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A Prospective Study To Compare Crestal Bone Loss And Radiographic Bone Density Of Different Implant Systems Subjected To Immediate Functional Or Non Functional Loading.

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Abstract
Purpose: To determine if there exists a difference in crestalbone boss and the quantitative radiographic bone density changesaround two different implant systems when subjected to immediate functional and non functional loading.
Materials and Methods:Implants of DENTIN and DENTSPLY XiVE systems were placed in 40 subjects who were partially edentulous in the mandibular arch and were immediately functionally and non functionally loaded. Four groups thus created were evaluated at baseline, 3 months and 6 months for changes in crestal bone levels and quantitative radiographic bone density changes.
Results and Conclusion: A greater degree of bone loss was observed with immediately functionally loaded implants of both systems.An increase in mean grayscale values with both immediate functionally and non functionally loaded at lateral apical level at 3 months and 6 months as well asa significant difference in the decrease of mean grayscale values between baseline and 3 months between immediate functionally and non functionally loaded implantswas seen. The degree of bone loss and decrease in crestal grayscale values from baseline to 3 months was greater with DENTIN implants as compared to DENTSPLY XiVE implants. It was concluded that a difference exists between immediate functional and non functional loading of implants when compared with respect to crestal bone loss and quantitative radiographic bone density changes.

Keywords: *Crestal bone loss, Implants,Immediate Loading*

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I. Introduction

The subject of whether the provisional restoration placed on the immediately loaded implant should be kept in direct occlusal contact or not is controversial. Some studies comparing immediate functionally loaded and non functionally loaded implants have found a significant difference in crestal bone loss and implant survival rates[1,2] while some others have found immediate functionally loaded and non functionally loaded implants to be comparable with respect to the same parameters.[3,4,5]The lack of consensus regarding whether or not immediately loaded implants should be functionally loaded loaded in occlusion makes this an area requiring further research.[6,7,8,]

Histological and histomorphometric studies have shown that immediately loaded implants osseointegrate just as well as delayed loaded implants. In addition, immediate loading of implants has been shown to stimulate the ossification process around implants, resulting in an improved bony foundation for the definitive prosthesis.[9,10] however, studies on the quantitative assessment of changes in mineral bone density around implants and the comparison between different loading protocols are scarce.

Implant system design features are one of the most fundamental elements that have a profound effect on implant primary stability and in influencing the functional surface area to sustain loading during or after osseointegration.[11]However, many of the studies on the effect of implant design on stress distribution have been in-vitro two- and three-dimensional finite element analysis studies[16,17,18]whereas in vivo studies have either compared implant systems[12]or immediate, early and delayed loading protocols without consideration of implant systems designs.[1-8]

Since there exists a dilemma regarding the protocol for immediate loading, the current study was conceptualized to determine whether there exists a difference in crestalbone boss and the quantitative radiographic bone density changesaround two different implant systems, under the demanding conditions of immediate functional and non functional loading.

II. Materials and Methods:

40 subjects who were partially edentulous in the mandibular arch were selected for the study. Extraction sites healed for at least 6 months, with sufficient bone volume (more than 11.0 mm in height and 6.0 mm in width) and insertion torque values of at least 35 Ncm during implant placement were the other inclusion criteria.

Subjects were excludedif they were inpoor general health, alcohol, drug and medication dependent, havingprevious history of radiotherapy or chemotherapy, cigarette smoking habit, or insufficient bone volume (less than 5 mm in width and 11 mm in height).

The implant systems used were DENTIN implants (DENTIN Implants Technologies Ltd, Gosh Segev, Israel) and DENTSPLY XiVE implants (DENTSPLY Friadent, Mannheim, Germany).

The 40 subjects selected were randomly divided into 2 groups, each consisting of 10 subjects:

GROUP I- DENTIN implants system with immediate functional loading

GROUP II- DENTIN implants system with immediate non functional loading.

GROUP III-DENTSPLY XiVE implants system with immediate functional loading.

GROUP IV-DENTSPLY XiVE implants system with immediate non functional loading.

The four groups weresubsequently evaluated at regular intervals.

Clinical Procedure

The edentulous space to be restored was assessed for adequate bone height and width on preoperative CT scan. A surgical template was used to guide the placement of implants. The osteotomy sites were prepared with sequentially increasing diameter of bone drills and implants inserted as recommended by the manufacturer. Minimum insertion torque values of 35 Ncm indicated adequate primary stability for the implant to be immediately loaded. Intraoral periapical radiographs (IOPA) taken immediately postoperatively served as the baseline radiographic record for all the 4 groups. Provisional restorations made of autopolymerising composite resin(Protemp^{TM}4, 3M ESPE, Minnesota, U.S.A)were checked for proximal contact and emergence profile and cemented using zinc oxide non eugenol temporary cement (Rely X^{TM} Temp NE, 3M ESPE, Minnesota, U.S.A). In group I and III (immediate functional loading), the provisional restorations were adjusted to have occlusal contacts only in centric occlusion, while in groups II and IV (immediate non functional loading), the provisional restorations adjusted to be free of all occlusal contacts in centric and eccentric positions. The provisional restorations were replaced with definitive metal ceramic restorations after 6 months.

Determination of changes in crestal bone levels

Crestal bone levels were evaluated from intraoral periapical radiographs takenusing long cone paralleling techniqueimmediately postoperatively (baseline), at 3 month and 6 month.

Digital photographs of the intraoral periapical radiographs were taken and analysed with computer imaging software (DBSWIN Version 5.5.0, Durr Dental, Germany). The implant-abutment junction was used as the reference point for all measurements. The distance between the implant-abutment junction and the most coronal level of bone deemed to be in contact with the implant surface was measured at baseline, 3 month recall and 6 month recall. The crestal bone level change was calculated as the difference between the reading at the time of examination and the baseline value.

Radiographic bone density assessment

Digital photographs of recorded intraoral periapical radiographs were analysed using image analysis software (GIMP Version 2.8.10) for peri-implant bone density measurements. The histogram tool was used to measure the mean pixel gray value ranging from 0 to 255 on the greyscale for representing the bone density of a selected region. For each implant, four 576 pixel regions of interest (ROIs) were selected on peri-implant bone. ROIs were located at the two levels around the implant: Crestal and lateral-apical and were recorded mesially and distally(Fig. 1). The ROIs were positioned two pixels away from the implant surface to avoid making contact with the metallic surface of the implant image. The mean of the four readings so measured were recorded for each implant.

Statistical Analysis

Repeated measures ANOVA followed by Tukey Post Hoc test was used to analyse the data collected during the course of the study.

Conflict Of Interest

No conflict of interest is reported in this study

Observations and results

The change in crestal bone level, representing crestal bone loss of the four groups at three periods is summarized in Table 1 and Figure 1. The change in crestal bone level was the highest in Group I followed by Group III, Group II and Group IV, the least.

Table 1: Change in crestal bone level (Mean ± SD, n=10) of four groups at three periods

Periods	Group I	Group II	Group III	Group IV	F value (3.36 DF)	p value
Baseline to 3 month	0.65 ± 0.03	0.48 ± 0.06	0.51 ± 0.04	0.35 ± 0.10	37.53	<0.001
3 month to 6 month	0.30 ± 0.01	0.21 ± 0.05	0.27 ± 0.01	0.18 ± 0.01	38.85	<0.001
Baseline to 6 month	0.95 ± 0.04	0.69 ± 0.08	0.78 ± 0.04	0.53 ± 0.11	61.80	<0.001

Significant (p<0.001) differences were seen in change increstal bone level among all groups except Group II and Group III at baseline to 3 month (Table 2).However, between 3 months to 6 months, the mean change in crestal bone level did not differ significantlywhen Groups I and Group III, and Group II and Group IV were compared.

Table 2: Comparison (p value) of mean change in crestal bone level between groupsfor each period by Tukey test

Comparisons	Baseline to 3 month	3 month to 6 month	Baseline to 6 month
Group I vs. Group II	<0.001	<0.001	<0.001
Group I vs. Group III	<0.001	0.205	<0.001
Group I vs. Group IV	<0.001	<0.001	<0.001
Group II vs. Group III	0.652	<0.001	0.022
Group II vs. Group IV	<0.001	0.100	<0.001
Group III vs. Group IV	<0.001	<0.001	<0.001

The change in lateral apicalhistogram gray scale values of the four groups at three periods is summarized in Table 3. In all four groups, the mean lateral apical histogram gray scale values showed a significant increase at all periods and were the highest in baseline to 6 month period.

Table 3: Change in lateral apical histogram gray scale value (Mean ± SD, n=10) of four groups at three periods

Periods	Group I	Group II	Group III	Group IV	F value (3.36 DF)	p value
Baseline to 3 month	4.68 ± 0.80	5.66 ± 0.53	4.90 ± 0.62	6.10 ± 0.73	9.50	<0.001
3 month to 6 month	4.15 ± 0.29	6.07 ± 0.59	4.96 ± 1.10	7.84 ± 1.21	32.81	<0.001
Baseline to 6 month	8.83 ± 1.00	11.73 ± 0.84	9.86 ± 1.27	13.94 ± 1.26	41.35	<0.001

Significant differences (p<0.01 or p<0.001) in the mean change in lateral apical histogram gray scale value were seen between among groups at baseline to 6 month except Group I and Group III (Table 6).

Table 4: For each period, comparison (p value) of mean change in lateral apical histogram gray scale value between groups by Tukey test

Comparisons	Baseline to 3 month	3 month to 6 month	Baseline to 6 month
Group I vs. Group II	0.013	<0.001	<0.001
Group I vs. Group III	0.886	0.188	0.178
Group I vs. Group IV	<0.001	<0.001	<0.001
Group II vs. Group III	0.076	0.038	0.003
Group II vs. Group IV	0.477	0.001	0.001
Group III vs. Group IV	0.002	<0.001	<0.001

The change in crestalhistogram gray scale value of the four groups at three periods is summarized in Table 3. Significant (p<0.001) differences increstal histogram gray scale value between groups at both baseline to 3 month and baseline to 6 month was observed.

Table 5: Change in crestal histogram gray scale value (Mean ± SD, n=10) of four groups at three periods

Periods	Group I	Group II	Group III	Group IV	F value (3.36 DF)	p value
Baseline to 3 month	-24.40 ± 7.41	-16.86 ± 5.14	-19.16± 3.70	-12.08 ± 4.47	9.11	<0.001
3 month to 6 month	4.34 ± 3.83	6.45 ± 6.57	5.49 ± 5.63	7.51 ± 6.08	0.58	0.633
Baseline to 6 month	-20.06 ± 6.04	-10.41 ± 6.01	-13.67 ± 5.00	-4.57 ± 4.56	14.11	<0.001

Significant differences ($p<0.05$ or $p<0.001$) were seen increstal histogram gray scale valuesbetween groups except Group I and Group III, Group II and Group III, and Group II and Group IV at baseline to 3 month (Table 4). In contrast, at 3 month to 6 month, the mean change in crestal histogram gray scale value did not differ significantly ($p>0.05$) among the four groups.

Table 6: For each period, comparison (p value) of mean change in crestal histogram gray scale value between groups by Tukey test

Comparisons	Baseline to 3 month	3 month to 6 month	Baseline to 6 month
Group I vs. Group II	0.017	0.836	0.002
Group I vs. Group III	0.147	0.968	0.059
Group I vs. Group IV	<0.001	0.594	<0.001
Group II vs. Group III	0.772	0.981	0.543
Group II vs. Group IV	0.210	0.975	0.096
Group III vs. Group IV	0.027	0.853	0.004

III. Discussion

The comparison of crestal bone loss around immediately provisionalized functionally and non functionally loaded implants performed in this study revealed greater bone loss occurring between baseline to 3 months as compared to 3 months to 6 months (Tables1 and 2). The unorganised, less-mineralized woven bone found at the implant-bone interface in the early stages of bone healing permits a greater degree of micromotionthan organised, mineralized lamellar bone, leading to the greatest risk of overload of implant and resultant crestal bone resorption and implant failure at 3 to 6 weeks after surgical insertion.[13]The micromotion of immediately provisionalized implants might differ depending on whether they are functionally or non functionally loaded. Significantly decreased bone density accompanied by the formation of crater-like defects in dynamically loaded implants in comparison to statically and non loaded implants has been observed.[14] The smaller degree ofcrestal bone loss with immediately provisionalizednonfunctionally loaded implants in the first 3 month after implant placement might be due to the micromotion of the implant not exceeding the critical threshold of 100 micrometres.[14] The observations of this study are in agreement with the work of **Margossian*et al***[2] who encountered greater bone loss in immediately provisionalizedocclusally loaded implants compared to immediately provisionalizednonocclusally loaded implants at 6 months.

A significantly greater degree ofcrestal bone loss was found with DENTIN implants(groups I and II), characterized bydiameter of 4.2 mm, square thread design, thread pitch of 1.2 mm and a parallel crest module in comparison to DENTSPLY XiVE implants (groups III and IV) which are characterized bydiameter of 4.5 mm, buttress thread design, threads pitch of 0.85 mm and flaring of the crest module by 0.185 mm per side, both with functional as well as non functional loading (Tables 1 and 2). The differences in macrosurface design between the two implant systems might have been a significant factor in the degree of crestal bone loss seen with the two systems.

Increasing implant diameter has a significant role in decreasing stress at the implant-bone interface by increasing the functional surface area.An increase in implant diameter by as little as 0.5 mm increases functional implant surface area by 10-15%.[13] Increasing implant diameter also results in as much as a 3.5-fold reduction of crestal strain.[15] When the diameter increases from 3.3mm to 4.1mm and from 4.1 mm to 4.8 mm, the maximum stress decreases by 29.6% and 34.1%, respectively, for vertical force.[16] The maximum stress and strain reduces with an increased diameter, especially when implants are loaded with buccolingual force.[16] Since the greatest stresses are concentrated at the crestal region of the implant, the increased width is more significant than length for an implant design, once adequate length has been established.[17]

Decreasing thread pitch increases the number of threads per unit length of an implant body, resulting in greater surface area per unit length of the implant body. Of all the design variables, pitch has the most significant effect on changing the surface area of a threaded implant.[13] Previous studies have found that regardless of whether force is vertical or oblique, peak stress is always concentrated on the cortical area around the implant cervical area especially at the first pitch.[18,19,20]A thread pitch of 0.8 mm has been found to be optimal for a screwed implant.[21]Thread pitch also determines the magnitude of the stress, with a contribution percentage of 26.12% for the implant body as compared to other thread features.[22]The decrease of maximum effective stress is affected more by varying implant pitch than by varying implant length, with the maximum effective stress around implants decreasing by 15% when screw pitch is changed from 1 to 0.9 mm, whereas a maximum effective stress reduction of just 5% is seen when screw pitch is changed from 0.9 to 0.7 mm.[23]

A flared crest module on the implant body places the crestal bone around an implant under compressive load, while a parallel sided crest module results in shear stress being transferred to the implant-bone interface at the crestal region.[13] Studies comparing implants with flared crest module as a stress reduction design feature have encountered less bone loss than those that do not incorporate stress reduction features in the crest module.[24]The incorporation of microthreads on the implant crest module as a feature to minimize crestal bone[25]have not shown them to be significant in controlling stress concentration and minimizing crestal bone loss.[26]

Numerous studies comparing thread shapes have reported less stresses with both compressive and shear forces with square threads.[27,28]However, recent investigations on the effect of thread shape on stress distribution havefound that while thread shape greatly influenced stress distribution in cancellous bone, it did not have a significant effect on stress distribution in cortical bone.[21,29,30]Furthermore, differences in thread shape have not found to significantlyaffect stress distribution at the implant-bone interface.[31] These studies suggest that the differences in degree ofcrestal bone loss encountered with DENTIN and DENTSPLY XiVE implants may not be entirely attributable to differences in their thead shape.

The change in alveolar bone density around immediately functionally and non functionally loaded implants were analyzed using the histogram tool of the image analysis software (GIMP Version 2.8.10). Alveolar bone density is represented by mean grayscale values, which range from 0 (black pixels) to 255 (white pixels).[32] Greyscale values of 128 indicate unchanged bone density,while values above 128 indicate mineral gain (increased bone density) and values below 128 represent mineral loss (decreased bone density). Mean grayscale values at the lateral apical level around both implant systems under immediate functional as well as non functional loading show an increase at both at 3 and 6 month recall as compared to baseline (Tables 3 and 4). A similar linear increase in pixel grey scale values for immediately loaded implants in contrast to a significant decrease in pixel grey scalewith conventionally loaded implants at 3,6 and 12 months after placement has previously been observed.[32]The stimulation of formation of mature, compact lamellar bone around immediately loaded implants accompanied by an increase in bone-implant-contact (BIC) percentage by as much as 67.6% to 78% in comparison to delayed loaded implants (BIC 53%) has been reported.[9,10,33]

The mean crestal histogram grayscale values with both implant systems, irrespective of whether they were immediately functionally or non functionally loaded, were found to decrease at baseline to 3 month, representing decreasing alveolar bone density in that period (Tables 5 and 6). Stress concentration typically is greatest at the crestal bone-implant interface of an implant.[18,19] This, along with the less mineralized, weaker woven bone formed following implant osteotomy explains the decreasing crestal bone density from implant placement surgery until the formation of woven bone is complete.[20]Furthermore, the significantly greater decrease in mean crestal histogram grayscale values with the immediate functionally loaded implants of both systems as compared to non functionally loaded implants from the time of implant placement till 3 months might very well represent greater bone loss accompanied by a greater degree of crestal bone demineralization occurring with immediate functionally loaded implants.[2]

An increase increstal grayscale values was noted with either loading situation and with both systems between 3 months and 6 months, illustrating the increase in bone mineral density that occurs with the conversion of less mineralized woven bone to the highly mineralized, organized lamellar bone.

IV. Conclusions

It was concluded from the results of this study that a significantly greater degree of crestal bone loss and reduction in crestal bone density occurs with immediate functional loading of implants, when compared to immediate non functionally loaded implants. However, both functional as well as non functionalimmediate loading of implants result in an improvement of alveolar bone density around the lateral and apical portions of the implant body. Differences in implant system designsare also significant in reducing stress concentration around immediately loaded implants.

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