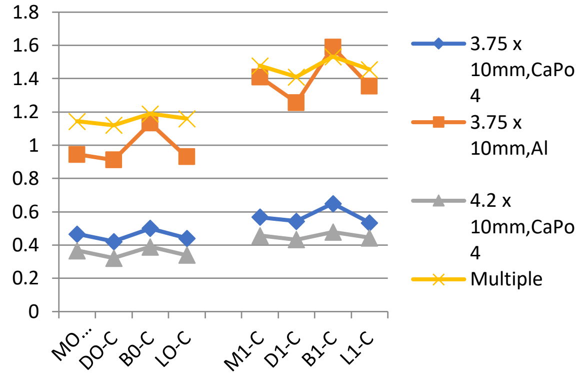


Figure 1 Graph representing crestal bone loss of 4 different types of implants using RVG

Both RVG and CBCT, reveals that in each group, there is an increase in crestal bone loss evaluated after 1 year of loading when compared to the time of loading. Calcium phosphate implants shows reduced bone loss at both intervals when compared to alumina blasted implants. Multiple-implant shows the highest range of crestal bone loss at both intervals. In each group, RVG shows more marginal bone loss in the mesial side of implant when compared to distal side of implant. Whereas CBCT reveals average crestal bone loss more in buccal side followed by mesial, lingual, and distal sides in all types of implants at the time of loading. Buccal side of multiple-implant shows less bone resorption when compared to alumina blasted implants after one year of loading. The average crestal bone loss of 3.75 and 4.2 implant is very much less when compared to multiple-implant supported and alumina blasted implant.



Graph 2 Graph representing crestal bone loss of 4 different types of implants using CBCT

Table 1 Mean crestal bone loss values of 4 different type of implants using RVG

Group	M_0-R Mean±SD	M_1-R Mean ± SD	D_0-R Mean ± SD	D_1-R Mean ± SD
1	0.378±0.13	0.444±0.13	0.333±0.150	0.40±0.130
2	0.789±0.10	1.140±0.17	0.722±0.190	1.10±0.273
3	0.260±0.15	0.367±0.20	0.244±0.113	0.35±0.123
4	1.050±0.36	1.456±0.23	1.030±0.260	1.37±0.150

Table 3 show the comparison of bone loss between different implant surface coatings Group 1 and Group 2 using RVG and CBCT. This data interprets that calcium phosphate implant has less bone loss compared to alumina blasted implants. The latter shows significant bone loss at the time of loading and after one year of loading. RVG shows marginal bone loss in mesial side more than distal side of both implants at two intervals. CBCT reveals average crestal bone loss maximum on buccal side followed by mesial, lingual, and distal side. Increase in bone loss seen at the end of one year when compared to the time of loading.

Table 4 shows the comparison of bone loss between Group 1 and Group 3 (different diameter).

Table 2 Mean crestal bone loss of 4 different type of implants using CBCT

Group	M_0-C Mean±SD	M_1-C Mean ± SD	D_0-C Mean ± SD	D_1-C Mean ± SD	B0-C Mean±SD	B1-C Mean±SD	L0-C Mean±SD	L1-C Mean±SD
1	0.467±0.07	0.567±0.08	0.422±0.13	0.544±0.11	0.489±0.07	0.650±0.51	0.440±0.09	0.533±0.07
2	0.944±0.20	1.411±0.17	0.911±0.15	1.256±0.25	1.133±0.17	1.589±0.11	0.930±0.29	1.355±0.12
3	0.367±0.11	0.456±0.08	0.322±0.13	0.433±0.08	0.389±0.10	0.478±0.09	0.340±0.13	0.444±0.08
4	1.144±0.28	1.478±0.21	1.120±0.23	1.411±0.11	1.189±0.24	1.533±0.08	1.160±0.17	1.456±0.11

Table 3 Comparison of bone loss between Group 1 and Group 2 (implant surface coating)

Type of radiograph	Surfaces	Group	N	Mean	Standard deviation	t	df	P value
RVG	Distal	1	9	-.111	.220	2.819	16	.012
		2		-.377	.178	2.819	15.34	.013
	Mesial	1	9	-.066	.150	3.68	16	.002
		2		-.355	.181	3.68	15.46	.002
CBCT	Distal	1	9	-.122	.044	2.99	16	.009
		2		-.344	.218	2.99	8.65	.016
	Mesial	1	9	-.100	.100	5.88	16	.000
		2		-.466	.158	5.88	13.51	.000
	Buccal	1	9	-.022	.044	8.72	16	.000
		2		-.455	.142	8.72	9.52	.000
	Lingual	1	9	-.055	.101	4.95	16	.000
		2		-.444	.212	4.95	11.45	.000

Table 4 Comparison of bone loss between Group 1 and Group 3 (implant diameter)

Type of radiograph	Surfaces	Group	N	Mean	Standard deviation	t	df	P value
RVG	Distal	1	9	-.111	.220	.231	16	1.00
		3		-.111	.105	.345	11.47	1.00
	Mesial	1	9	-.006	.150	.485	16	.634
		3		-.100	.141	.485	15.94	.634
CBCT	Distal	1	9	-.122	.044	.447	16	.661
		3		-.111	.060	.263	14.67	.661
	Mesial	1	9	-.100	.100	.263	16	.796
		3		-.088	.078	.268	15.11	.796
	Buccal	1	9	-.022	.044	2.68	16	.016
		3		-.088	.060	2.68	14.67	.017
	Lingual	1	9	-.055	.101	1.07	16	.297
		3		-.100	.070	1.07	14.29	.299

Table 5 Comparison of bone loss between Group 1 and Group 4 (single versus multiple)

Type of radiograph	Surfaces	Group	N	Mean	Standard deviation	t	df	P value
RVG	Distal	1	9	-.111	.220	2.38	16	.030
		4		-.344	.194	2.38	15.75	.030
	Mesial	1	9	-.066	.150	4.26	16	.001
		4		-.400	.180	4.26	15.48	.001
CBCT	Distal	1	9	-.122	.044	2.98	16	.009
		4		-.288	.161	2.98	9.18	.015
	Mesial	1	9	-.100	.100	3.50	16	.003
		4		-.333	.173	3.50	12.80	.004
	Buccal	1	9	-.022	.044	4.33	16	.001
		4		-.344	.218	4.33	8.65	.002
	Lingual	1	9	-.055	.101	4.21	16	.001
		4		-.300	.141	4.21	14.50	.001

It was found out that larger diameter (4.2×10 mm) shows less marginal bone loss when compared to 3.75×10 mm implant.

Table 5 shows the comparison of bone loss between single versus multiple (Group 1 and Group 4). It is evident from the measurements that in both RVG and CBCT multiple implants has a highly significant amount of bone loss when compared to single implants.

Table 6 shows the comparison between CBCT and RVG. It is observed that CBCT values are higher than RVG values. The average bone loss values occurring after one year is greater than values obtained at the time of loading. CBCT shows more accurate and reliable values than RVG both clinically and statistically.

Table 6 Comparison between CBCT and RVG

Sides at different time	Type-1	Type-2	Type difference	p-value
M_0	0.622	0.730	0.108	0.207
M_1	0.852	0.977	0.125	0.163
D_O	0.583	0.694	0.111	0.169
D_1	0.808	0.911	0.103	0.189

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DISCUSSION

Endosteal implant is effective and appropriate for replacing single teeth, as well as for rehabilitating edentulous arches. The long-term preservation of crestal bone height around osseointegrated implants is often used as a primary success criterion for different implant systems. Radiographic evaluation of bone is a very important and viable means of detecting health and stability of bone around the peri-implant hard tissue. A decrease of crestal bone level indicates that the implant is loosening its bony anchorage.

The aim of this study is to examine the effect of several variables on marginal bone loss around implant supporting fixed restorations. Inspite of lack of consensus on what factors affect marginal bone loss, the generally accepted guidelines for implant induced bone loss is same as described by Alberktsson in 1986 that the success criteria for implant include average bone loss should be less than 1.5 mm in the first year of service, and thereafter less than 0.2 mm annually.[4] Jung, et al in his studies reported that more than 50% of the total bone loss recorded in 12 months period occurred during the first three months. The rapid initial bone loss might be the result of periosteal elevation, surgical trauma, the preparation of the recipient bed and stress concentration from excessive tightening of the implant.[10] Roccuzzo et al in his study described that the mean marginal bone loss of 0.65 mm for implants after 6 weeks loading and 0.77 mm after 12 weeks loading was observed when comparing 68 implants subjected to initial loading by the common technique.[11]

Various causes of greater crestal bone loss in the 1st year of implant function are surgical trauma, occlusal overload, peri-implantitis, presence of microgap, reformation of biologic width and implant crest module design. It has been documented that, subtle changes in shape, length, width and number of endosseous implants can influence success rate.[5]

Various imaging radiographs are available for the evaluation of the recipient site, such as IOPA radiographs, panoramic radiograph, CBCT, oblique cephalometric radiographs, digital subtraction radiography. Radiographs are helpful in assessing stress concentration around implants, thereby obviating excessive alveolar bone loss.[12] For this study CBCT and digital-RVG had been used for assessing crestal bone loss and then compared the values between both of them. The RVG was taken using long cone paralleling technique with the help of radiographic film holders (Rinn XCP; Densply) to minimize distortion and errors. Both RVG and CBCT was taken at the time of loading and after one year of loading. This invivo study was undertaken to compare the crestal bone loss occurring along the implants of different diameters, surface coating, and single versus multiple implants and also to find out the difference between values of both CBCT and RVG.

Implant surface treatment

The surface texture plays a very important role in osseointegration process. The composite effect of surface energy, composition, roughness, and topography influences the biological response of the local tissue in terms of protein adsorption and cellular adherence.

Calcium phosphate surface coated implants that were used in this study, is a resorbable blast media which does not involve acid-etching, once the surface was coated with the active layer and the inventors claim the ill-effects of acid etching such as boundary degradation as a surface that is 100% free of acid residues is formed.

Rajpal in his study has suggested that rough surface implants show less bone loss when compared to smooth surface implants.[13] Jimbo et al in 2013 did a study to evaluate the early integration of 5 commercially available implants and found that in all five groups the trabecular regions were characterized by woven bone formation which was in close contact with the implant surface.[14] All the above study shows similar results as of our study. The possible reason of calcium phosphate showing less resorption might be due to the fact that the surface roughness and micropores on the Group 1 implant will help to convert part of the shear force component into compressive and tensile component. The adjacent crestal bone osseointegrates into the micropores, elevations and depressions of the rough surface of implant.

From the results obtained in our study, it can be observed that, overall average crestal bone loss of Group 1 at the time of loading using RVG was 0.35 mm and average crestal bone loss of Group 2 was 0.755 mm. The overall average crestal bone loss of Group 1 at the time of loading using CBCT was 0.454 mm and average crestal bone loss of Group 2 was 0.979 mm. Difference of bone loss with both types of implants using different radiographs at this stage was statistically significant. Surgical trauma and lack of positive stimulation due to occlusal forces may have caused this observed bone loss and these observations are commensurate with other studies.[15]

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After twelve months of loading the implants ie. one year of implant service, average annual crestal bone loss with Group 1 implants using RVG was 0.422 mm and with Group 2 implants was 1.122 mm. The difference in crestal bone loss between Group 1 and 2 was statistically significant on the mesial, distal, and lingual side of the implants. On the buccal side, the difference was not statistically significant, though average bone loss was more on the buccal side as compared to other three sides. The reason for greater bone loss on buccal side could be that the buccal plate is more dense and compact as compared to the interdental bone or the lingual plate, hence has comparatively less vascularization and healing potential. Average crestal bone loss was maximum on the buccal side of implants, followed mesial, lingual and distal sides. Using CBCT, the crestal bone loss was 0.574 mm in Group 1 and 1.402 mm in Group 2. Both these figures are below 1.5 mm of annual bone loss in the first year of implant service and fulfil the success criteria as described by Albertsson.[4]

Implant diameter

In the present study, the crestal bone loss in relation to the size of the dental implant was evaluated using CBCT and RVG. All implants were placed at the same level of the crestal bone and have the same length but different diameter. Group 1 with diameter of 3.75×10 mm and Group 3 with diameter of 4.2×10 mm was used. Taking the size of implant into consideration, the mean crestal bone around Group 1 at the time of loading using RVG was 0.355 mm and after one year was 0.462 mm. The overall average bone loss of Group 3 using RVG at the time of loading was 0.255 mm and after one year was 0.452 mm. Group 1 with 3.75×10 mm diameter implant has the highest bone loss at the end of the first year in comparison to 4.2 mm implants. This pattern of bone crestal bone loss was maintained at the end of one year of evaluation. The difference in the crestal bone level at the time of loading and after one year between different implant diameters were not statistically significant. Mesial side shows more bone loss than distal side at both time intervals.

Bone loss measured using CBCT at the time of loading in Group 1 was 0.454 mm and in Group 3 was 0.255 mm. After 12 months values in Group 2 was 0.574 mm and in Group 3 was 0.361 mm. The p-values for both mesial and distal aspects of implants were found to be non-significant ($p<0.05$ is highly statistically significant). Thus, in this study, the bone loss was found to be non-significant for both 3.75 mm and 4.2 mm diameter implants on both mesial, distal, buccal and lingual aspects of implants. Ding has reported that increasing the diameter and length of the implant decreased the stress and strain on the alveolar crest and the diameter had a more significant effect than length to relieve the crestal stress and strain concentration.[16] There are many studies which supports the result of our study.[17-19]

Single implant versus multiple implant

When two or more consecutive posterior teeth are missing, each tooth has to be separatively restored by single tooth implant. Splinting multiple implants to replace the consecutive teeth has been thought to help in distribution of functional loads and therefore reduce marginal bone loss.[17] However, single-tooth implant restoration has shown predictable longterm results.[20,21] In addition, separate single-tooth implants are advantageous in aesthetic and passive framework fit while splinted implants effectively distribute functional loads.[22,23]

In our study, we compared and evaluated the marginal bone changes between functionally loaded single and multiple implants in the posterior jaws for up to 1 year. Overall crestal bone loss around single implant using RVG at the time of loading was 0.355 mm and after one year was 0.422 mm. The mean crestal bone loss around multiple-implant using RVG at the time of loading was 1.044 mm and after one year of loading was 1.417 mm. it is observed that multiple-implant shows statistically significant bone loss at both intervals. The CBCT values of Group 1 was 0.454 mm at the time of loading and after one year was 0.574 mm whereas Group 4 shows 1.153 mm at the time of loading and 1.467 mm after one year of loading. The CBCT values also shows statistically significant bone loss in single implants when compared to multiple implants. Kwon, et al in his study stated that separate single-tooth implant restorations to replace consecutive missing teeth may clinically function well in the posterior.[24] This study also is in accordance with our results.

Radiographs

Periapical radiography represents a generally accepted method to assess the longterm evaluation of interproximal crestal bone changes of osseointegrated implants; however, the sensitivity for detecting small changes in bone level is low.[25] A major limitation of periapical radiographs is that only two dimensional-images can be obtained and superimposed bone structures in the interproximal areas are visualized. These limitations can be resolved with three-dimensional scanning techniques such as CBCT; which can improve the detection of anatomical sturctures and have the capacity to assess bone quality in greater detail.[26] A possible drawback of 3D scannings is the higher radiation dose received by the patient compared with the 2D-imaging-techniques.[27]

In our study, the values obtained from CBCT shows higher value when compared to RVG. However, the values were not statistically significant. The overall crestal bone loss using RVG on mesial side at the time of loading and after one year was 0.622±0.38 mm and 0.85±0.50 mm respectively and on distal side was 0.58±0.36 mm and 0.80± 0.48 mm, respectively. The overall mean crestal bone loss using CBCT on mesial side at the time of loading and after one year was 0.730±3.7 mm and 0.977±0.49 mm respectively and on distal side was 0.694±0.11 mm and 0.911±0.10 mm respectively. The p-values for both mesial and distal aspects of implants were found to be non-significant ($p<0.05$) is highly statistically significant. The result of this study is in accordance with study conducted by Adell et al who determined that the mean bone loss for Branemark osseointegrated implants was 1.5 mm for the 1st year.[28]

The sample size of the study is limited. The reliability of radiographic methods for the assessment of marginal bone level around oral implants is influenced by technical factors such as X-ray beam angulations, strict parallelism between implant and the sensor plane and also the thickness of ridge into which implants are placed. Grouping based on occlusion can also be done as marginal bone changes can occur due to occlusal loading patterns and traumatic occlusion.

Further studies can be conducted using a larger population. A longer follow up is recommended to substantiate the data presented in the study. Bone loss occurring in complicated situations such as implant supported full mouth rehabilitation can be investigated. The amount of bone loss occurring in cases where graft have been placed can also be taken as one parameter. To evaluate the intra-surgical versus the radiographic level assessments in measuring peri-implant bone loss.

Within the limitation of this study, it can be concluded that different implant parameters like diameter, surface coating and number of implants has a definite role in the peri-implant bone level around implants. Also, CBCT helps to accurately detect the bone level changes in each follow-up visits and thereby helps the patient to take corrective measurements on the right time and thus prevent failure of implants.

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