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CONE BEAM COMPUTED TOMOGRAPHY (CBCT) BASED SURGICAL STENT: A VALID ADJUNCT FOR PRECISE IMPLANT PLACEMENT.

Clinical Research

Dr Srinivasan.B*	Senior Lecturer, K.L.E Society's Institute of Dental Sciences, Bengaluru-560022, Karnataka, India * Corresponding Author
Dr Sudarshan	Reader, K.L.E Society's Institute of Dental Sciences, Bengaluru-560022, Karnataka, India
Dr Balakrishna.R	Professor, Head of the department, K.L.E Society's Institute of Dental Sciences, Bengaluru-560022, Karnataka, India
Dr G.C.V	Reader, K.L.E Society's Institute of Dental Sciences, Bengaluru-560022, Karnataka, India
Dr Jannu. A	Senior Lecturer, K.L.E Society's Institute of Dental Sciences, Bengaluru-560022, Karnataka, India

ABSTRACT

3 Dimensional imaging in the form of cone beam computed tomography (CBCT) has become a welcome boon as an aid in implant planning and designing. In the developing countries with limited access and utilisation of better technology, alternate means of obtaining satisfactory results with interventional procedures are required. The aim of this study was to evaluate the accuracy of surgical stent fabricated with image analysis values derived from CBCT scan in precise implant placement.30 patients with single edentulous site in either maxilla or mandible were considered for the study. Radiographic stent fabricated for diagnostic imaging was converted to surgical stent for intra-operative use with values derived from CBCT scan. Pre- and Post-operative parameters were evaluated for precision in implant placement. The mean of distance of implant from tooth present mesially and distally, along with linear distance of the implant from buccal and lingual cortex is 0.0418 mm (maximum – 3.15 mm). Whereas, the mean of angular deviation observed is 0.849° (maximum – 3.162°). The surgical stent fabricated with the aid of CBCT is a valuable aid in precise implant placement. The precision of both the surgical stent and the technique can be further improved based on the findings of this study.

KEYWORDS

Diagnostic stent; Surgical stent; Dental implant; Cone beam computed tomography; Guide sleeve.

Abbreviations :-

%	Percentage
°	Degrees
3-D	3 dimensional
AAOMR	American Academy of Oral and Maxillofacial Radiology
ASA	American Society of Anesthesiologists
CAD-CAM	Computer-aided design and computer-aided manufacturing
CBCT	Cone beam computed tomography
CT	Computed tomography
DPR	Digital Panoramic Radiography
EAO	European Academy of Osseointegration
EC	Executive Council
FOV	Field of view
mm	Millimetre
No.	Number
OROI	O' ring ortho implant
SD	Standard deviation
Sl.	Serial
Yr	Year

1. Introduction

Loss of a tooth is both a psychological and physically disabling condition for a patient. So it becomes the prime responsibility of the dental surgeon to make sure to address this disability and put all efforts in rehabilitating the patient with a prosthethic and esthetically fulfilling tooth replacement. Despite significant advances in devices and techniques, placing dental implants in a correct position still remains a challenge. Diagnostic casts, probing depths and panoramic radiography can lead to unpredictable results as they do not give three-dimensional (3-D) radiographic information required for correct positioning and orientation of implant.(Talwar et al., 2010)

With recent advancements in the techniques of implant placement, there is a rising trend towards prosthetically driven implants. But since there is a greater probability for manual errors during implant placement, there is a need for a surgical aid that would increase the accuracy of implant placement. This accuracy can be achieved with the help of a surgical stent or guide.

Though the conventionally prepared stents which are being used are valid surgical aids, the precision of such stent is important. The implants placed with these stents should meet the optimal prosthetic requirement. Therefore, it is necessary to improve the accuracy of such stents with the help of CBCT scanning.

In a clinical scenario, where the availability of CAD-CAM surgical guides is not easily available to the clinician, the need to find alternate cost-effective means arises. This study is designed to evaluate the efficacy of the surgical stent that can be fabricated with the data obtained from CBCT scan in precise placement of dental implants.

1.1. Objective of research

Limitation of access to CAD-CAM technology or 3-D printing to many practicing clinicians of the world, raises the need to use alternate methods to achieve precision in implant planning and placement procedure. With the use of CBCT scan; a surgical stent can be fabricated in an ergonomic manner as a guidance tool for implant placement. This procedure might help clinician improve success of implant planning with limited and economic use of technology.

1.2 Review of literature

Nickenig et al., 2007; in their study evaluated the reliability of implant placement after virtual planning of the implant positions using CBCT data and surgical guide templates. A total of 102 patients (205 implants) were included in this study. They were treated with a system that allows transfer of virtual planning to surgical guide templates. In only 8 cases, the surgical guides were not used because a delayed implant placement was necessary. The predictability of the implant size was high; only one implant was changed to a smaller diameter because of insufficient bone. In all cases, critical anatomical structures were protected and no complications were detected in the post-operative radiographs. The authors concluded the study based on the results that implant placement after virtual planning of implant positions using CBCT data and surgical templates can be reliable for pre-operative assessment of implant size, position and anatomical complications. It is also indicative of cases amenable to flapless surgery.

Park et al., 2009; performed a study to measure and compare the accuracy of posterior implant placement using 3 precision surgical guides with varying occluso-gingival heights and to evaluate the difference in accuracy of implant placement through precision guides as compared to freehand placement. Three groups of surgical guides were fabricated with occluso-gingival heights of 4 mm, 6 mm and 8 mm respectively. A jig was fabricated for accurate positioning in bone substitute blocks. 90 implants were placed in the first molar site on the mannequin set up. 30 implants were placed for each group; 15 through the guide and 15 implants free hand. A reference implant was used in all cases. The distance between reference implant and the placed implants were measured at both implant and abutment levels using a coordinate measuring machine. Apex position and angulation discrepancy was also checked. The results of the comparative study was that the distance from the reference point to the point of measurement was significantly smaller for implants placed through the guide compared to free hand placement at both implant and abutments levels. The angular discrepancy was also significantly smaller for placement through the guide. This study draws the conclusion that precision surgical guides with 4 mm occlusal-gingival height allow placement as accurate as precision guides with 8 mm. Placement through the guide reported the target position more accurately than freehand.

Pal et al., 2010; conducted a study with an aim to demonstrate the accuracy and clinical precision of conventional surgical stent protocol for optimum installation of dental implants in terms of position and diameter. 45 patients were included in this study and 89 implants were placed in different sites. On a diagnostic cast a radiographic stent was fabricated using self-curing material. Holes were drilled in the centre point of the proposed implant site for the assessment of the diameter and position of the implant and filled with guttapercha. This stent was placed in the mouth and radiograph was taken to evaluate the position of guttapercha. The efficacy of the stents was then evaluated at the time of surgical exposure for implant placement and after the surgery, with the help of radiographs.The authors concluded the study by stating that if each step of the protocol used for the study is followed precisely, then it is possible to deliver optimum implant installation in terms of position and diameter and later on function at a very much reduced rate and time, as taken in CT and CAD/CAM technology which are the most acceptable methods.

George et al., 2011; described a unique method of fabricating cast based surgical guides. For optimal function and esthetics, implant placement should be directed by the position and angulation of the eventual restoration. A prosthetically driven concept often requires the use of radiographic and surgical guides to facilitate proper implant positioning. In the technique described by the authors, initially the position of the proposed implant facio-lingually and mesio-distally must be marked on a diagnostic cast. Light polymerising tray material was adapted to the cast with a cut opening in the guide at proposed implant position using a dental surveyor and 2 mm drill blank to indicate the angulation of the implant using periapical radiograph. Light polymerising gel was then adapted around the 2 mm blank, following which the blank was removed and a 2 x 10 mm rod was adapted to the hole. With the radiographic guide in position, a radiograph was taken to verify the angulation and bone height available. For converting this radiographic guide to surgical guide, a hole in the proposed implant position was drilled using drill bit and then a guide sleeve was placed over a bushing placed in the hole. And the position of the guide sleeve was verified after re-positioning the cast on a surveyor. Once the position was verified, light polymerising material was adapted to the guide to stabilize the guide sleeve. This surgical guide was used to perform the implant osteotomy. The surgical guide fabricated by this method provides orientation of implant placement in mesio-distal and bucco-lingual positions and angulations, surgical access and visibility, broad indications for use, simplicity for fabrication and cost efficiency.

Giordano et al., 2012; conducted a study using paper laser scanning to evaluate, by indirect methods, the accuracy of computer- design surgical guides in the oral implant supported partially or completely edentulous patients. Five implant supported rehabilitations for a total of 23 implants were carried out by computer designed surgical guides, performed with master model developed by muco-compressive and muco-static impressions. The comparison between the post-surgical implant replica positions and the positions in the pre-operative cast for the five patients, showed a maximum distance in the range 1.02 - 1.25 mm, an average distance in the range of 0.21 - 0.41 mm and a standard deviation in the range 0.21 -0.29 mm. The results demonstrated the accurate transfer of implant replica position by virtual implant insertion into a pre-operative cast and a post-operative cast obtained from the impressions. With the indirect methods by laser scanning technique the extra radiation for post-surgical CT scan can be eliminated.

Tyndall et al and American Academy of Oral and Maxillofacial Radiology (AAOMR) ., 2012; in their review of literature done since the year 2000 publication of original position statement on selection for radiology in dental implantology conclude that panoramic imaging along with intraoral periapical radiography can be used for initial assessment for implant site. But since proper evaluation and proper planning for implant placement requires cross-sectional imaging, AAOMR recommends use of CBCT for this purpose. The CBCT imaging protocol should include the smallest field of view (FOV) necessary and available with optimal exposure parameters. For periodic postoperative implant monitoring, periapical and in some cases panoramic images provide adequate imaging. Finally, all CBCT volumes, regardless of clinical application, should be systematically evaluated for signs of abnormalities. This can be performed by the referring dentist or specialist (such as an oral and maxillofacial radiologist) competent in the interpretation of CBCT.

Harris et al., 2012; reported the current European Academy of Osseointegration (EAO) recommendations for the use of diagnostic imaging in implant dentistry. They state that medical exposure to ionizing radiation must be justified and result in a net benefit to the patient. The as low a dose as is reasonably achievable principle must also be applied taking into account any alternative techniques that might achieve the same objectives. Cone beam computed tomography has become available offering cross-sectional imaging and 3D reconstructions at potentially lower doses when compared with medical multi-slice CT and with high diagnostic capability. Moreover, the relative low cost of CBCT equipment means that it is economically viable for purchase by clinicians and hence more likely to be used. Development in CBCT technology is going on in a faster rate as do its application in the field of implant dentistry.

Turbush et al., 2012; performed an in-vitro study with an aim to compare the accuracy of three different types of stereolithographic surgical guides: bone supported, tooth-supported and mucosa-supported. From the data of CBCT scan of an edentulous patient was done 30 acrylic resin mandible models were made using stereolithography.10 of the mandibles were digitally modified with addition of 4 teeth before fabrication and 10 were modified after fabrication with soft acrylic resin to simulate mucosa. 5 implants for each resin model was planned virtually using software programme. A total of 150 implants were planned and placed by using stereolithographic guides. Pre-surgical and post-surgical CBCT scans were super-imposed to compare the virtual implant placement with actual implant placement. Evaluation of the mean angular deviation of the long axis and mean linear deviation at implant neck and apex were done between planned and placed implants. The variation in angular deviation of the placed implants with tooth supported, bone-supported and mucosa supported stereolithographic surgical guides was observed. The mean linear deviation at neck and apex for tooth supported guides was also calculated. The results show that stereolithographic surgical guides may be reliable in implant placement; there were no statistically significant differences among the 3 types of guide in terms of angular deviation. The mucosa-supported guides were less accurate than both tooth-supported and bone-supported guides in terms of linear deviation of the implant neck and apex.

Ramasamy et al., 2013; reviewed the literature on conventionally used radiographic templates in terms of their fabrication, advantages, disadvantages and the computer aided surgical guides. Accurate implant placement is required to achieve best functional and aesthetic outcomes which can be achieved by means of a surgical guide which provides adequate information regarding implant placement and at the time of surgery it fits on to the existing dentition or on to the edentulous span. A surgical template enables a predictable and a safe minimally invasive surgery. There are various types of surgical guides which can be fabricated using different techniques. The main objective of surgical template is to direct the implant drilling system and provide an accurate placement of the implant according to the surgical treatment plan. To precisely transfer the plan to the operative site, customized conventional radiographic or computer image guided surgical templates have become a treatment of choice.

Greenberg., 2015; in his review of literature discussed the use of CBCT in dental implant planning and guided surgery. CBCT has opened a new era of office based diagnostic capability and responsibility. It helps in evaluation of an implant site in relation to hard structures and neighbouring important anatomical structures. Double scan technique is useful in reducing human errors in evaluation and transfer of CT derived information onto the surgical templates. Many software applications are available to evaluate the implant site and helps in fabrication of surgical template. CAD-CAM derived surgical guides are superior but have the disadvantage of cost and inadequate accessibility. Disadvantages of CBCT include learning curve, use of software, digital or traditional impression taking and the additional cost of both a radiographic guide and surgical guide.

2. Experimental

2.1 Subjects:

35 patients reporting to the Department of Oral and maxillofacial surgery of the institution (author's) with one or more edentulous regions in either of the jaws were selected for the study. Inclusion criteria included- male and female patient within the age group of 20-60 years under American society of Anesthesiologists (ASA) I health status and with good oral hygiene. Exclusion criteria included – patients with ASA II or higher health status, those with parafunctional habits such as bruxism, patients indicated for vertical or horizontal augmentation of bone, patients with signs of periapical lesion or active periodontal disease and patients with known allergy for any of the materials used for the study.

2.2 Procedure

Prior approval from the institutional ethics committee was obtained for conducting the study. Patients were asked to sign an informed & written consent form which explains the procedure and informs complications that may arise as a result of the surgery. All the data was collected in implant case study form. All patients were evaluated for any unknown systemic diseases via a routine haematological investigation and general physical examination.

Patient with single (Figure 1) or multiple edentulous site fulfilling the inclusion criteria are chosen for the study. A radiographic teeth supported stent was first fabricated on the diagnostic cast model (Figure 2). The patient was subjected to CBCT scan of the implant site with the radiographic stent placed intra orally. Evaluation of the parameters and virtual implant planning was done using software (CS 3D imaging software, Carestream dental ©) analysis of the CBCT scan images. The stent was then modified based on the values (four linear measurements and one angular measurement –Figure 3, Figure 4, Figure 5 respectively) derived from the analysis of CBCT scan. The diagnostic stent was thus converted into a teeth supported surgical stent with a drill guide. Pre-operative medication prescribed included

Amoxicillin 1.0gm orally 2 hours prior to surgery. The implant placement (Myriad™ dental implants system) was done in a standard surgical procedure with the aid of surgical stent (Figure 6, Figure 7). Preoperative, intraoperative and post-operative photographs were taken as a part of the documentation process with informed consent of the participants. One week post operatively CBCT scan of the dental implant was done and evaluation of the same parameters was done to verify the accuracy of the implant placed with the help of the surgical stent (Figure 8, Figure 9 and Figure 10).

Figure 1. Edentulous #15 region.

Figure 2. Diagnostic stent with radiopaque marker fabricated over diagnostic cast.

Figure 3. Pre-operative evaluation of linear measurement of distance of the proposed implant from the adjacent mesial and distal tooth at the crestal level by software analysis of CBCT scan.

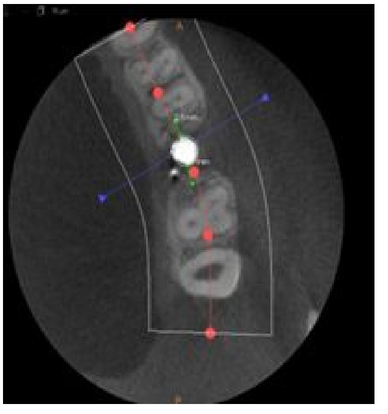


Figure 4. Pre-operative evaluation of linear measurement of distance of the proposed implant from the buccal and lingual cortices at the crestal level by software analysis of CBCT scan.

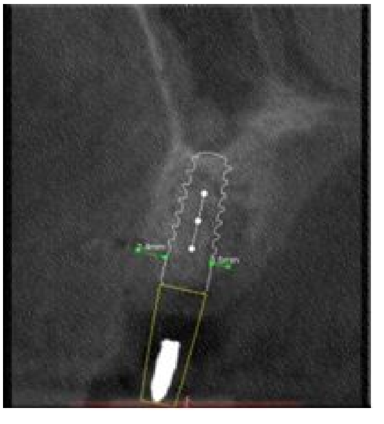


Figure 5. Pre-operative evaluation of angular measurement of the proposed implant by software analysis of CBCT scan.

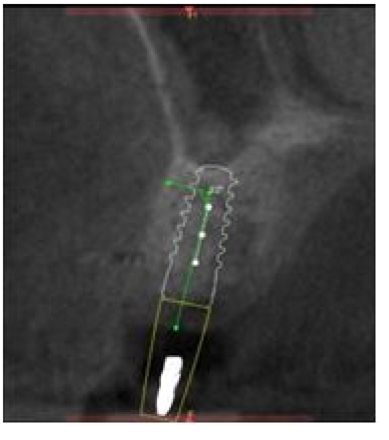


Figure 6. Intra-operative use of surgical stent along with drill guide for implant placement.

Figure 7: Implant placed in the edentulous #15 region.

Figure 8. Post-operative evaluation of linear measurement of distance of the placed implant from the adjacent mesial and distal tooth at the crestal level by software analysis of CBCT scan.

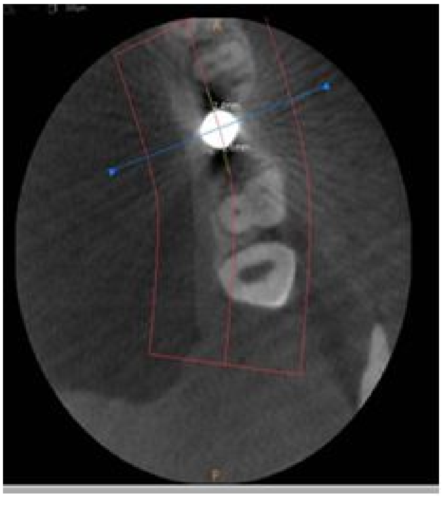


Figure 9. Post-operative evaluation of linear measurement of distance of the placed implant from the buccal and lingual cortices at the crestal level by software analysis of CBCT scan.

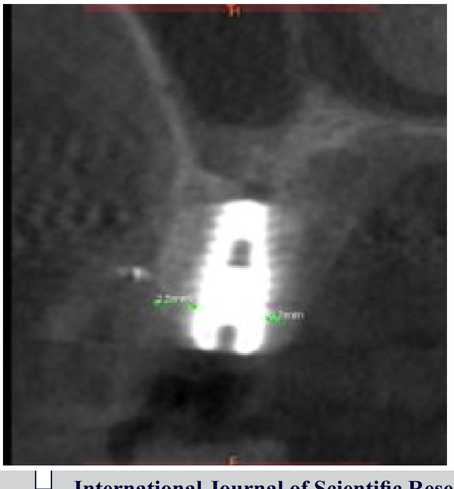


Figure 10. Post-operative evaluation of angular measurement of the placed implant by software analysis of CBCT scan.

Preoperative measurements were then compared with the post-operative measurements of the achieved implant position.

The parameters evaluated include:

A. Mesial distance between the implant and tooth: It is a linear measurement calculated between the implant margin and the most prominent point of the tooth present mesial to the proposed/placed implant at the crestal bone level.

B. Distal distance between the implant and tooth: It is a linear measurement calculated between the implant margin and the most prominent point of the tooth present distal to the proposed/placed implant site at the crestal bone level.

C. Distance of implant from buccal cortex: It is a linear measurement calculated between the implant margin and the buccal cortex to the proposed/placed implant site at the crestal level.

D. Distance of implant from lingual cortex: It is a linear measurement calculated between the implant margin and the lingual cortex to the proposed/placed implant site at the crestal level.

E. Angulation of the implant: An angular measurement made with the axis passing through the centre of proposed/placed implant to the plane parallel to the base of the mandible.

The mean values and mean of differences between the pre-operative and post-operative values were evaluated. Paired t-test was used to evaluate and compare the mean of the pre-operative and post-operative values and $p<0.05$ was considered significant.

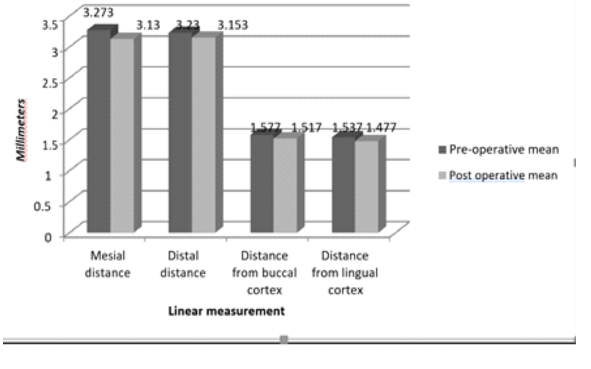
3. Results and discussion

3.1 Results

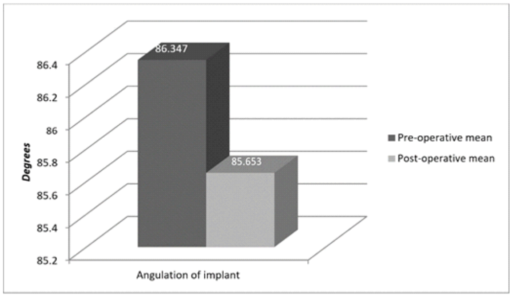
A total of 35 patients were selected for the study and 5 patients were excluded due to incomplete records. Out of 30 patients selected, 17 were male (age: 20-60 yr, mean- 32.41 yr) and 13 were female (age: 20-48 yr, mean- 32.38 yr). Out of the 30 edentulous sites, 12 were in the anterior region and 18 in the posterior region.

The mean value of pre-operative and post-operative linear (Graph 1) and angular parameters (Graph 2) was evaluated.

Graph 1- Mean value of pre-operative and post-operative linear parameters.



Graph 2 : The mean of pre-operative and post- operative angular parameter



The mean of the differences between the pre-operative and post-operative paired values is given in Table 1.

Table 1: Mean of the paired differences of the pre-operative and post-operative values.

Variables	Paired differences	
	Mean	Standard deviation
Mesial distance between the proposed/placed implant and tooth	0.1430 mm	0.5030
Distal distance between the proposed/placed implant and tooth	0.0767 mm	0.3234
Distance of proposed/placed implant from buccal cortex	0.0600 mm	0.4174
Distance of proposed/placed implant from lingual cortex.	0.0600 mm	0.3125
Angulation of the proposed/ placed implant.	0.6933 º	6.6113

The results of the paired-t test along with the standard deviation values of the four linear parameters (pre-operative and post-operative) and 1 angular parameter (pre-operative and post-operative) is given in Table 2.

Table 2: Paired t-test and standard deviation to compare the pre-operative and post- operative values.

Variable	N	Mean	Std. Dev	p-Value
Mesial distance between the proposed implant and tooth (mm)	30	3.273	0.9340	0.130
Mesial distance between the placed implant and tooth (mm)	30	3.130	0.8286	
Distal distance between the proposed implant and tooth (mm)	30	3.230	1.2625	0.204
Distal distance between the placed implant and tooth (mm)	30	3.153	1.2325	
Distance of proposed implant from buccal cortex (mm)	30	1.577	0.6781	0.437
Distance of placed implant from buccal cortex (mm)	30	1.517	0.6958	
Distance of proposed implant from lingual cortex (mm)	30	1.537	0.5922	0.302
Distance of placed implant from lingual cortex (mm)	30	1.477	0.6801	
Angulation of the proposed implant (degrees)	30	86.347	11.3789	0.570
Angulation of the placed implant (degrees)	30	85.653	12.4004	

Statistical analysis was done to evaluate the difference and statistical significance of the paired values i.e., pre-operative and post-operative difference of mean linear and angular measurement (Table 3 and 4).

Table 3 Mean and standard deviation of paired difference between the pre-operative and post-operative values of the linear and angular parameter. *CI for diff.- Confidence interval for difference

Pair	Variables	Paired Differences			
		Mean	Std. Dev	95% CI for Diff	
				Lower	Upper
Pair 1	Pre-operative and Post-operative mesial distance between proposed/ placed implant and tooth	0.1430 mm	0.5030	-0.0448	0.3308
Pair 2	Pre-operative and Post-operative distal distance between proposed/placed implant and tooth	0.0767 mm	0.3234	-0.0441	0.1974
Pair 3	Pre-operative and Post-operative mesial distance between proposed/placed implant and tooth	0.0600 mm	0.4174	-0.0959	0.2159
Pair 4	Pre-operative and Post operative distance between proposed/placed implant and lingual cortex	0.0600 mm	0.3125	-0.0567	0.1767
Pair 5	Pre-operative and Post-operative angulation of the proposed/placed implant.	0.6933°	6.6113	-1.7754	3.1620

Table 4.Paired difference correlation of the pre-operative and post-operative values of the linear and angular parameters. $p<0.05$ is considered statistically significant.

Pair	Variables	N	Correlation	p-Value
Pair 1	Pre-operative and Post-operative mesial distance between proposed/ placed implant and tooth	30	0.844	<0.001
Pair 2	Pre-operative and Post-operative distal distance between proposed/ placed implant and tooth	30	0.967	<0.001
Pair 3	Pre-operative and Post-operative mesial distance between proposed/ placed implant and buccal cortex	30	0.816	<0.001
Pair 4	Pre-operative and Post-operative distance between proposed implant/ placed and lingual cortex	30	0.888	<0.001
Pair 5	Pre-operative and Post-operative angulation of the proposed/placed implant.	30	0.849	<0.001

On evaluating the differences of pre-operative and post-operative values of all the parameters, the values are statistically significant ($p < 0.05$).

3.2 Discussion

It is important for a dental surgeon to replace what has been lost, while planning and performing dental rehabilitation with implants. The two pronged view of restoring the esthetics and function has led dental surgeons towards a concept of prosthetically driven implantology. With technological advancements, three dimensional assessment of implant site has become deeply rooted in the treatment planning stage. The success of dental implants in the treatment of patients is directly related to patient evaluation and good treatment planning. (Ramasamy et al., 2013)

In 2000, the American Academy of Oral and Maxillofacial Radiology (AAOMR) published a position paper on the role of imaging in dental implant treatment planning. They state "After reviewing the current literature, the AAOMR recommends that some form of cross- sectional imaging be used for implant cases and that conventional cross-sectional tomography is the method of choice for gaining this information for most patients receiving implants." Since then, the introduction and increased use of maxillofacial CBCT has had an impact on the availability of digital, cross-sectional imaging and expanded imaging clinical application for dental implant imaging. (Tyndallet al., 2012)

A teeth supported radiographic stent is fabricated using auto-polymerising resin on the diagnostic cast. The proposed implant site was marked approximately with gutta-percha points. The radiographic stent is very important for the success of implant placement and accurate transfer of radiographic measurements and fabrication of surgical stent. The radiographic markers help in pre-designing the direction of implant placement and in comparing the angulations of radiopaque markers with the available bone and also in the locating the position of vital structures to determine the best angulation of the implant. (Lal et al., 2006 a;b; Basten et al., 1996; Basten 1995; Almog etal., 2001; Becker et al., 2000)

De Kok et al., 2014; quoted the ideal requisites of radiographic stent to be the following:-

I. Radiopaque indicator of correct tooth form and position without inducing scatter.

ii. Retentive and stable intra-orally.
iii. Comfortable
iv. Sterilisable, if used as a surgical guide
v. Compatible with scanner (hardware) platform.

The measurements obtained from the CBCT scan with radiographic stent in situ, are used to convert the radiographic stent into a surgical stent. The main objective of surgical template is to direct the implant drilling system and provide an accurate placement of the implant according to the surgical treatment plan. To precisely transfer the plan to the operative site, customize conventional radiographic or computer image guided surgical templates have become a treatment of choice. (Ramasamy et al., 2013)

Factors that influence the accurate placement of implants using surgical guide includes, the length of surgical guide sleeve, the diameter of the surgical guide sleeve and the distance between the mucosal surface of the surgical template to the implant osteotomy site. Choi M et al., 2004; based on the results of their study made few recommendations to help reduce the deviations in implant angle. They suggested for accurate implant angulations: a longer length of a surgical guide channel should be utilized, if inter-arch distance permits, and the smallest diameter that fits the selected surgical drill fits should be utilized when the use of optimal surgical guide channel length is not possible. (Choi et al., 2004)

In vitro studies conducted in the past indicate that creating surgical guides with computer assistance results in an average precision within 1 mm of implant position and within 5 ° of deviation for implant inclination.

In the present study it has been observed that the mean of linear measurements taken at crestal level i.e., distance of implant from tooth present mesially and distally, along with linear distance of the implant from buccal and lingual cortices was 0.0418 mm (maximum – 3.15 mm). Whereas, the mean of angular deviation observed was 0.849° (maximum – 3.162°). According to the literature, the differences in both linear and angular measurements found in the present study are in comparison with other studies.

In a cadaver study done by van Steenberg et al., 2002; reported a mean 0.8 mm deviation (maximum 1.4 mm) at implant entry level and a mean of 0.9 mm (maximum - 1.5 mm) at the apex level. The discrepancy at axis was 1.8 ° (maximum - 3.8 °). (vanSteenberghe et al., 2002)

Cassetta M et al., 2011; in their in-vitro studies observed mean deviation values of linear measurements was 2 mm while the angular deviations was 5 °. The reproducibility and stability of the template position during the CT scan and implant placement is important for accuracy. (Cassetta et al., 2013)

Based on the results of the presents study, to further reduce the errors and to increase the accuracy of surgical stents for optimal implant placement, the following are few of the suggestions that should be taken into consideration:-

a. For accurate transfer of the measurements and to reduce the manual errors, double scan of the diagnostic stent should be done for precise alignment of planes during evaluation of the CBCT scan images.
b. The stability of the surgical stent can be improved by fabricating the stent which is either tooth supported or bone supported (use of pins/ bone screws).
c. To reduce the angular deviation of the implant, a guide sleeve of length atleast 4 mm or more (limited by the inter-occlusal distance between the jaws) should be used.
d. The angular deviations can also be reduced by using the guide sleeve which is closest in diameter to that of the drill bit used (from pilot drill to the final drill). This can be done either with multiple surgical stents with guide sleeves of varying diameters or fabrication of single surgical stent that can accommodate guide sleeves of varying diameters.
e. To increase the accuracy of the surgical stent, it is important to note that the distance between the gingival surface of the surgical stent and the mucosa should be as minimal as possible.
f. A surgical stent that can be fabricated with both guide sleeves and drill guides are more accurate than stents with only one of these components.

4. Conclusion

Within the limitations of this study, a considerable effort has been put to imbibe the benefits of CBCT in the fabrication of a surgical stent that would help in precise implant placement. Though, the measurement (linear and angular) errors found in this study are within acceptable limits, it can further be reduced by modifying the procedure of surgical stent fabrication. Factors that seem to influence the accuracy of the surgical stent includes, accuracy of evaluating CBCT scan images, stability of the stent, the length and diameter of surgical guide sleeves, use of drill guides and the distance of the stent from the mucosa. It is needless to say that patient factors such as bone density, amount of available bone, the presence of vital anatomic structures in the implant site and the general physical conditions are few of the other crucial factors that determine the success of implant.

Thus, to improve the clinical accuracy and to provide a minimally invasive surgical procedure for implant placement, it is mandatory to have a good surgical stent. The results of this study can be used as guidelines for fabrication of better surgical stents.

Geographical coordinates : Asia (Continent), India (Country)12.9716° N, 77.5946° E
Year of study : 2015

Research highlights :

1. Economical surgical stent fabrication.
2. It is an alternate procedure for 3D printing or CAD-CAM printed stent.
3. Study outcomes are comparable to those already present in the literature.

Limitations of the study

1. Calibration and standardisation of CBCT scans haven't been performed in the present study. This leads to a level of manual errors while doing the analysis of scans.
2. Risk of angular deviation is high, due to use of single sleeve for implant placement.
3. In the present study tooth supported diagnostic and surgical stent was used for implant placement.

Recommendations

1. Standardisation of scans with use of radiopaque material embedded in diagnostic stents should be used to achieve reproducible and repeatable analytical values. Scans done with both diagnostic stent and post-operative scan must be reformatted to same orientation.
2. To avoid this, use of sleeves of various diameters corresponding to the implant size should be done with consequent change in diameter of drill bit for osteotomy preparation.
3. According to the literature, bone supported surgical stent are better compared to tooth supported stents.

Funding and policy aspects
No recommendations

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