ORIGINAL RESEARCH

Comparative Evaluation of Ridge Width for Implant Placement Using Ridge Mapping on the Diagnostic Cast, Cone-beam Computed Tomography, and Direct Surgical Measurements

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Abstract

Aim: This study was undertaken with an objective to find out the accuracy and reliability of presurgical ridge mapping (RM) on a diagnostic cast for linear measurements in the horizontal direction on cone-beam computed tomography (CBCT) and direct surgical assessment.

Materials and methods: In total, 25 patients based on inclusion and exclusion criteria were selected. An acrylic stent with two points marked at 3 mm and 6 mm from the soft tissue summit of the alveolar ridge was fabricated. Linear measurements at these points were estimated with three techniques viz. RM on the diagnostic cast, CBCT, and direct surgical *in situ* measurements after flap reflection.

Results: Considering direct *in situ* surgical measurements as the gold standard with an accuracy of 100%, the accuracy for CBCT and RM on the diagnostic cast was 95.5% and 87.4%, respectively, for the maxillary arch. Whereas the accuracy for CBCT and RM on the diagnostic cast was 88.6% and 92.2%, respectively, for mandibular arch.

Conclusion: The three approaches discussed are reliable for the assessment of ridge dimensions in the horizontal direction. Ridge mapping on the diagnostic cast is a simple, precise, noninvasive technique without any radiographic exposure.

Clinical significance: Ridge mapping on a diagnostic cast along with two-dimensional (2D) radiography can be used as a valuable chairside diagnostic tool in the treatment planning prior to dental implant placement in the cases of a regular alveolar ridge and even mucosal lining. This clinical technique provides zero radiation exposure and is also cost-effective.

Keywords: Alveolar ridge width, Cone-beam computed tomography, Dental implants, Ridge mapping.

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Introduction

Dental implants have emerged as a successful treatment modality for missing teeth in the past few decades. However, the placement of a dental implant requires careful presurgical treatment planning along with the precision of the operator in order to fulfill the esthetic and functional demands of the patient. Furthermore, the dental implant site is surrounded by various important anatomical landmarks like the maxillary sinus, inferior alveolar nerve, etc. which are likely to get damaged in the absence of accurate treatment planning leading to various complications.

Evaluation of the alveolar bone dimensions is an important prerequisite for the accurate placement of a dental implant. Presurgical evaluation of dental implant carried out with the conventional radiographic method like the panoramic radiograph or the periapical radiograph holds a major disadvantage that these radiographic techniques only provide a two-dimensional (2D) image of the site and may also overestimate or underestimate the real dimensions of the alveolar ridge.[1] In order to overcome the limitations of conventional radiographic methods, Wilson pioneered the RM technique in the year 1989. It was authenticated as a reliable method to evaluate bone availability for dental implant surgery by Traxler in 1992. In this, buccolingual measurements of the residual bone are made on a diagnostic cast using an acrylic stent or it can be measured directly after reflection of the mucoperiosteal flap using a bone caliper which is considered as the gold standard.[2–4]

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In earlier years, indirect RM or direct surgical measurements were the preferred methods for the estimation of the ridge dimensions prior to implant placement. But with the advent of CBCT, these two methods are losing their popularity. Cone-beam computed tomography offers the advantage of computing measurements of buccolingual proximity to the adjoining anatomical structures in an interactive display model along with densitometric analysis readily without flap reflection and well before scheduling the implant surgery. Although CBCT is the preferred method for the assessment of the alveolar bone dimensions, it, however, has some limitations like the access to the facility in remote areas, high cost, and radiation exposure of about 200 mGy (20 rad).[5] It has been reported that artifacts caused by metal objects may sometimes lead to overestimation/underestimation of the ridge dimensions.[2,6,7]

The width of attached gingiva and gingival phenotype are crucial factors for long-term success of implants which are often overlooked. Thin gingival phenotype is a predisposing factor for fenestration and dehiscence whereas inadequate width of attached gingiva creates a hindrance in the maintenance of proper oral hygiene which could result in plaque accumulation followed by peri-implant diseases. In both scenarios, the possibility of implant failure is very high.[8] So indirect RM offers the additional advantage of estimating the gingival thickness along with the measurement of the buccolingual dimensions of the alveolar ridge.[3]

To the best of our knowledge, very limited literature is available where three different diagnostic modalities have been compared and correlated for the evaluation of available alveolar ridge width prior to dental implant placement.

Direct surgical measurements of the ridge after reflection gives a precise estimate of the available width of the alveolar ridge. It is, therefore, considered a gold standard. The tenet of this study was to estimate the available buccolingual dimensions of the alveolar ridge by RM on the diagnostic cast, CBCT, and to correlate direct surgical measurements.

Materials and Methods

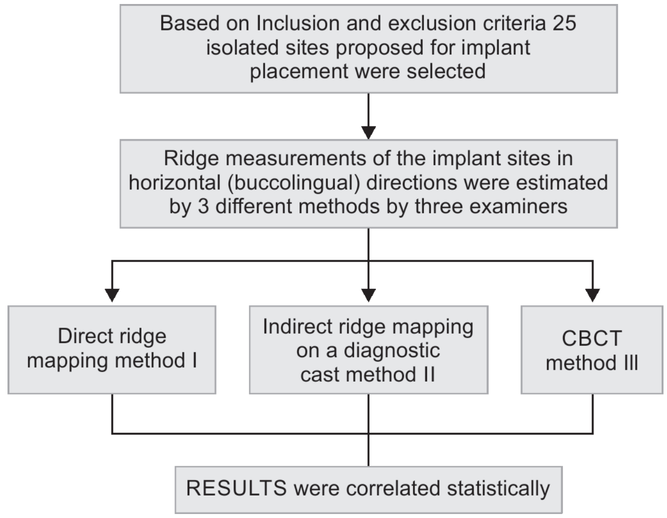
After obtaining clearance from the Institutional Committee (IEC No: ITSDCGN/2018/001), a signed informed consent from each patient data was collected from the Out Patient Department (OPD) of the Department of Periodontics at ITS Dental College and Research Centre, Greater Noida.

Based on a pilot study having 4 maxillary and 4 mandibular sites, the results of which were not included in the present study, the following sample of 9 maxillary and 16 mandibular sites was chosen by a certified statistician. Based on the inclusion and exclusion criteria, 25 patients in the age range of 25–50 years proposed for dental implant placement were enrolled in the study for a period of 12 months from January 2019 to January 2020.

The inclusion criteria were the patients with: Systemic health and presence of a partially edentulous ridge, presence of at least one periodontally healthy and stable tooth adjacent to the edentulous area to serve as an abutment for guidance stents, a healing period ≥6 months after extraction of the tooth in the area of implant placement, and good oral hygiene. The patients with smoking habits/tobacco use, immunocompromised state, those on bisphosphonate therapy, radiation therapy, hormone replacement therapy, having underlying systemic disease/conditions like osteoporosis, post-menopausal women, suffering from Periodontitis Stage III and IV (AAP, 2017), dentofacial trauma, and having any contraindication to implant placement were excluded from the study.

The alveolar ridge measurements of each site were taken by three different methods at Point 1 (3 mm from the deepest point of the crest of a ridge) and Point 2 (6 mm from the deepest point of the crest of a ridge) as described below (Flowchart 1).

Flowchart 1: Brief study outline



Method I: Measurements Based on RidgeMapping Procedure on Diagnostic Cast

Diagnostic casts were prepared from alginate impressions followed by the construction of a clear acrylic stent on the edentulous region. According to the protocol adopted by Torabi et al., two pairs of points were marked on the diagnostic cast at the buccal and lingual/palatal aspect of the site indicated for implant placement. These points were marked at 3 mm (Point 1) and 6 mm (Point 2) from the soft tissue summit of the alveolar ridge on the diagnostic cast. These markings were then transferred from the study cast to the acrylic stent by drilling holes of 1 mm diameter to serve as guidance stents.[4]

Fig. 1: Fabrication of the acrylic guidance stent

The study cast was sectioned along with the markings and then traced on a graph paper which served as a pre-calibrated ruler (1 mm^2/box) to obtain the outline of the ridge.

The acrylic stent with markings was transferred to the patient's mouth after disinfection. A #25 endodontic file with a rubber stopper was used to perform trans-gingival probing at Point 1 and Point 2 on both buccal and lingual/palatal aspects by three independent periodontists. These recordings were then transferred to the graph paper already having ridge tracing obtained from the diagnostic cast. The exact buccolingual width of the alveolar ridge at the two points mentioned as X (Point 1) and Y (Point 2) on the graph paper was obtained by subtracting the thickness of the gingiva measured by trans-gingival probing from the ridge tracing drawn from the diagnostic cast (Fig. 1).

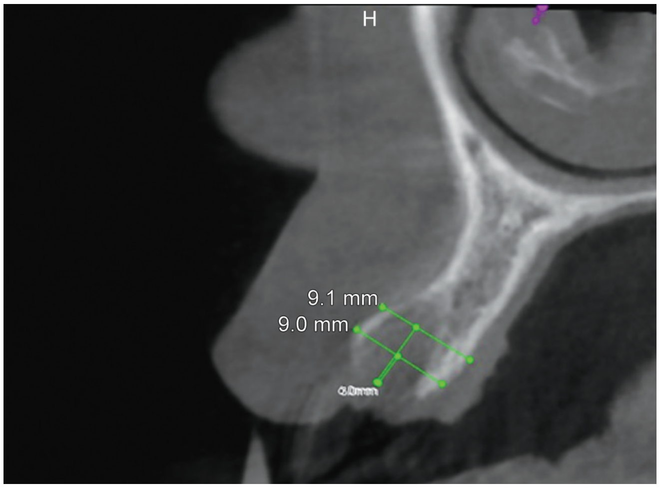


Fig. 2: CBCT evaluation of the alveolar ridge dimensions at Point 1 and Point 2

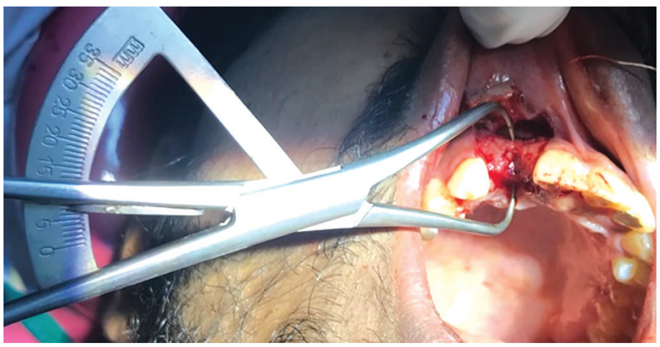
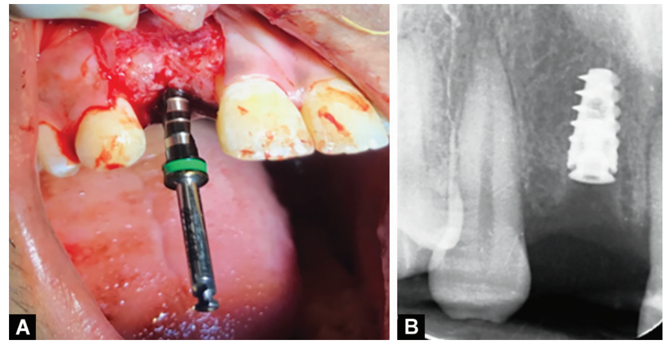


Fig. 3: Ridge mapping via direct surgical measurements



Figs 4A and B: (A) Osteotomy at the implant site; (B) Implant placement

Table 1: Comparison for Methods I, II, and III in maxilla and mandible

Method	*Point*	*N*	*Mean ± SD*	*p value*
Maxilla				
I	1	9	5.56 ± 1.01	0.609 (NS)
	2	9	6.30 ± 1.20	
II	1	9	5.33 ± 1.17	0.40 (NS)
	2	9	6.64 ± 0.90	
III	1	9	6.00 ± 0.87	0.186 (NS)
	2	9	7.06 ± 1.49	
Mandible				
I	1	16	5.16 ± 0.94	0.315 (NS)
	2	16	6.63 ± 1.16	
II	1	16	5.63 ± 1.103	0.381 (NS)
	2	16	6.63 ± 0.90	
III	1	16	5.97± 0.82	0.041 (NS)
	2	16	7.09 ± 1.31	

NS, not significant

Method II: Measurements Based on CT Scan Procedure

Cone-beam computed tomography scan was performed for all the subjects with the CT machine Carestream C S 9300 model (Rochester, New York, USA) with a minimum field of view (FOV) of 5 × 5 set at 90 kVp, 4 mA, 8 seconds. A clear image was selected to make measurements at both Point 1 and Point 2 from the reference point (Fig. 2).

Method III: Measurements Based on Direct Surgical Exposure

Direct measurement of the width of the alveolar ridge was done after full-thickness flap reflection under local anesthesia using bone calipers (GDC implantology bone caliper BC 35 and GDC vernier calliper) at Point 1 and Point 2 from the reference point as marked on the previously described acrylic stent just prior to implant placement (Fig. 3).

After the measurements of the alveolar ridge by all the three modalities as a part of presurgical treatment planning, the patients underwent implant placement at the designated sites (Fig. 4).

Statistical Analysis

The results obtained were subjected to statistical analysis using: Kolmogorov–Smirnov to test the normality of the data, Shapiro–Wilk test, and ANOVA test to analyze the various parameters recorded in the study by all the three methods. *Post hoc* tests and Unpaired *t*-test were used for intergroup comparisons at both Point 1 and Point 2 by all the three methods. Pearson's correlation (R^2) analysis was used to analyze the relationship between the data obtained from CBCT and diagnostic cast measurements and to correlate it with measurements made on direct surgical exposure which is the gold standard measurement. The mean difference with the standard error was also calculated, and the data were then subjected to statistical analysis. *P* value ≤0.05 was considered statistically significant.

Results

Overall, 25 sites were proposed for implant placement in both maxilla and mandible. The mean values of all the groups in both the arches did not show any statistically significant difference (Table 1).

Comparison between Method II and Method III

On intergroup comparison between Method II (CBCT) and Method III (Direct Surgical Exposure) in the maxilla, the mean difference in the alveolar measurements at Point 1 was 0.67 ± 0.48 mm whereas at Point 2 was 0.41 ± 0.58 mm. But the results were not statistically significant. Similarly, no statistically significant difference was obtained at Point 1 and Point 2 in the mandibular arch (Tables 2 and 3 and Figs 5 and 6).

Table 2: Mean difference of values in mandibular arch for Methods I, II, and III at Point 1 and Point 2

		Ridge mapping (in mm)	*CBCT (in mm)*	*Direct surgical exposure (in mm)*	*Mean diff. ± SE b/w ridge mapping and direct surgical measurement (in mm)*	*p value*	*Mean diff. ± SE b/w CBCT and direct surgical measurement (in mm)*	*p value*
At 3 mm	Mean ± SD	5.22 ± 1.12	5.71 ± 1.37	5.97 ± 0.83	0.75 ± 0.40	0.16	0.26 ± 0.40	0.80
At 6 mm	Mean ± SD	6.69 ± 1.20	6.69 ± 1.10	7.09 ± 1.32	0.41 ± 0.43	0.61	0.41 ± 0.43	0.61

CBCT, cone-beam computed tomography; SE, standard error; SD, standard deviation

Table 3: Mean difference of values in maxilla for Methods I, II, and III

		Ridge mapping (in mm)	*CBCT (in mm)*	*Direct surgical exposure (in mm)*	*Mean diff. ± SE b/w ridge mapping and direct surgical measurement (in mm)*	*p value*	*Mean diff. ± SE b/w CBCT and direct surgical measurement (in mm)*	*p value*
At 3 mm	Mean ± SD	5.56 ± 1.01	5.33 ± 1.17	6.00 ± 0.86	0.44 ± 0.48	0.63	0.67 ± 0.48	0.37
At 6 mm	Mean ± SD	6.28 ± 1.20	6.64 ± 0.90	7.06 ± 1.49	0.78 ± 0.58	0.38	0.41 ± 0.58	0.76

CBCT, cone-beam computed tomography; SE, standard error; SD, standard deviation

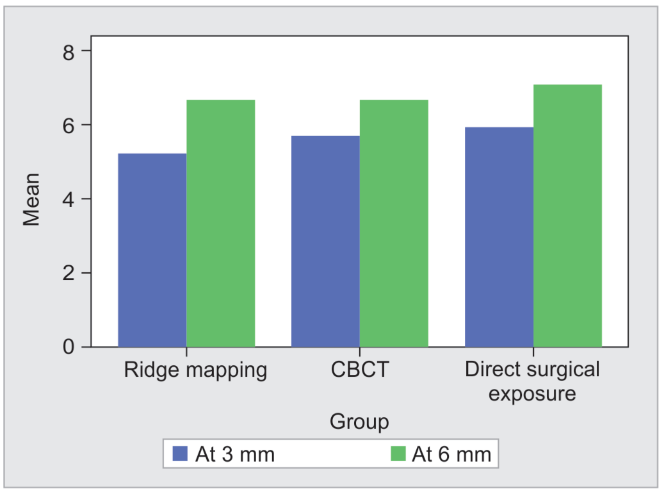


Fig. 5: Mean difference of values in mandibular arch for Methods I, II, and III at Point 1 and Point 2

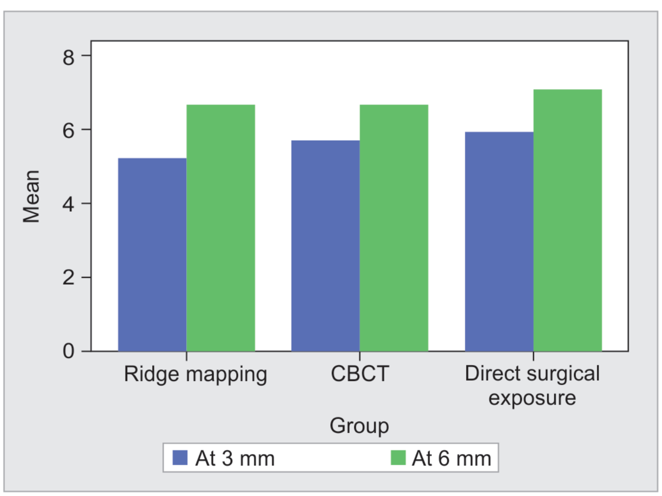


Fig. 6: Mean difference of values in maxilla for Methods I, II and III at Point 1 and Point 2

Comparison between Method I and Method III

Intergroup comparison between Method I (RM on diagnostic cast) and Method III (Direct Surgical Exposure) in the mandible revealed a mean difference of 0.75 ± 0.40 mm at Point 1 and 0.41 ± 0.43 at Point 2. These results were not statistically significant. Similarly, the mean difference obtained for the maxillary arch at both Point 1 and Point 2 was also not statistically significant (Tables 2 and 3 and Figs 5 and 6).

Correlation between Methods I, II, and III

The correlation coefficient (R^2) at 3 mm, all the three methodologies revealed a positive correlation, out of which, direct surgical exposure and RM revealed a weak correlation, while CBCT revealed a strong correlation (R^2~0.70). However, at 6 mm, all the three methodologies revealed a weak positive correlation indicating the same efficacy of the techniques (Figs 7 and 8).

Comparative Evaluation of the Accuracy of CBCT and Indirect RM to the Direct Surgical Measurements at Point 1

The overall results did not reveal any statistically significant difference when Method I (RM on diagnostic cast) and Method II (CBCT) were compared to Method III (Direct Surgical Exposure). Considering the direct surgical exposure as 100% accurate, it was revealed that the results obtained for the maxillary arch at Point 1 percentage accuracy of CBCT was 95.5% and for RM on the diagnostic cast was 87.4% whereas at Point 2 the accuracy with both CBCT and RM was 94.3%.

Comparative Evaluation of Accuracy of CBCT and Indirect RM to the Direct Surgical Measurements at Point 2

In the mandibular arch at Point 1, the accuracy was 88.6% with CBCT and 92.6% for RM whereas at Point 2 it was found to be 94.3% and 88.8% for CBCT and RM, respectively.

Discussion

Various advancements have been introduced for the presurgical treatment planning of implants starting from conventional radiography like orthopantomogram, periapical radiography to CBCT till date.

Evaluation of the alveolar bone dimensions is an important prerequisite for the accurate placement of a dental implant. Clinically it can be done by the RM method wherein a specialized caliper is used under local anesthesia after the reflection of the mucoperiosteal flap to measure the available buccolingual width of

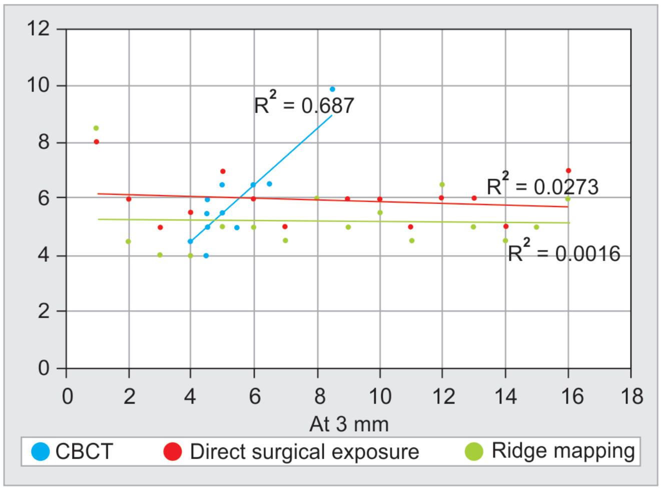


Fig. 7: Pearson's correlation coefficient (R^2) for Methods I,II and III at Point 1

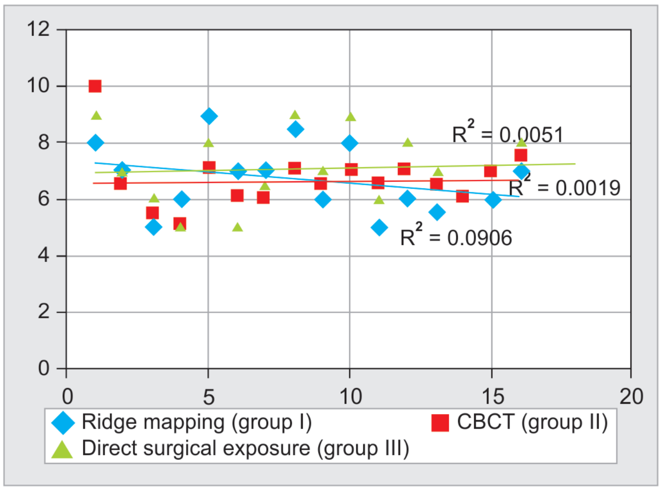


Fig. 8: Pearson's correlation coefficient (R^2) for Methods I, II and II at Point 2 at 6 mm

alveolar bone. This method gives the most accurate measurements of the alveolar ridge width, and is, therefore, considered as the gold standard.

The present study was conducted to analyze the accuracy of CBCT and RM to *in situ* surgical evaluation of available bone dimensions prior to implant placement.

Bone quality and quantity are an essential considerations for implant success. Prior to implant placement, it is imperative for the clinician to assess bone height, width, and the long axis of the alveolar bone and also to identify and locate several anatomical landmarks. The proposed research was focused on assessing the capabilities and limitations of RM as a more viable and cost-effective alternative to CBCT for characterization of mandibular and maxillary bone width availability.

Ridge mapping (RM) is an important, however, often overlooked method for the assessment of patients requiring implant therapy. It can provide information about bone width and contour at relative ease. Wilson first proposed this technique in 1989, and Traxler in 1992 verified it is a reliable method for evaluation of the available bone dimensions for dental implant placement.[9,10] Bone evaluation limited to the use of low cost 2D radiography such as periapical and panoramic radiographs may be insufficient, therefore, the third dimension, i.e., the buccolingual width, can be assessed with the help of methods like RM on the diagnostic cast. The measurement of ridge width on the diagnostic cast can be accomplished by using RM calipers. This technique has various advantages like it is relatively simple and can be carried out at chairside, cost-effective, and no radiation exposure to the patient.

This study provides us with the data for evaluation and analysis of an alternative to the expensive radiographic technique, which is simple and may be carried out as a chairside diagnostic modality in cases where the bone and soft tissue profiles are favorable on initial clinical examination of visual and palpation methods.

In our study, two point measurements (3 mm and 6 mm from the alveolar crest) were taken to measure the alveolar ridge width by direct surgical exposure, RM on the diagnostic cast, and also by CBCT. The reason behind the two point measurement was to avoid the discrepancies that could be caused by the presence of bony defects at different bone heights which could be detrimental for implant stability. A study by Zhang et al. analyzed the distribution of various bone defects in relation to different root types and sites. They found a higher prevalence of buccal undercuts in the maxillary anterior teeth region and on the lingual aspect of the mandible near the alveolar crest in healthy individuals. However, the occurrence of undercuts was less in the patients suffering from severe bone loss caused by periodontitis.[4] This finding could be attributed to the loss of the buccal cortical plate due to the presence of periodontal disease. These undercuts could lead to the perforation of the cortical plate and other complications during immediate dental implant placement. Zekry et al. concluded that most of the fenestrations are found at a depth of 5 mm from the alveolar crest. But these fenestrations are rarely found in the diseased bone as the persisting inflammatory activity already leads to the alveolar bone resorption.[9]

In a total of 25 proposed sites, the mean difference between CBCT and RM on the diagnostic cast when compared to direct surgical measurement was not significant in both maxillary and mandibular arch at Point 1 (3 mm from the alveolar crest) and at Point 2 (6 mm from the alveolar crest). Buccolingual measurements of the alveolar ridge on surgical exposure are considered as the gold standard because it provides the exact measurements of the width of the alveolar ridge available for implant placement to the clinician. It gives an insight to any type of bone deformity present on the site of placement, thereby giving an opportunity for a definitive treatment plan.[10] The mean width measurement was lesser with RM on the diagnostic cast, followed by CBCT as compared to direct surgical measurements though the difference was not statistically significant. The underestimation of the results obtained by direct cast measurements can be attributed to the application of excessive pressure during penetration of the calipers through the alveolar mucosa while taking measurements with the stent may lead to bending of the tips of the caliper, thereby providing underestimated values of the ridge width.[10] Secondly, there could have been the presence of any bone deformity on the implant site like a deep undercut again leading to the recording of erroneous values. Thirdly, the most suggestive explanation is the dimensional changes that may have occurred in the diagnostic cast made of type V die stone on an irreversible hydrocolloid impression material. Also in the literature, it is documented that the storage time and environmental temperature may influence the dimensional stability of the alginate impression material. It has also been suggested that alginate impression material should be poured within 12 minutes at room temperature in 100% humidity or maximum within 45 minutes if the impression is stored at 4˚C at 100% humidity failing in which there are possibilities of shrinkage of the impression, leading to dimensional inaccuracy in the cast poured from it.[11]

Similarly, underestimation of dimensions in buccolingual extent by CBCT can be possible because of difficulty in defining the cortical borders of the alveolar bone on the CBCT image or the presence of an artifact leading to an unclear image.[1,6]

Conflicting evidence is also available in the literature wherein the overestimation of dimensions is reported because of incomplete penetration of the thick alveolar mucosa or keratinized tissue by the tips of the calipers.[11]

Few authors have suggested that measurement using a caliper may be used as a reliable method for assessing the alveolar ridge width prior to implant placement as compared to CBCT.[5]

Chugh et al. concluded that the RM technique may be used along with 2D imaging techniques like panoramic and intraoral radiographs in cases where the pattern of the alveolar ridge and the thickness of mucosa appears regular. They further suggested that CBCT may be prescribed in situations where there are anatomical discrepancies in the alveolar ridge, vestibular depth is inadequate, and RM is not feasible.[12] A systematic review by Fokas et al. showed that CBCT measurements can be erroneous, therefore, safety margin of 2 mm should be considered when using this technique. However, CBCT can be used adjuvantly as a diagnostic tool, alongside direct measurements and RM.[13]

In comparison of the three techniques and considering the accuracy of direct surgical measurements as 100%, the accuracy for CBCT was more than 94% and with RM it was almost 89%, suggestive of a positive correlation with direct surgical measurement. In a recent study, it was found that the indirect method of RM can be equally considered for the assessment of available alveolar ridge width in the absence of bone calipers and CBCT for the dental implant placement.[14]

The percentage of accuracy while considering measurements of direct surgical exposure as accurate, it was observed in the study that no significant difference was present in both the techniques. Rather the result obtained in the lower arch showed more sensitivity to RM as compared to CBCT at Point 1.

According to the results obtained from our study, there is no significant difference in CBCT, RM, and direct surgical exposure measurements in terms of horizontal measurements. The possible explanation for the similarity in the values obtained by all the three methods may be attributed to the fact that the three of these techniques are accepted modalities for ridge estimation, and enough evidence is available for their validation.[15,16] Thus our study further substantiates the fact that no statistically significant difference is seen among these three approaches and is suggestive that Direct Ridge Mapping and Indirect Ridge Mapping with conventional radiographs can be used as a substitute for CBCT in estimating the buccolingual measurements of the alveolar ridge in areas with limited facilities. Even though the patient may be able to afford CBCT but this method would avoid the unnecessary radiation exposure of the patient. But the usage of CBCT is indicated when there is ridge resorption, maxillary anterior ridge concavities, high lingual frenal attachment areas, and vestibular depth is less and RM is not feasible. But considering the limitations of CBCT like the cost, the requirement of specialized armamentarium, and trained personnel, various artifacts can be caused by metal objects and also may sometimes overestimate/underestimate ridge dimensions. Another disadvantage is the high radiation exposure of the head and neck region of the patient. Thereby, the research emphasizes the utility and applicability of RM technique along with panoramic and intraoral radiographs is adequate in cases, where dimensions of the alveolar ridge and the thickness of the mucosal lining appear to be regular.

Consequently, the gain of this information will benefit both the patient and the dental practitioner. Though the current advance of CBCT technology is promising albeit in a low cost setting, it may not be feasible, therefore, this fact has allowed for and inspired this search for a cost-effective alternative to accurately assess bone width dimensions and to finally corroborate their concordance with *in situ* surgical evaluation and thus minimizing chances of implant failure.

Ridge mapping on a diagnostic cast along with 2D radiography can be used as a valuable chairside diagnostic tool in the treatment planning of dental implant placement in the cases of a regular alveolar ridge and even mucosal lining. Gingival thickness less than 3 mm would fail to form a stable epithelial connective tissue attachment.[17] So this study highlights the importance of the peri-implant gingival thickness which plays a prime role in the long-term success of the implant. This clinical technique provides a zero radiation exposure and is also cost effective.

Future studies with a larger sample size focusing on the anterior and posterior segments of both the arches should be taken into consideration. The comparisons at various locations should be focused upon due to variation in the surgical anatomy of arches to yield clinically and statistically significant results. Also, the usage of a radio- opaque material (e.g., Gutta Percha points) while taking the CBCT would give a better interpretation of the measurements of the ridge dimensions.

Conclusion

The result of present study ridge estimation with CBCT and diagnostic cast are very similar to the measurement carried out with *in situ* surgical site measurements by direct technique without any statistical significance difference. Therefore, it can be concluded that RM can also prove to be a valuable tool in the pre-treatment planning in the areas where the topography of the alveolar ridge appears regular.

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