ORIGINAL RESEARCH

Evaluation of Different Preosteotomy Determinants as Affecting the Success of Implant Therapy: A "CBCT"-based Clinical Study

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Abstract

Aim: The success of implant therapy is of greatest concern for clinicians because a minor negligence can lead to ultimate failure of treatment. However, comprehensive and precise treatment planning can ensure high success rate of implant therapy. Cone-beam computed tomography (CBCT) is an innovation that allows clinicians to explore all related factors in details. This study was conducted to evaluate different preosteotomy determinants as affecting the success of implant therapy in the maxillary anterior region using CBCT.

Materials and methods: This study was conducted on 98 partially or complete denture patients willing for artificial replacement of their missing teeth by implant or implant over-denture. Demographic details of participating patients were collected. Furthermore, comprehensive local examination was also done to finalize the site of placement of implant. Cone-beam computed tomography was attempted in all patients for determining accurate implant location, status of bone, and other interrelated determinants of implant success. Cone-beam computed tomography was also prescribed for patients so as to have presurgical idea of implant dimensions as shown in virtual placement of implant. To rule out any interobserver bias, the interpretations of CBCT images were completed by two independent experienced observers.

Results: In the 98 studied patients, 61 were males and 37 were females. The study was restricted to the maxillary anterior region only. The studied preosteotomy determinants were available bone height and width in the edentulous region from ridge crest up to the maxillary sinus floor or the nasal fossa floor. A total of 107 implants were placed virtually (on CBCT) in the maxillary anterior region and compared quantitatively in postosteotomy phases. Implant placement sites were the maxillary central incisor region (39), the lateral incisor region (31), and canine (37). Authors also noticed that the relative length and width of virtual implant remained unaffected in 97% of the cases.

Conclusion: Cone-beam computed tomography showed accurate status of various presurgical determinants like trabeculae, peri-ridiculer pathology, and amount of horizontal and vertical bone losses. Hence, it was further concluded that all these presurgical determinants greatly affect the final success rate of implant therapy. It is therefore deemed necessary to judiciously consider and clinically manage such factors before attempting implant in the maxillary anterior region.

Clinical significance: Presurgical evaluation of factors associated with implant dimensions significantly assists clinicians in deciding the finest treatment option. All additional information provided by CBCT genuinely led to a change in the treatment plan that provides enhanced clinical outcome with lesser postoperative complications.

Keywords: Cone-beam computed tomography, Dental implant, Implant planning, Maxillary sinus, Prosthodontics.

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Introduction

In this third millennium, three-dimensional (3D) imaging technique "cone-beam computed tomography" (CBCT) has instituted many landmarks in the field of dental diagnostic imaging. At present, CBCT is the most commonly advised dental imaging tool for various head and neck diagnostic and rehabilitative procedures.[1,2] Prosthodontists usually recommend CBCT for pretreatment planning while restoring missing teeth by dental implants. Other imperative usages include detection of oral and maxillofacial pathologies that are otherwise untraceable and unidentifiable by routine two-dimensional (2D) radiography. Because it is a very innovative method of radiologic analysis, general dental practitioners are by and large unaware of its indication, contraindications, advantages, disadvantages, usage precautions, handling tactics, technical considerations, and prescription methods. Cone-beam computed tomography was first ever introduced in 1996 in Western countries for identifying maxillofacial pathologies.[3–7] In developing countries like India, it has been newly introduced. As we all are aware that the overall success of any implant treatment is of greatest concern for practitioners. It required strict clinical protocols to be followed, failing which the treatment would be a "failure" and the concerned implant would be indicated for extraction regrettably. Though, complete planning of all associated factors can ensure

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the high success rate of implant.[8–10] Cone-beam computed tomography is one such innovation that allows clinicians to explore all such determinants in details leading to a lower failure rate. These factors majorly include dimensional and associated bony analysis of implant with related local, anatomic, and pathologic factors.[11–13] Hence, considering all these intermingling facts, the authors planned this study to evaluate different preosteotomy determinants as affecting the success of implant therapy using CBCT. Special emphasis was also given to qualitative assessment of anterior maxilla as depicted by the CBCT analysis.

Materials and Methods

This study was completed in the Department of Prosthodontics of the institute. The study was performed on 98 partially or complete denture subjects who reported to OPD for artificial replacement of their missing teeth by single or multiple implant or implant overdenture. Personal and contact details of patients were recorded. Comprehensive local examination was also attempted to finalize the provisional site of placement of implant. All participating patients were informed in detail about the study. Informed consents were obtained from all participating patients. All patients were subjected to CBCT for determining accurate location, status of bone, and other interrelated determinants of implant success like proposed dimension of implant, status of adjacent bone loss, proposed angulation of osteotomy, etc. Authors have also planned to obtain presurgical idea of bony dimensions of the proposed implant site as shown by CBCT in all three planes (coronal plane, sagittal plane, and axial plane). CBCT images were obtained using a CS9300 scanner with field of view (FOV) 11 × 8 cm. Three-dimensional cross-sectional images were produced at a cross-sectional interval of 1.0 mm. The resolution was adjusted at 0.18 × 0.18 × 0.18 mm. The NNT software with slice thickness of 0.1 mm was used in this study. All possible linear horizontal and vertical measurements were adjusted in the implant program or software tools for measurements. Qualitative and quantitative measurements were recorded for available bone height and bone width in the edentulous region from ridge crest (or subcrustal area) till the maxillary sinus floor. All these measurements were completed on the CBCT scan in all three planes such as the coronal plane, the sagittal plane, and the axial plane (Figs 1 and 2). To omit any interobserver bias, the radiographic interpretations of CBCT images were attempted by two different and independent experienced observers. Results were subjected to the statistical analysis. A p value less than 0.05 was considered significant.

Results

All recorded data were sent for statistical analysis using statistical software Statistical Package for the Social Sciences version 21 (IBM Inc., Armonk, New York, USA). The finalized data were subjected to suitable statistical tests to obtain p values, standard deviation, Chi-square test, standard error, and 95% CI. Response evaluation and analysis showed some very crucial inferences. These assumptions were shown to have clinical explicabilities as well. In all 98 studied subjects, 61 were males and 37 were females. The authors studied some very prominent preosteotomy determinants like available bone height and width in the edentulous region from ridge crest up to the maxillary sinus floor or the nasal fosse floor. A total of 107 implants were placed virtually on CBCT with fixed length and width. These implant dimensions were compared quantitatively in postosteotomy phases of patients. Implant placement sites were the maxillary central incisor region (39), the lateral incisor region (31) and canine (37) (Fig. 3). During data evaluation, authors noticed that the relative length and width of virtual implant remained unaffected in 97% of the cases. Table 1 showed variation of virtual implant dimension vs actual implant placed at osteotomy stages. The p values were reported to be nonsignificant for all three categories. In group I, the estimated CBCT dimensions were almost equal to the actual dimensions placed at osteotomy sites. The actual implant dimensions were finalized at the time of osteotomy solely based on CBCT suggestions, clinical inferences, subjective responses of patients, panoramic radiographs, clinical expertise of operator, and manufacturer's guidelines. In this group, the measured standard deviation and standard error were 0.898 and 0.039, respectively, with a Pearson Chi-square value of 2.745. In group II, the estimated CBCT dimensions were not equal to the actual dimensions placed at osteotomy sites. In this group, the measured standard deviation and standard error were 0.956 and 0.056, respectively, with a Pearson Chi-square value of 2.688. In group III, the estimated CBCT dimensions were unable to compare with the actual dimensions placed at osteotomy sites. This could be explained on the basis of miscellaneous factors like patient uncooperation, technical

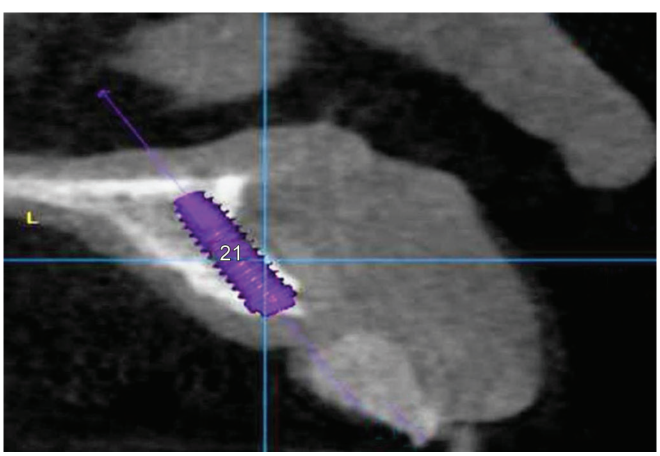

Fig. 1: Preosteotomy virtual positioning of implant as per bone availability and trabeculae pattern in the right maxillary central incisor region (width of <3.5 mm would be suitable as the buccal plate is quite thin to accommodate)

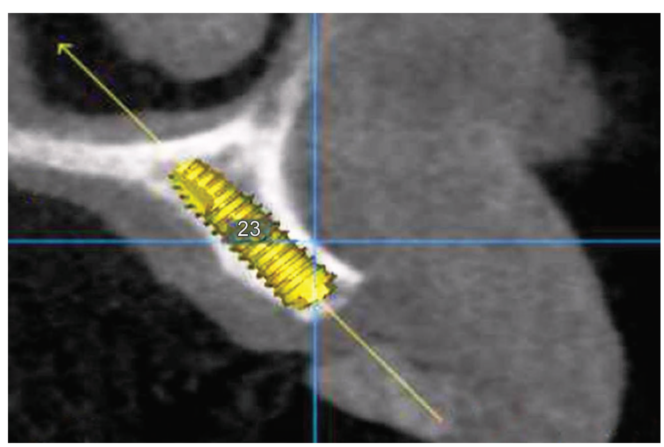

Fig. 2: Preosteotomy virtual positioning of implant as per bone availability and trabeculae pattern in the right maxillary canine region (width and length of 3.5 mm × 11.5 mm would be suitable to accommodate nearby lining of maxillary sinus and the Schneiderian membrane)

Table 1: Variation of virtual implant dimension vs actual implant placed at osteotomy stages ($n = 107$)

Group	*Length and diameter of implant*	*Number*	*Std. deviation*	*Std. error*	*95% CI*	*Pearson Chi-square value*	*Level of significance (p value)*
Group I	CBCT dim. = actual osteotomy dim.	104 (97%)	0.898	0.039	1.96	2.745	0.080
Group II	CBCT dim. ≠ actual osteotomy dim.	2 (2%)	0.956	0.056	1.96	2.744	0.060
Group III	Unrelatable	1 (1%)	0.395	0.039	1.96	2.876	0.100

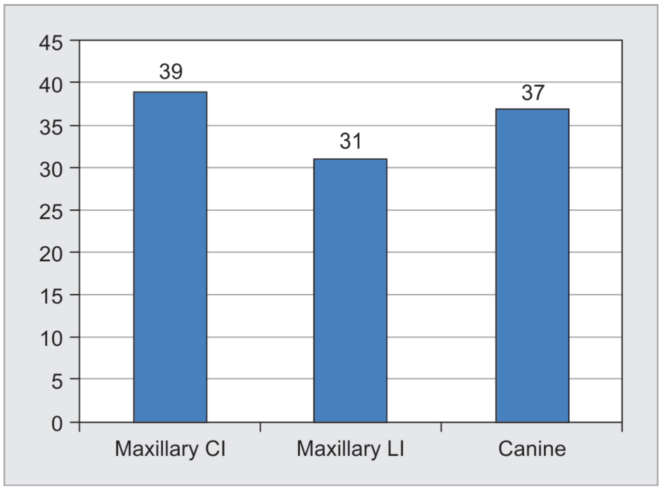

Fig. 3: Position of implant

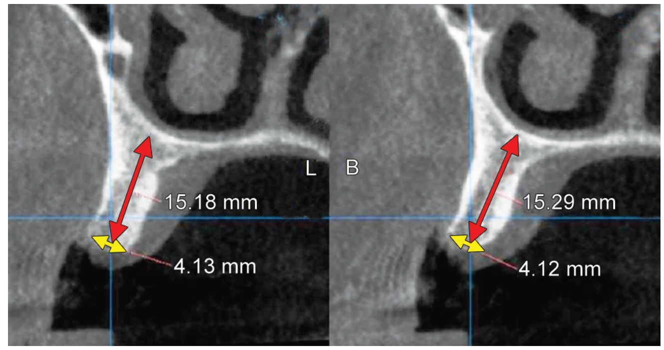

Fig. 4: Presurgical bony analysis (CBCT) of the maxillary right canine region showing moderate to advance residual ridge resorption with intact overlying sinus floor (left) and medium course randomly oriented trabeculae and intact mildly thickened cortices (right). In few regions, mild to moderate trabeculae sclerosis or condensation is also noted in the peri-radicular region of canines. Additionally, moderate peripheral mucosal thickening is noted in sections through right maxillary sinus

issues, etc. In this group, the measured standard deviation and standard error were 0.395 and 0.039, respectively, with a Pearson Chi-square value of 2.876. Detailed qualitative assessment of anterior maxilla has showed variety of bony details. Most of the maxillary central and lateral incisor region showed course to condensed randomly oriented trabeculae and intact mildly thickened cortices (such patterns are usually suggestive of moderate or patchy low D3-type bone). Comprehensive assessment of the canine region showed moderate to advance residual ridge resorption with an intact overlying sinus floor. In some cases, mild to moderate trabeculae sclerosis or condensation was also noted in the peri-radicular region of canines. Few of the cases also illustrated focal ovoid to irregularly shaped cement-osseous density in root areas of lateral incisors (Figs 4 and 5). In addition, moderate peripheral mucosal thickening was also found in sections through left maxillary sinus. For virtual implant placement, provisional dimensional simulation was attempted as per available bone height-width. Minimum 3 mm of interimplant clearance was ensured. Clearance of 1.0 mm from buccal lingual cortices and 1.5 mm from adjacent teeth was also maintained. However, as per user's instruction, CBCT virtual implant simulation is based only on detected available bone quality and quantity. Hence we must always correlate with the clinical data to formulate a definitive treatment plan. Three-dimensional reconstructions for two or more implant placement provide (1) 3D estimation of implants and associated superstructures, (2) 3D measurements of the extension of the maxillary sinus, (3) 3D measurements of the grafted bony volume (if required), and (4) 3D reestimation of the prosthodontic phase after osteotomy and implant placement (Fig. 6). Furthermore, it also assists clinician in preosteotomy preparation of (1) different implant dimensions, (2) implant angulations, and (3) interimplant distances that could

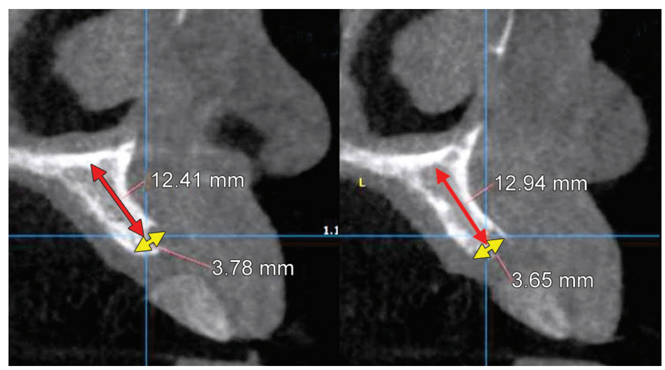

Fig. 5: Presurgical bony analysis (CBCT) of the maxillary right central incisor region showing small course to condensed randomly oriented trabeculae (left) and intact mildly thickened cortices (right). Such patterns are typically suggestive of moderate or patchy low D3-type bone

provide optimal treatment outcomes with minimum complications (Fig. 7). Three-dimensional reconstructions also allows the operator to visualize the bony morphology, nerve patterns, joint structures, position, and extent of maxillary sinuses much more comprehensively than conventional 2D radiographs. The newer-generation CBCT scans also provide axial views at right angle to the long axis of patient by rotating a radiation source emitting fan-shaped beam 360° around.

Discussion

Dental radiography is considered as one of the most frequently used diagnostic tools in daily dental practice. Dental radiography

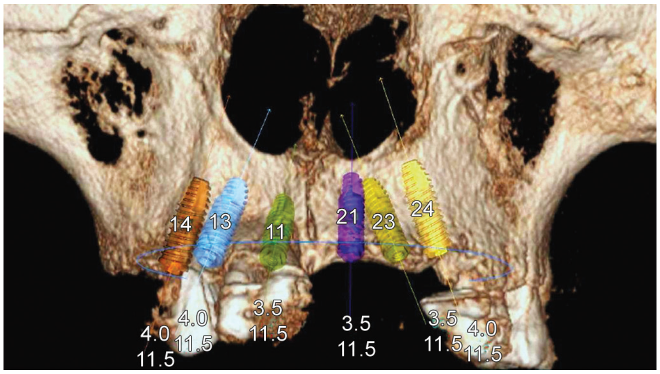

Fig. 6: Three-dimensional reconstruction view (CBCT) of anterior maxilla showing pre-osteotomy planning of different implant dimensions, implant angulations and interimplant distances that could provide optimal treatment outcomes with minimum complications. Additionally, visualization of the bony morphology, nerve patterns, joint structures, position, and extent of maxillary sinuses can be done more comprehensively than routine two-dimensional radiography

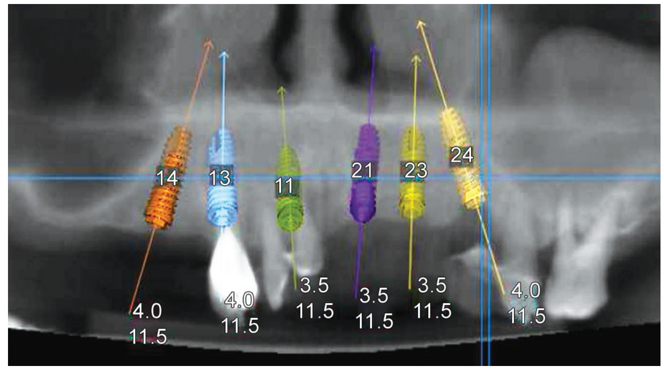

Fig. 7: Presurgical dimensional and angulation analysis (CBCT) of the anterior maxillary region wherein multiple implants are to be placed (implant supported arch rehabilitation). Note the different length, width, and angulations of virtually positioned implants as per available bone and adjacent maxillary sinus lining

roughly imparts more than one-quarter of all medical radiographs being done in Europe by dental practitioners. Since the invention of X-rays 121 years ago, dental radiographs have been the major source of diagnostic information in the oral and maxillofacial rehabilitation. However, these 2D imaging techniques are incapable to illustrate complicated 3D anatomical regions and related anomalies.[14–17] Recent literature has well illustrated that the CBCT images were more precise than routine CT images. The American Association of Oral and Maxillofacial Radiology has recommended cross-sectional views for planning dental implants because these views provide the deeper accessibility with low-radiation dose. Thus, CBCT imaging must be used comprehensively in dental implantology so as to ensure optimal success rate with minimum complications. The advancements of 3D imaging have completely revolutionized diagnostic procedures in the field of dental radiology. With the subsequent discovery of multislice computed tomography, 3D imaging has been systematically reformed because it record images rapidly without hassle. Multislice computed tomography also facilitates accurate dental and maxillofacial diagnosis with precise evaluation of bone density. However, rapid introduction of CBCT in maxillofacial imaging has largely replaced multislice computed tomography for assessing osseous structure with low radiation exposure. Other advantages of CBCT include its low-cost and limited volumetric scanning of anatomical structures.[18,19] Any 3D analysis of maxillofacial structures facilitates clinicians to plan properly, work with confidence, and evaluate outcomes postoperatively. Like all other technological innovations, CBCT imaging has also clear-cut indications and restrictions. Cone-beam computed tomography usually allows the operator to visualize 3D and multiplanar angles for a more precise diagnosis at lower cost and reduced radiation exposure compared to that of usual computed tomography scans. In addition, CBCT overcomes few common drawbacks of conventional computed tomography, such as image distortion, magnification, and superimposition. Conversely, CBCT is not suitable for detailed assessment of soft-tissue pathologic conditions of the craniofacial and temporomandibular region. Right selection of preoperative imaging modality is a very imperative step in the assessment and treatment planning procedure before implant osteotomy.

Repesa et al. estimated accuracy of measurements on CBCT images in the subjects who have received implants of different manufacturers and designs. They also attempted to see if there is any statistically significant correlation between four studied groups irrespective of the material of which implants are manufactured. Their study results clearly showed that CBCT gives accurate dimensions of placed dental implant in relation to dimensions of the manufacturer of the implant.[20] They further stated that the material from which dental implants have been manufactured does not considerably affect the accurateness of the dimension. These finding were in accordance to our results as far as the selection of length and width of implants is concerned. In 2010, Worthington et al. evaluated and estimated the CBCT data to aid in the implant planning by virtual implant positioning with presumed implant length and width. They concluded that virtual implant planning by the CBCT technique allows the operator to construct and visualize the final outcome prior to the actual execution of treatment. They further recommended that CBCT scans are precise and may be used to enhance communication and synchronization of a multidisciplinary team to achieve the desired clinical results. Virtual planning of implant width and length also facilitates the operator to consider multiple treatment circumstances until the finest treatment plan is achieved.[21] Our study results were also in accordance to these inferences since in our study CBCT data showed that the relative length and width of virtual implant remained unaffected in 97% of the cases. Deeb and associates also studied clinical importance of CBCT in the implant dimensional analysis and associated need of bone grafting. Their study results illustrated that CBCT scans precisely predict implant width in 100% of cases and length in more than 95% of cases.[22] These finding were quite comparable with study results of ours wherein we reported accuracy up to 97%. In 2012, the International Congress of Oral Implantologists (ICOI) presented the consensus report wherein they presented ICOI recommendations regarding the logical usage of CBCT in implant dentistry with the objective of providing scientifically based guidance to practitioners about its use as an adjunct to conventional imaging modalities.[23] Correa et al. in 2014 also explored the relative implant size (width and length) as dictated and finalized digital panoramic radiographs, CBCT-assisted panoramic views, and CBCT cross-sectional images. Their results were very contrasting than that of ours. They showed that implant size as measured in cross-section images was thin and small than implant size measured in a panoramic image or CBCT-based panoramic view. The differences were significant and could be explained on the basis of the differences in implant systems being evaluated.[24]

Conclusion

Within the limitations of the study authors concluded that the proposed dimensions of virtually placed implant remained unchanged in majority of cases, therefore confirming the relative significance of presurgical planning using CBCT. Also, CBCT showed actual status of different presurgical determinants like trabeculae, signs of any peri-radicular pathology, and amount of horizontal and vertical bone losses. Authors have also genuinely attempted the qualitative analysis of maxillary anterior bone wherein they found certain very interesting inferences that could be used for accurate presurgical planning of implant therapy. Therefore, it was further concluded that all these presurgical determinants largely affect the final success rate of implant therapy. Furthermore, it is very crucial to judiciously consider and clinically manage such factors before initiation of implant in the maxillary anterior region.

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