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ORIGINAL RESEARCH

Evaluation of Predictability of Suitable Implant Lengths as related to Accurate Treatment Planning using Recent Roentgenographic Measures: A Key to Success

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ABSTRACT

Background and aim: Selection of suitable length of dental implants is very subjective and largely depends on clinical evidences and operator's expertise. The present study was aimed to assess the role of cone beam computed tomography (CBCT) and cephalograms as far as the selection of right implant length is concerned.

Materials and methods: The study includes 220 patients for whom radiographic and follow-up records were obtained. There were 105 males and 115 females in the age range of 22 to 58 years. A total of 98 implant sites in different edentulous areas were studied. Length of implant was predicted at treatment planning and compared with finally placed implant at surgical stages. It also includes the in-depth exploration of (1) number of implants placed per patient, (2) implant per edentulous areas, (3) implant location, and (4) implant region. For prediction of implant lengths, CBCT results were obtained and compared with cephalometric findings. Accuracies of implant lengths as planned by CBCT and cephalometric images were also studied at treatment planning and surgical stages.

Statistical analysis and results: Upon statistical comparisons, we found that larger implant lengths chosen at treatment planning stage did not change in 65.5% of patients. In addition, the smaller length implants were just about the same as that with larger dimensions. The CBCT results were satisfactory (up to 98.5%). Cephalometry was performed well in this prediction, especially in posterior mandible (87.9%). However, its performance in anterior maxillary region was not satisfactory (69.6%). Intergroup comparisons of CBCT and cephalometric results at different regions were significant ($p < 0.001$).

Conclusion: Our study results show insignificant changes in the length of implants that was exactly planned using CBCT scans. Therefore, accurate prediction of implant lengths can be done using CBCT scans as they have superior and advanced tools that facilitate presurgical decision-making. Lateral cephalometric evaluation has been shown as an imperative radiographic tool for determining implant lengths as it confirmed the significance bone resorption on the selection of implant length at different sites.

Clinical significance: The CBCT and lateral cephalogram offer excellent anatomical details that can be judiciously applied for treatment planning and other clinical decision-making, including selection of correct implant length. Our study advocates thorough cephalometric evaluations of mandible wherein implants are to be placed for implant-supported overdentures.

Keywords: Cephalogram, Cone beam computed tomography, Dental implants, Implant planning, Surgical guide.

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INTRODUCTION

In the third millennium, permanent tooth replacement therapies with implants have been widely practiced by dentists and patients as they attain reliable functional and esthetic results. However, success of any implant treatment largely depends on the careful and accurate treatment planning. Unlike other dental replacement prostheses, implant therapy is somewhat more technique-sensitive that requires high attention in its planning compared with its real execution/placement.[1,2] On the whole, the overall success of dental implants usually depends on morphology and density of alveolar bones, implant designs, and surgical procedure. Dental implants are frequently used to retain fixed and removable dental prostheses that are otherwise nonretentive or loose. Therefore, length and diameter of implant plays a key role in their long-term success. Radiological detection and location of anatomical landmarks have also been widely used.[3-5] Though a number of rontegenographic tools are available, selection of exact imaging must be done in order to select right sized implant. Some other factors that must be considered include alveolar bone quality and quantity, number of sites, need for bone grafting, ease of use, and costs of imaging methods.[1]

After the late 1980s, conventional radiographic techniques like intraoral and panographic images have been overwhelmed by recent imaging modalities like CBCT.[6-8] As they offer improved and higher quality sectional imaging, most of the clinicians have started recommending tomographic imaging to look into potential implant sites. The American Academy of Oral and Maxillofacial Radiology has also recommended CBCT as the best option for implant planning and execution.[9] Dental implant length is the measurement from the platform to the top of implant. Usually, lengths between 8 and 13 mm are the most commonly used as it corresponds quite closely to average root length. As a factual myth, it is being said in the implant dentistry that longer implants guarantee improved success rates although there is no established linear relationship between implant length and success rate of the implant. Several meta-analysis and finite-element studies have shown that increasing the implant length may only increase the success rate to a certain extent and that too in an unexpected pace.[10-12] As mentioned earlier, this study was aimed to investigate the predictability of CBCT and cephalogram in determining correct implant length in relation to their planning and survival rates.

MATERIALS AND METHODS

The study was completed in the Department of Prosthodontics in the last 3 years, wherein a total of 220 edentulous patients were selected for the study. Radiographic records and other follow-up outputs were obtained and analyzed. The study was presented to and approved by the Institutional Ethical Committee. All patients provided signed informed consent as an agreement to participate in the study. Patients were either partially or completely edentulous, with single and/or multiple edentulous spaces at various locations of maxilla and mandible. Exclusion criteria included systemic diseases, localized bone disease with oral manifestations, and gross anomalies related to maxillofacial structure. All patients were subjected to lateral cephalogram and CBCT scanning using NewTom CBCT machine working at 120 kVp and 5 mA with a resolution of $0.1 \times 0.1 \times 0.1\ mm^3$. The radiographic film was developed using standard procedure, while the CBCT images were obtained using a cone beam dental CT scanner (Imaging Sciences International, Hatfield, USA). Slice thickness was kept standard at 0.1 mm in New Net Technologies software. For cephalogram, a 15×30 cm film cassette was used with a regular Kodak intensifying screen and Kodak dental film (Eastman Kodak Company, Rochester, USA). All radiographic images were converted in JPEG format and assessed by cross-sectional and three-dimensional (3D) reconstructions keeping a cutting interval of 1 mm. All radiographs were analyzed by an experienced dental implant surgeon in standard conditions on a viewing box. The normal lengths of the implants as provided by the manufacturer were 7.0, 8.0, 9.0, 11.0, 13.0, and 15.0 mm. The lengths of planned implants were noticed at this step. The CBCT images were further explored for detailed site assessment and relations of surrounding anatomical structures with virtually placed implant. All implants were successfully placed following the conventional two-stage surgical technique. All finalized implant dimensions were recorded for comparative assessments and statistical analysis.

STATISTICAL ANALYSIS AND RESULTS

All the observational findings were compiled and sent for statistical evaluation using statistical software Statistical Package for the Social Sciences version 21 (IBM Inc., Armonk, New York, USA). Dimensions of all placed implant were evaluated using the McNemmar test, which is a nonparametric test for two related dichotomous variables. The Chi-square test was also employed to compare the relative occurrences between the different maxillary and mandibular regions; p-value <0.05 was considered as significant. Among all subjects, there were 105 males and 115 females in the age range of 22 to 58 years. We have analyzed total 98 implant sites in various edentulous areas. Other demographic details including rate of changes in length and width, implant position, and areas of placement have been summarized in Table 1. The larger implant lengths (11, 13, and 15 mm) that were finalized during treatment planning did not change in 65.5% of patients. Also, the smaller length implants (7, 8, and 9 mm) were approximately the same as that with bigger dimensions. On the contrary, when comparing the

Table 1: Demographic details of patients

	n	*Occurrence (%)*
Implant per patient (No.)		
1	104	47.2
2–3	44	20.0
4–5	39	17.7
6/>6	33	15.0
Implants per edentulous area (No.)		
1	98	44.4
2	52	23.6
3	24	10.9
4/>4	46	20.9
Implant location		
Incisal	126	23.1
Canine	143	26.2
Premolar	112	20.5
Molar	163	29.9
Implant region		
Anterior maxilla	129	24.4
Posterior maxilla	133	25.2
Anterior mandible	122	23.1
Posterior mandible	143	27.1

lengths in treatment planning to those noticed during surgery, only 38% of cases reported unaffected. Also, the number of implants width of smaller lengths was larger than the number of longer implants. The CBCT results were found to be acceptable (minimum 94.2% and maximum up to 98.5%). Cephalometry was performed well in this prediction, especially in posterior mandible (87.9%). However, its performance in anterior maxillary region was not satisfactory (69.6%). We have also found that the overall number of smaller and larger length

Table 2: Evaluation of accuracies of implant lengths as planned by CBCT and cephalometric images (compared at treatment planning and surgical stages)

Site of placement	*CBCT appraisal (in %)*	*Cephalometric appraisal (in %)*	*p-value*
Anterior maxilla	95.4	69.6	<0.001
Posterior maxilla	97.8	81.4	
Anterior mandible	94.2	71.2	
Posterior mandible	98.5	87.9	

$p < 0.001$ (Sig.)

implants were roughly identical between treatment planning and surgical stages (Tables 2 and 3). It also confirms that implant site position (maxilla or mandible, anterior or posterior) had no effect on the perceived length at the diverse planning and implant placement stages ($p > 0.05$, Figs 1 and 2). Cephalometric further confirms about the effective space available in the body of mandible for implant placement. Here we found decrease in implant length from anterior to posterior sites (unresorbed cases, Fig. 3) and increase in implant length from anterior to posterior sites (resorbed cases, Fig. 4).

DISCUSSION

Dental implant planning is one of the most critical steps which is usually performed by gathering the radiographic information of various types of images. This study assesses how accurately CBCT and cephalograms can assess suitable implant length as per the situations. Only one implant per patient was noticed in about 104 patients. Maximum number of implants was noticed in molar

Table 3: Incidences of sites with and without change in implant lengths (compared at treatment planning and surgical stages)

		Between treatment planning and surgery		
Implant length		*With changes* (CBCT)*	*Without changes* (CBCT)*	*Total*
Between treatment planning and surgery	With changes* (cephalogram)	45	75	120
	Without changes* (cephalogram)	49	51	100
	Total	94	126	220

*Changes in apparent length

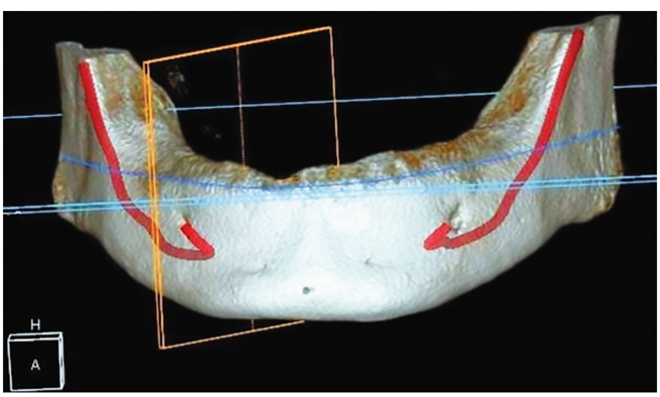

Fig. 1: Patterns of alveolingual nerve as related to the implant lengths (3D reconstruction view)

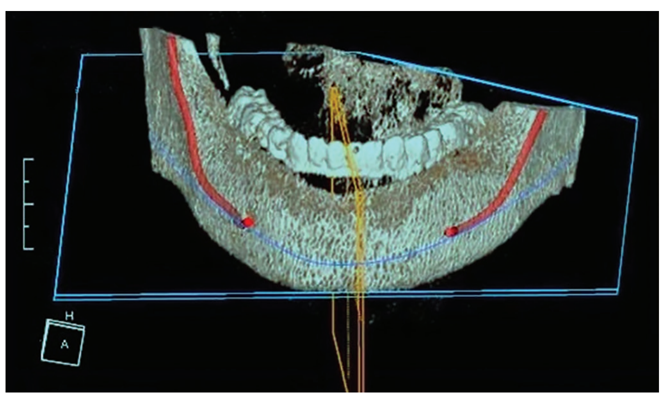

Fig. 2: Patterns of alveolingual nerve related to implant-supported overdenture (3D reconstruction view)

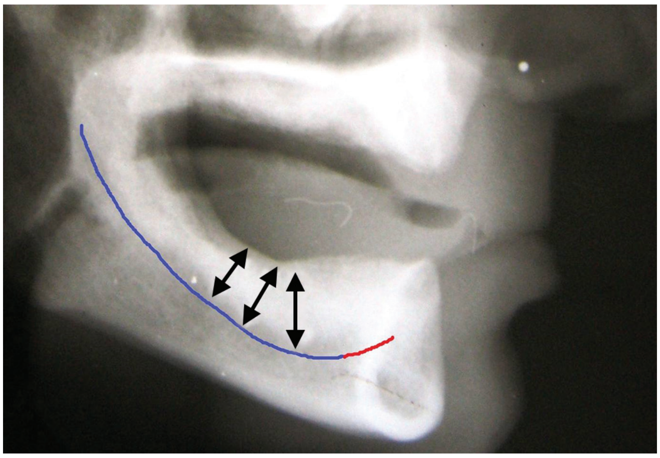

Fig. 3: Cephalometric evaluation of implant length of unresorbed mandible (decrease in length from anterior to posterior sites)

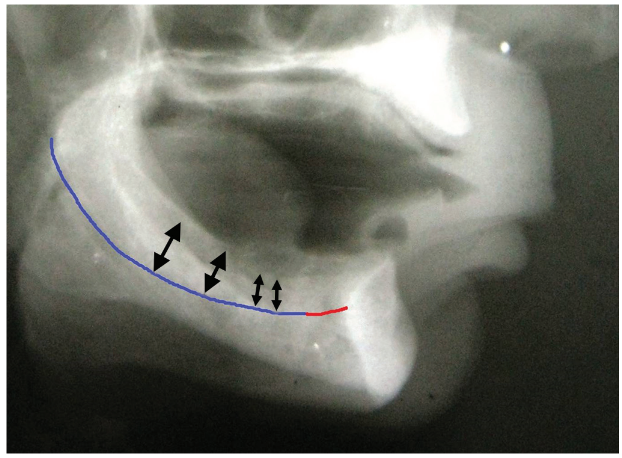

Fig. 4: Cephalometric evaluation of implant length of resorbed mandible (increase in length from anterior to posterior sites)

region predominantly in mandibular posterior region. Only one implant was reported in each edentulous space in about 44.4% patients. The region-related differences could be attributed and explained by the difference in the specialty and experience of each clinician. Our study results clearly indicate that CBCT drastically increases the accurateness of treatment planning in foretelling implant length that is exactly found at surgical stages. This was in agreement with the study results of Hudieb and Kasugai.[13] Lateral cephalograms have also been proved as an imperative tool in estimating only implant length and not implant width. When the images and tracings obtained from cephalograms were compared, it was revealed that implant lengths are increasing when moving from anterior to the posterior mandible. Our study results also indicated that the overall length requirement of implant was lesser in resorbed mandible when compared with unresorbed mandibular ridges. Tyndall and Brooks[14] and Harris et al[15] have also demonstrated similar results in their studies. However, there were very little differences observed in the prediction of length if implanted by different radiological methods. There were very little differences observed between predicted and actual (at surgery) implant lengths. This was in agreement with the study results of Kobayashi et al.[16] They have also demonstrated key role of CBCT in precise implant selection in terms of implant length as well as height. The CBCT can be used in postoperative evaluation of bone grafts and the implant's position in the jaw bones. It records the data and these data can be used to fabricate a surgical template that can act as perfect reference guide for placement of the implants. While conventional CT relates Hounsfield unit (HU) numbers, the bone density numbers from CBCT are not correct and may not be interrelated with HU. This forms the conceptual basis and rationale why bone density numbers derived from this technique cannot be recognized over a group of CBCT machines. Silva et al[17] and Batenburg et al[18] also showed somewhat similar ideology for CBCT technologies. The CBCT images of the mandible can assist operator to assess the size of the lingual concavity in the mandibular symphyseal regions. Seldom, the mandible can exhibit an unexpected lingual concavity in the posterior part of the mandible.

Literature has well evidenced that CBCT is very useful in estimating the clearance of implant in relation to the inferior alveolar canal (IAC). The CBCT images can clearly illustrate whether the canal is single or divided and buccolingual crossing patterns.[19,20] Mozzo et al[21] have very well explained it in their study.[21] The CBCT scans could also assist in identifying the IAC from large sinusoidal spaces. It also displays cross-sectional sections of each of the planned implant sites. All sectional images are generated automatically by the software which is followed by 3D constructions of implant site and related implant placement parameters. Contrary to CBCT, a cephalometric image only furnishes two-dimensional assessment of implant planning in terms of length/diameter.[22,23] Schropp et al[24] studied this by comparing panoramic and conventional cross-sectional tomography for preoperative selection of implant size. Though it is being used frequently, it is a cost-effective measure as compared with conventional CBCT. An additional factor related with the decrease in implant length is alveolar bone ridge thickness. In lateral cephalogram, an asymmetrical bony crest leads to overvalued measurement of the available bone noticeable in the CBCT scan. The surgical procedure may include crestal bone flattening, which decreases the bone height and, consequently, the implant length. Sometimes, a change in the finalized implant dimensions during surgery may be expected. The rationale behind can be related to specific local conditions, like bone density, not assessed in CBCT scans and supposed objectively only during surgery.[25-27] The best possible treatment planning can be reached only when consideration is given to all basic anatomical and clinical information. Three-dimensional virtual models and 3D virtual surgery actually provide us prospect to combine the inputs from a multidisciplinary team to create a single optimal treatment plan.

CONCLUSION

Over and above, the lateral cephalograms and CBCT are shown to improve the ability to predict the real implant length. We found insignificant changes in the length of implants than that was exactly planned using CBCT scans. It will not only reduce the inaccuracy in surgical planning but also reduces the incidences of long-term implant failures. A lateral cephalometric assessment clarifies the effect of bone resorption on the selection of implant length. Moreover, virtual planning allows operator to investigate multiple treatment options until the optimum treatment plan is achieved. Our study results could be treated as suggestive for predicting correct implant length. However, we expect other large-scale studies to be conducted that could further establish certain concrete guidelines in this prospect.

CLINICAL SIGNIFICANCE

Lateral cephalogram and CBCT furnish the anatomical details that can produce a joint treatment plan and achieve optimal outcomes for clinician and patient. Methodical analysis of cephalograms for mandibular bone resorptions patterns is advocated as their misinterpretation can adversely affect the selection of right sized implant. For complete rehabilitation of mandibular arches, selection of suitable length of implant requires comprehensive knowledge of available implant systems and prospects of patients. The accurate and well-defined planning of implants to replace missing teeth can prevent recognized and concealed treatment problems. That is how it aids the clinician and benefits the patient in every aspect.

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