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Comparative evaluation of crestal bone loss following conventional and guided implant placement: A prospective clinical-radiographic study

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Abstract:
Crestal bone preservation is important for long-term implant success and guided surgery may reduce surgical trauma. This prospective randomized clinical-radiographic study included 33 patients allocated to conventional or computer-guided implant placement. Plaque index, bleeding on probing, probing depth and keratinized tissue width were assessed at baseline, 6 months and 9 months, while CBCT assessed crestal bone levels at baseline and 9 months. Peri-implant soft-tissue parameters improved in both groups without significant intergroup differences (p>0.05). Thus, guided placement showed significantly less mesial and distal crestal bone loss at 9 months than conventional placement (p<0.05).

Keywords: Cone beam computer tomography **(**CBCT), conventional implant placement, crestal bone loss (CBL), endosseous implant, guided implant placement

Background:
Dental implants have proven to be a highly predictable treatment option for the replacement of missing teeth. Implant supported prosthetic rehabilitation offers superior results compared to other routine prosthetic treatment modalities based on concept of osseointegration, first introduced by P.I. Brånemark. With the passage of time, implant therapy has proven to have a high success rate. However, maintenance of peri-implant tissue stability, especially crestal bone, is an essential factor that determines the success of implant therapy **[1, 2].** The crestal bone plays an important role in providing structural support to peri-implant soft tissues. As per the success criteria of implant therapy, marginal bone loss should be less than or equal to 1.5 mm within the first year of loading, while it should be less than or equal to 0.2 mm every subsequent year **[3].** Despite following these success criteria, there will be some degree of bone loss due to various factors such as surgical trauma; implant placement and compromise of the vascular supply are considered to be the primary causes of crestal bone loss **[3, 4].** Conventional implant placement involves reflecting a full-thickness flap for better visualization of the implant site. However, this technique may cause increased marginal bone loss, greater surgical trauma etc **[4, 5].** On the other hand, Computer-guided implant surgery is a minimally invasive accurate 3D implant placement without flap reflection technique which reduces surgical trauma and helps in maintaining crestal bone stability **[6-10].** Despite these advantages, the clinical superiority of guided implant placement techniques to conventional techniques is still controversial. As some clinical trials and meta-analyses have shown that flapless implant placement techniques result in less crestal bone loss whereas other reported similar amounts of bone loss when performed optimally **[11-13]**. Additionally, recent systematic reviews have shown that other aspects may also play a more important role than the implant placement techniques themselves **[14, 15].** Therefore it is of interest to evaluate the clinical and radiographic performance of conventional and computer-assisted implant placements through comparisons of the peri-implant soft tissues and crestal bone loss over a 9-month follow-up period to assess whether computer-assisted implant placements offer better maintenance of marginal bone and peri-implant tissue stability.

Materials and Methods:
The present prospective, randomized clinical-radiographic study was conducted in the Institutional Department of Periodontology and Oral Implantology, after obtaining institutional ethical clearance certification. Out of 38 study subjects, 33 randomly selected patients on the basis of inclusion (subjects between 18 and 60 years with sufficient alveolar bone height and width, with a minimum of 2 mm keratinized gingival tissues) and exclusion criterion (systemic conditions, smokers, extraction sites less than 4 months old, pregnant or lactating women and people with parafunctional habits etc)., have submitted signed informed consent after listening to the pros and cons associated with study. The sample size calculation was done by using the G*Power software version 3.1.9.6 with a power of 90%, alpha error of 5% and an effect size of 1.15, which gave us a minimum sample size of 30. To include the probability of some dropouts, a total of 33 study subjects were randomly assigned to two groups: Group I (conventional implant placement) 17 Patients With 17 Implant Site and Group II (guided implant placement) 16 Patients With 17 Implant Site just prior to surgery. In Group I, implant placement was performed using the conventional open flap surgical technique. Prior to the surgical procedure, all patients underwent preoperative clinical and radiographic evaluation. Following the administration of local anaesthesia and implementation of strict aseptic measures, a crestal incision was placed in the edentulous area and a full-thickness mucoperiosteal flap was carefully reflected to expose the underlying alveolar bone. Sequential osteotomy preparation was then carried out using the manufacturer-recommended drilling protocol under copious sterile saline irrigation to prevent thermal injury to the bone. Implant fixtures of appropriate dimensions were inserted into the prepared osteotomy sites with adequate primary stability and immediate RVG was taken. Following implant placement, the flap was repositioned and sutured using 4-0 non-resorbable sutures to achieve primary closure. In order to enable sufficient osseointegration and peri-implant tissue maturation, definitive

prosthetic rehabilitation was carried out three months after implant placement. Immediate CBCT was taken after suturing considered as baseline for marginal bone level and at 9 months post- operatively. In Group II, implant placement was performed using a computer-guided flapless surgical approach with the aid of a prefabricated surgical guide. The surgical guide was fabricated using Digital Imaging and Communications in Medicine (DICOM) data obtained from cone beam computed tomography (CBCT) combined with stereolithography (STL) data acquired through intraoral scanning. The integration of CBCT and intraoral scan data enabled virtual implant planning and prosthetically driven three-dimensional positioning of the implants prior to surgery. Based on the finalized digital treatment plan, a customized surgical guide was fabricated to guide precise implant placement during the surgical procedure. Under local anaesthesia and strict aseptic conditions, the surgical guide was positioned intraorally and verified for proper fit and stability. Osteotomy preparation was performed through the guide sleeves according to the digitally planned angulation, depth and position without raising a mucoperiosteal flap. Implants were subsequently inserted through the guide in a minimally invasive flapless manner, thereby preserving soft tissue architecture, minimizing intraoperative bleeding, reducing surgical trauma and maintaining periosteal blood supply to the underlying bone and immediate RVG was taken followed by placement of the gingival former. In order to enable sufficient osseointegration and peri-implant tissue maturation, definitive prosthetic rehabilitation was carried out three months after implant placement in group II. Immediate after prothesis CBCT was taken considered as baseline for marginal bone loss and at 9 months post- operatively. All surgical procedures in both groups were carried out by the same experienced operator under standardized clinical conditions to minimize operator-dependent variability and procedural bias. Post-operative instructions and medications were prescribed for all patients. The patients were placed on maintenance therapy program and recalled at three-month intervals for periodic follow-up and evaluation till 9 month post prosthesis cementation. All patients of both groups completed the treatment and follow up protocol without fail. All clinical parameters such as plaque index, bleeding on probing (Ainamo and Bay), pocket probing depth and keratinized tissue width were recorded at baseline, 6 months and 9 months. Radiographic parameters such as crestal bone levels (Mesial and distal bone levels were recorded in reference to bone implant contact) were recorded at baseline (immediately after prosthesis) and 9 months (after prosthesis cementation) for Group I and II respectively by using cone beam computed tomography.

Results:

All the 33 patients selected for the surgical procedure had completed the study without any complication. Out of full mouth PI, BPI, PPD and KD Scores on intragroup comparison only PD was statistically significant ($p<0.05$) utilising One way ANOVA test which on post hoc evaluation reported to be statistically significant ($p<0.05$) at 0-3, 0-6 & 6-9 month post-operative **(Table 1 and 2)** respectively whereas on Intergroup comparison for all the clinical parameters were statistically non-significant ($p>0.05$) **(Table 3).** Both Group I and Group II demonstrated significant changes in crestal bone loss over time ($p < 0.05$). At baseline, the mean ± standard deviation of crestal bone loss on the mesial and distal aspects for Group I and Group II were 0.4 ± 0.11 vs 0.2 ± 0.08 and 0.5 ± 0.11 vs 0.3 ± 0.09, respectively which on Intergroup comparison revealed statistically non-significant ($p > 0.05$) difference on either aspect using the independent t-test. At 9 months, Intragroup comparison reported statistically non -significant changes whereas the intergroup comparison on the mesial and distal aspect showed that the mean crestal bone loss in Group I (1.4 ± 0.07 and (1.3 ± 0.06)) was significantly higher than in Group II (0.7 ± 0.04 and 0.8 ± 0.04) respectively reported to be statistically significant ($p < 0.05$) using one way Anova and the independent t-test respectively (**Table 4, 5).**

Table 1: Intra- Group (GROUP I & GROUP II respectively) comparision of clinical parameters (PI, BOP, PPD, KTW) utilising one way ANOVA test (p value < 0.05 considered to be significant)

Parameter	Time Point	Conventional GROUP I (Mean ± SD)	Guided GROUP II(Mean ± SD)	Intergroup p-value	Significance
Plaque Index	Baseline	1.45±0.414	1.25±0.110	0.72	NS
	6 Months	1.30±0.507	1.00±0.120	0.09	NS
	9 Months	0.90±0.507	0.258	0.06	NS
Bleeding on Probing	Baseline	0.9 ± 0.458	0.8 ± 0.200	0.82	NS
	6 Months	0.8 ± 0.516	0.7 ± 0.040	0.76	NS
	9 Months	0.8 ± 0.507	0.7 ± 0.410	0.06	NS
Pocket Probing Depth	Baseline	4.20 ± 0.12	3.20 ± 0.10	0.22	NS
	6 Months	4.32 ± 0.13	3.35 ± 0.10	0.21	NS
	9 Months	4.48 ± 0.13	3.52 ± 0.08	0.09	NS
Keratinized Gingiva	Baseline	2.95 ± 0.21	2.96 ± 0.18	0.92	NS
	6 Months	2.93 ± 0.19	2.96 ± 0.18	0.69	NS
	9 Months	2.90 ± 0.21	2.92 ± 0.19	0.78	NS

Table 2: Intra- Group (GROUP I & GROUP II respectively) comparision of clinical parameters (PI, BOP, PPD, KTW) utilising Bonferroni Post-Hoc Pairwise test (p value < 0.05 considered to be significant)

Parameter	Comparison	Conventional Implant Group (Mean Difference, p value)	Guided Surgery Implant Group (Mean Difference, p value)	Interpretation
Plaque Index	Baseline vs 06 months	+0.150, 0.775	+0.250, 1.000	NS
	Baseline vs 09 months	+0.550, 0.081	+0.800, 0.682	NS

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	06 months vs 09 months	+0.400, 0.775	+0.550, 0.682	NS
Bleeding on Probing	Baseline vs 06 months	+0.300, 0.823	+0.300, 0.775	NS
	Baseline vs 09 months	+0.600, 0.216	+0.700, 0.823	NS
	06 months vs 09 months	+0.300, 1.000	+0.400, 0.216	NS
Pocket Probing Depth	Baseline vs 06 months	−0.2200, 0.000*	−0.1867, 0.000*	Significant
	Baseline vs 09 months	−0.3667, 0.000*	−0.3400, 0.000*	Significant
	06 months vs 09 months	−0.1467, 0.010*	−0.1533, 0.000*	Significant
Keratinized Gingiva	Baseline vs 06 months	+0.0200, 1.000	0.0000, 1.000	NS
	Baseline vs 09 months	+0.0533, 1.000	+0.0400, 1.000	NS
	06 months vs 09 months	+0.0333, 1.000	+0.0400, 1.000	NS

Table 3: Inter – Group comparison of clinical parameters (PI, BOP, PPD, KTW) utilising independent t-test (p value < 0.05 considered to be significant)

Parameter	Time Interval	Conventional Implant Group (Mean ± SD)	Guided Surgery Implant Group (Mean ± SD)	p-value	Interpretation
Plaque Index (Full Mouth)	Baseline	1.45 ± 0.414	1.25 ± 0.110	0.72	NS
	6 Months	1.30 ± 0.507	1.00 ± 0.120	0.09	NS
	9 Months	0.90 ± 0.507	0.45 ± 0.258	0.06	NS
Bleeding on Probing	Baseline	0.90 ± 0.458	0.80 ± 0.200	0.82	NS
	6 Months	0.80 ± 0.516	0.70 ± 0.040	0.76	NS
	9 Months	0.80 ± 0.507	0.70 ± 0.410	0.06	NS
Pocket Probing Depth	Baseline	4.20 ± 0.12	3.20 ± 0.10	0.22	NS
	6 Months	4.32 ± 0.13	3.35 ± 0.10	0.21	NS
	9 Months	4.48 ± 0.13	3.52 ± 0.08	0.09	NS
Keratinized Gingiva	Baseline	2.95 ± 0.21	2.96 ± 0.18	0.92	NS
	6 Months	2.93 ± 0.19	2.96 ± 0.18	0.69	NS
	9 Months	2.90 ± 0.21	2.92 ± 0.19	0.78	NS

Table 4: Intra- Group (GROUP I & GROUP II respectively) comparision of Radiographical parameters (Crestal bone loss) utilising one way ANOVA test (p value < 0.05 considered to be significant)

Parameter	Group	F value	p-value	Interpretation
Bone Loss (Baseline–09 Months)	Conventional Implant Group	0.082	0.776	NS
	Guided Surgery Implant Group	156.457	0.69	NS

Table 5: Inter – Group comparison of Radiographical parameters (Crestal bone loss) utilising independent t-test (p value < 0.05 considered to be significant)

Bone Loss						Independent t test
Time	**Group**	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**	**p-Value**
Baseline	Conventional Implant(GROUP I)	17	0.4	0.11	0.03	0.34(NS)
Bone Loss Mesial	Guided Surgery Implant(GROUP II)	17	0.2	0.08	0.02	
Baseline	Conventional Implant(GROUP I)	17	0.5	0.11	0.03	0.857(NS)
Bone Loss Distal	Guided Surgery Implant (GROUP II)	17	0.3	0.09	0.02	
9 Month	Conventional Implant(GROUP I)	17	1.4	0.07	0.02	0.04*
Bone Loss Mesial	Guided Surgery Implant(GROUP II)	17	0.7	0.04	0.01	Significant
9 Month	Conventional Implant(GROUP I)	17	1.3	0.06	0.02	0.03*
Bone Loss Distal	Guided Surgery Implant(GROUP II)	17	0.8	0.04	0.01	Significant

Discussion:

In the present study, significant improvement in plaque index (PI), bleeding on probing (BOP) and probing depth (PD) was observed in both implant placement techniques; however, no significant intergroup differences were noted. These findings suggested that patients in both groups maintained comparable optimal oral hygiene practices, contributing to favorable peri-implant soft tissue health. The findings of the present study are in accordance with those reported by Dhingra *et al.* **[16]**, Bernard *et al.* **[17]** and Vercruyssen *et al.* **[18]** who observed stable plaque accumulation and minimal bleeding on probing in patients with adequate oral hygiene maintenance. Bernard *et al.* **[17]** further stated that stable BOP values were more closely related to effective maintenance protocols than to the surgical technique employed. In contrast, Wang *et al.* **[19]** and Lops *et al.* **[20]** reported significant increases in BOP values in both guided and conventional implant groups, which were attributed to inadequate plaque control. In contrast to our study, are the differences in patient compliance and maintenance protocols. Nevertheless, current studies highlight the importance of meticulous oral hygiene and supportive periodontal care in maintaining peri-implant tissue health irrespective of the surgical approach used. In the present study, both the conventional and guided implant groups demonstrated statistically significant intra-group reductions in mean probing pocket depth (PPD) values over time, with no significant inter-group differences. These findings indicate comparable peri-implant soft tissue maturation and remodeling in both implants placement techniques. These results are consistent with the studies by Bernard *et al.* **[17]** and Naeini *et al.* **[21]**, who also reported no significant differences in probing depth between guided and conventional implant placement techniques during long-term follow-up. Moreover, the thickness of the keratinized gingival tissues showed no change throughout the study period in both groups, with no significant difference observed between the groups. Zhang *et al.* **[22]** however, clinically stable peri-implant soft tissue conditions were consistently observed in patients of both the groups on intergroup comparison in present study which is in consistency with the systematic review and meta-analysis conducted by Stefanini *et al.* **[23]** who reported that the presence of ≥2 mm of keratinized mucosa was associated with reduced marginal inflammation, lower plaque accumulation, decreased soft tissue recession and improved patient comfort. As in our study ≥2mm thickness of keratinized is one of the inclusion criteria. Although no statistically significant differences were found in probing depth or marginal bone loss in pooled cross-sectional analyses, prospective studies showed significantly lower bleeding on probing in implants surrounded by adequate keratinized mucosa. Sabri *et al.* **[24]** Reis *et al.* **[25]** Crestal bone loss (CBL) is an important parameter for assessing implant success, reflecting the biological response of peri-implant tissues to surgical trauma and functional loading. Janda and Mattheos **[26]** Vilela *et al.* **[27]** in the present study, significant changes in crestal bone levels were observed from baseline to nine months, with guided implant placement showing better early bone preservation compared to conventional freehand placement. These findings are consistent with Lagdive *et al.* **[28]** and Chandrasekhar *et al.* **[29]**, who attributed improved bone preservation in guided surgery to reduced surgical trauma and preservation of periosteal blood supply. Histological evidence also suggests that flapless guided approaches help maintain alveolar ridge integrity and support favorable bone healing. In contrast, Bernard *et al.* **[17]**, Vercruyssen *et al.* **[18]** and Lops *et al.* **[21]** reported no significant long-term differences in marginal bone loss between guided and conventional implant placement. The discrepancy may be related to differences in follow-up duration, implant systems and operator experience. Nevertheless, the bone loss observed in the present study remained within the success criteria proposed by Albrektsson *et al.* **[2]**. Moreover, other studies El Kholy *et al.* **[30]** Guentsch *et al.* **[31]** Kessler *et al.* **[32]** Lim *et al.* **[33]**. Tallarico *et al.* **[34]** and Ye *et al.* **[35]** stated that difference in data acquisition, including the generation of 3D surface scans, CBCT imaging and factors related to the surgical template, such as its type, dimensions, sleeve design, sleeve position and offset parameters, have been reported to influence implant placement accuracy. On the other hand Smitkarn *et al.* **[36]** addressed primary stability lower in implants placed using fully guided surgery than those using freehand surgery and this was found to be due to the fact that in guided surgery, the implant was inserted completely through the surgical guide, which allowed control of vertical depth only indirectly through the guide markings and the surgeon had very little tactile perception of implant stability other than the torque value. In contrast, in freehand surgery, the surgeon had a direct view of the bone level and vertical position of the implant and could determine the depth in relation to the tactile perception of the primary stability, Mahmoud *et al.* **[37]**. In relation to costs, Younes *et al.* **[38]** found that performing guided surgery increased the cost of treatment due to the need for a surgical guide, specific instruments and tools, as well as specific planning software.

Conclusion:

Guided implant placement showed more favourable outcomes in terms of crestal bone loss as compared with conventional implant placement. The improved accuracy, predictability and consistency associated with guided surgery may contribute to better peri-implant tissue stability and reduced variability in outcomes. It is advised that more randomized clinical trials are required to arrive at a definitive conclusion.

Limitations:

Including a short follow-up period, limited sample size, single-center study, patient-reported outcomes were not assessed.

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