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Difference in implant measurements made on cone beam computed tomography scans taken with and without radiographic stent

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ABSTRACT

Background and Objectives: Cone beam computed tomography (CBCT) is the most efficient imaging modality for assessment of implant site. The efficacy of preoperative CBCT scans can be enhanced by the use of radiographic stent. This study sought to assess the differences in implant measurements made on CBCT scans taken with and without radiographic stent. Materials and Methods: This cross-sectional study was conducted on 118 CBCT sections available in the electronic files of five patients who had undergone CBCT with radiographic stent. Four oral and maxillofacial radiologists and three maxillofacial surgeons were requested to locate the site of teeth on original radiographs taken with stent and cropped images without the stent and record them in a form. A gold standard form was also filled out by an oral and maxillofacial radiologist. Results: Errors in selection of correct cut (>2 cuts from the gold standard cut) had a frequency of 6.1% and 41.1% in scans taken with and without radiographic stent, respectively. Selection of correct cut had a significant correlation with the use of radiographic stent and the observer's specialty (both Ps<0.001) but had no correlation with the type of tooth or left/right quadrant of the jaw (P>0.05). Conclusion: Radiologists had higher odds than surgeons for selection of correct cut in presence and absence of stent. Also, the odds of selection of correct cut by both radiologists and surgeons were higher in presence of stent.

Keywords: Stents, Cone-Beam Computed Tomography; Dimensional Measurement Accuracy; Dental Implants

INTRODUCTION

Dental implants revolutionized the reconstruction of orofacial esthetics and function. Appropriately planned dental implant therapy has a high success rate and well obviates the functional and esthetic needs of patients [1]. Osseointegrated dental implants are now a superior alternative to conventional dentures in patients with optimal quality and quantity of bone. However, decisions regarding the site of implant placement and its direction, dictated by the amount of residual bone [2], are made based on radiographs. Success of implant treatment highly depends on the accuracy of data provided by radiographs; thus, radiographic assessments should have high validity and reliability [3].

Intraoral and panoramic radiography are conventionally accepted for bone height measurement at the surgical site [4]. However, multidetector computed tomography (MDCT) and CBCT are the most efficient imaging modalities for implant treatment of edentulous patients or those requiring multiple implant placement or ridge augmentation [5]. The error rate of CBCT for linear measurements has been reported to be much lower than that of multi-slice computed tomography [6]. Recently, a CBCT system was exclusively developed for maxillofacial imaging [7]. The era of three-dimensional (3D) dental digital imaging was started by the introduction of low-dose craniofacial CBCT scanners [8]. The CBCT systems enable volumetric reconstruction of images [9], provide cross-sectional images of the height and width of alveolar bone and accurately locate the anatomical structures such as the inferior alveolar nerve canal and the maxillary sinuses. The accuracy and reliability of CBCT for dental measurements have been previously confirmed [8,10,11]. The most efficient images for assessment of implant site include axial sections, reformatted panoramic images and serial thin-slice transplanar images.

Clinical efficacy of preoperative radiographs can be greatly enhanced by the use of a radiographic stent since it accurately relates the acquired data from radiographs to an anatomical or surgical site. Moreover, in conventional computed tomography (CT), radiographic stent can help perceive the association of an image slice or cross-section with an anatomical region of interest [12]. A radiographic/surgical template plays a fundamental role in ideal positioning and installation of implants with the use of a prosthetic restoration.

Radiographic stents are used for more accurate assessment of width and height of available bone prior to treatment planning for implant placement or surgical procedures. Stents can be fixed or removable [13] and are fabricated of a clear, stable and rigid material. They must cover adequate number of teeth for the purpose of fixation and stabilization; in edentulous patients, stent must be sufficiently extended to the attached gingiva [14].

At present, the computer added designing (CAD)/ computer added machining (CAM) technology and CT enable the fabrication of a surgical implant stent, which enables the clinician to accurately locate the site of implant placement pre-operatively [15-17]; by doing so, dental implants can be surgically inserted without elevating a flap [18,19]. The selected implant sites are marked by the use of markers made of spherical or bar-shaped radiopaque materials (metal, composite resin or gutta percha) mounted in an acrylic stent. The patient uses the stent and undergoes radiography. By doing so, the markers are visualized on diagnostic radiographs. Moreover, the radiographic stent may be used as a surgical guide to determine the entry angle of the pilot bur and eventual implant angulation.

For ideal visualization, the thickness of markers must be less than the thickness of image slice in conventional CT. Diagnostic dentures covered with barium paste are also used to determine the implant site on radiographs. These dentures can help predict the spatial correlations between the prosthesis and implant fixtures. Usually non-metal radiopaque markers (gutta percha and composite resin) are used in CT because metallic markers can cause image artifacts. Some metals cause less artifacts than other metals and some CBCT systems cause less scattered metal artifacts than MDCT systems [12].

To the best of authors' knowledge, no previous study has evaluated the role of radiographic stent in accuracy of implant measurements made on CBCT scans. Thus, this study sought to assess the differences in implant measurements made on CBCT scans taken with and without radiographic stent. The differences in this regard among radiologists and oral and maxillofacial surgeons were evaluated as well.

MATERIALS AND METHODS

This cross-sectional study was conducted on 118 CBCT sections retrieved from the electronic files of five patients who had taken CBCT scans with radiographic stent in a private oral and maxillofacial radiology clinic. The inclusion criteria were as follows:
-Patients with CBCT scans taken with radiographic stent;
-Patients who had extracted their teeth a while ago and had extraction sockets filled with bone.

All CBCT scans had been taken with Planmeca CBCT 3D ProMax® unit (Planmeca, Helsinki, Finland) with the exposure settings of 12-14 mA, 82-84 kVp and 12s and viewed using Planmeca Romexis imaging software release 1.2.3 in high resolution mode.

The CBCT scans were interpreted by four radiologists and three maxillofacial surgeons (Figures 1 and 2). First, electronic files of five patients were manipulated by an oral and maxillofacial radiologist as follows: by selecting "panoramic" in the software menu, the optimal focal trough was defined on an axial view with adequate thickness to obtain an optimal panoramic view on which, all opaque markers of stent were identifiable. Next, "implant" was selected from the software menu and the respective sections were made in the right and left quadrants of the jaw; the CBCT scans of the implant were converted to 2D view and the file was saved. Other parameters such as panoramic arch, the initiation and termination points of sectioning, number of sections, etc. remained unchanged in the file. In the "adjust" menu, "define data range" was selected and the image was cropped and the stent was deleted. The 2D view file was then saved. The CBCT scans of all five patients were modified as such and saved. The saved files were then printed and a code was typed on the radiographs instead of patient's name. Radiographs of the same patient with and without stent had different codes.

First, radiographs taken with stent were viewed and interpreted by four oral and maxillofacial radiologists and three oral and maxillofacial surgeons and the location of teeth # 1-7 in each quadrant was determined by selecting the number of correct section in the form. One week later, radiographs taken without stent were evaluated by the same observers.

The gold standard form was filled out by an oral and maxillofacial radiologist by taking into account the fact that the most opaque cut at the site of each tooth was considered as the correct cut. In statistical analysis, the previous and next cuts to the respective cut were considered as the correct cut as well. The forms were then collected and subjected to statistical analysis.

Generalized estimating equation (GEE) with exchangeable correlation matrix and binary logistic regression model were used to assess the effect of presence/absence of stent, right/left quadrant and type of tooth on selection of correct cut by the observers (since the data were homogeneous). The intraclass correlation coefficient (ICC) was evaluated by two-way random model. The absolute agreement and single measures were calculated and reported as well.

RESULTS

A total of 118 CBCT sections of 10 quadrants of five patients with and without radiographic stent were evaluated by seven observers including four oral and maxillofacial radiologists and three oral and maxillofacial surgeons.

Errors in selection of correct cut (≥2 cuts farther from the gold standard cut) had a frequency of 6.1% with the use of radiographic stent and 41.1% without the use of radiographic stent. Figure 3 shows the frequency percentage of selection of different cuts based on the distance from the standard cut (with and without stent). Performance of the observers with regard to the selection of correct cut is presented in Table 1. The inter-rater reliability of the observers is presented in Table 2. The ICC values showed excellent agreement among the observers (both radiologists and surgeons) for the CBCT scans taken with and without radiographic stent. Figure 4 shows the percentage of errors from the gold standard in the right and left quadrants. The percentage of errors from the gold standard for the radiologists and surgeons is presented in Figure 5. The percentage of errors from the gold standard based on the type of tooth is shown in Figure 6. The frequency percentage of different cuts selected by the radiologists and surgeons based on distance (number of cuts) from the correct cut in presence and absence of stent is shown in Figures 7 and 8. The correlation of jaw quadrant, presence/absence of stent, specialty of the observer and tooth type with the percentage of error from the gold standard is shown in Table 3.

Table 1. Performance of the observers with regard to the selection of correct cut

		With stent		**Without stent**	
		Perfect cut (+/- 1 cut)	Error (+/- 1 cut)	Perfect cut (+/- 1 cut)	Error (≥2 cuts)
Quadrant	Right	96.95%	3.05%	59.9%	40.1%
	Left	90.77%	9.23%	57.95%	42.05%
Tooth type	Central incisor	92.31%	7.69%	61.76%	38.24%
	Lateral incisor	94.34%	5.66%	62.26%	37.74%
	Canine	97.01%	2.99%	59.7%	40.3%
	First premolar	94.34%	5.66%	65.38%	34.62%
	Second premolar	98.11%	1.89%	60.38%	39.62%
	First molar	93.22%	6.78%	57.38%	42.62%
	Second molar	85.71%	14.29%	39.47%	60.53%
Observer	Radiologists	96.61%	3.39%	72.29%	27.71%
	Surgeons	89.74%	10.26%	39.75%	60.25%

Table 2. Inter-rater reliability of the observers

	ICC Total	**ICC - Surgeon**	**ICC - Radiologist**
With stent	0.993	0.988	0.997
Without stent	0.898	0.967	0.925
Total	0.940	0.976	0.960

**All P-values < 0.001*

Table 3. Correlation of quadrant (right/left), presence/absence of stent, specialty of the observer and tooth type with the percentage of error from the gold standard

		OR	95%CI	P-value
Quadrant	Left	1.34	0.66-2.69	0.42
	Right	1		
Stent	Absence	13.45	6.69-27.07	<0.001
	Presence	1		
Specialty	Surgeon	3.91	2.16-7.09	<0.001
	Radiologist	1		
Tooth type	Second molar	2.74	1.27-5.88	0.01
	First molar	1.19	0.69-2.02	0.53
	Second premolar	0.83	0.45-1.56	0.56
	First premolar	0.79	0.41-1.51	0.47
	Canine	0.89	0.49-1.63	0.71
	Lateral incisor	0.9	0.54-1.48	0.67
	Central incisor	1		

OR: Odds ratio

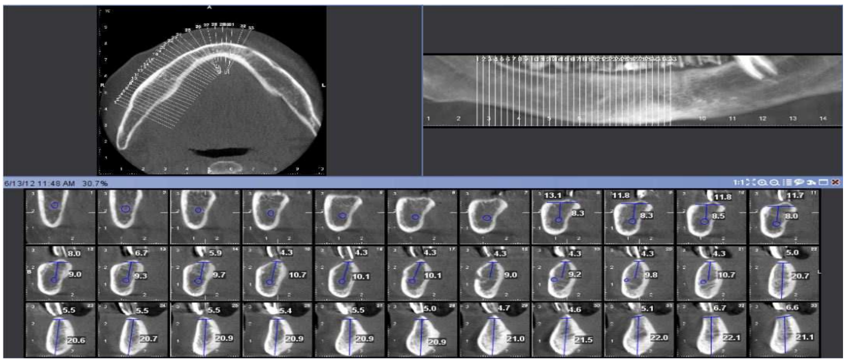

Figure 1. CBCT with Stent

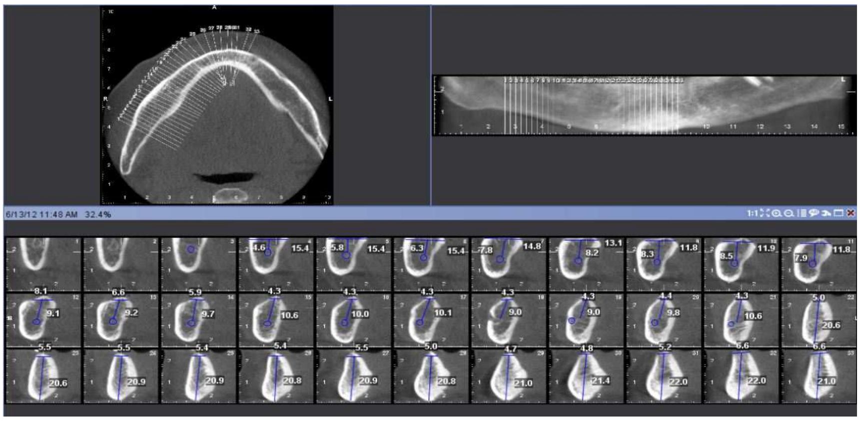

Figure 2. CBCT without Stent

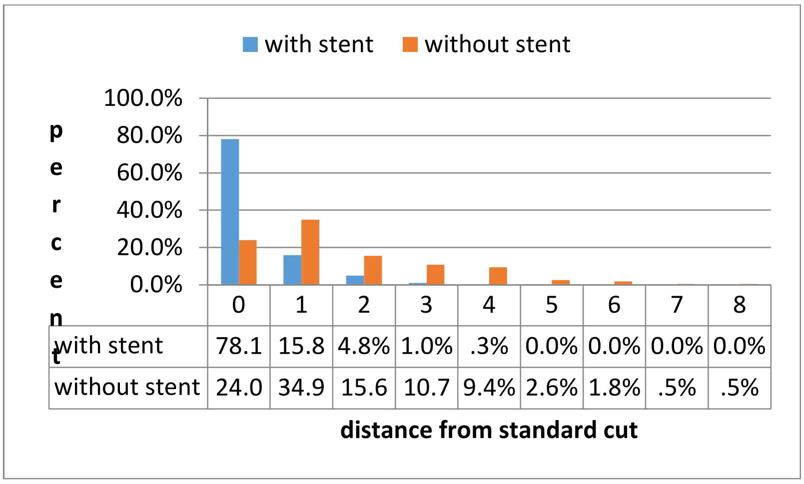

Figure 3. Frequency percentage of selection of different cuts based on the distance from the standard cut

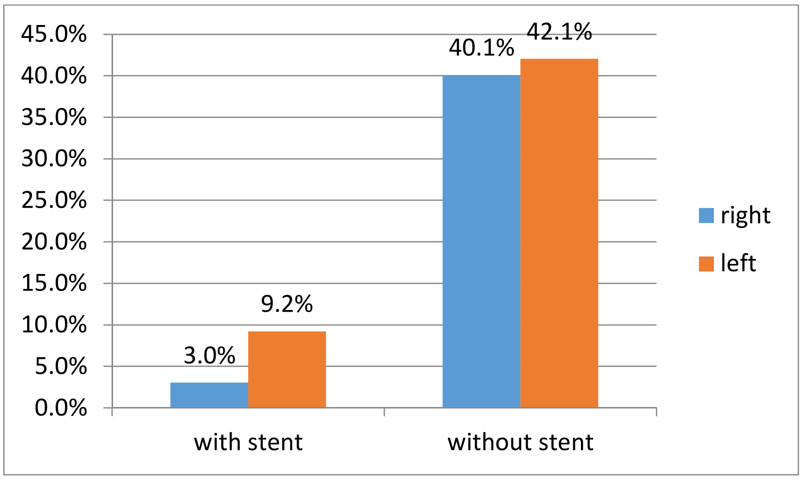

Figure 4: Percentage of errors from the gold standard in the right and left quadrants

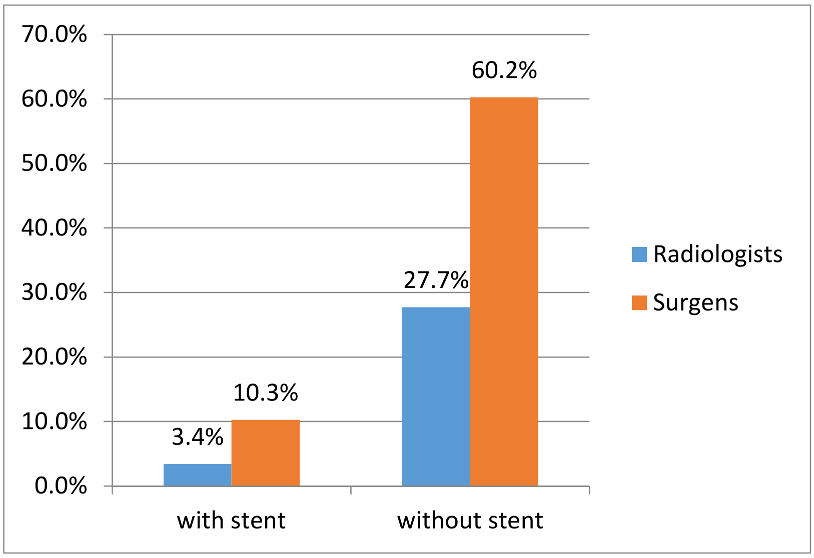

Figure5:Percentage of errors from the gold standard for radiologists and surgeons

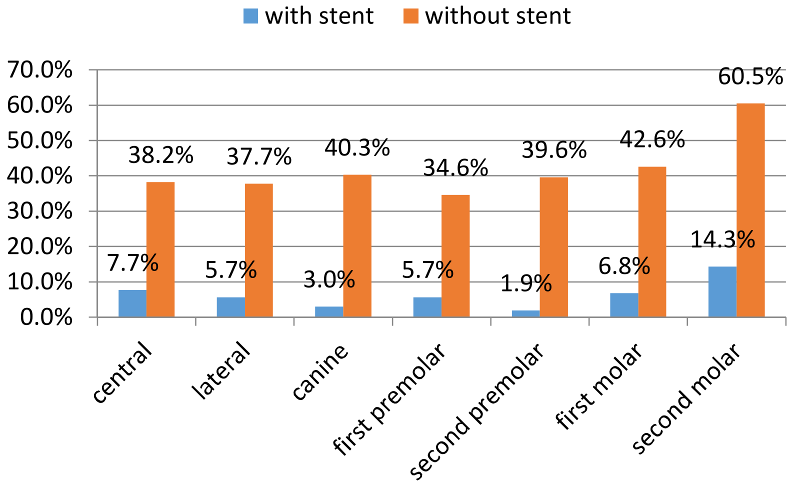

Figure 6: Percentage of errors from the gold standard based on type of the tooth

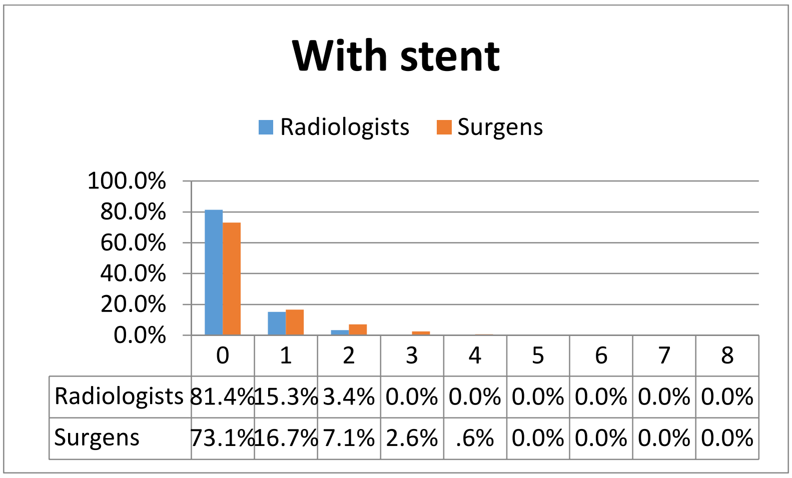

Figure 7:Frequency percentage of different cuts selected by the radiologists and surgeons based on distance(number of cuts) from the correct cut in presence of stent

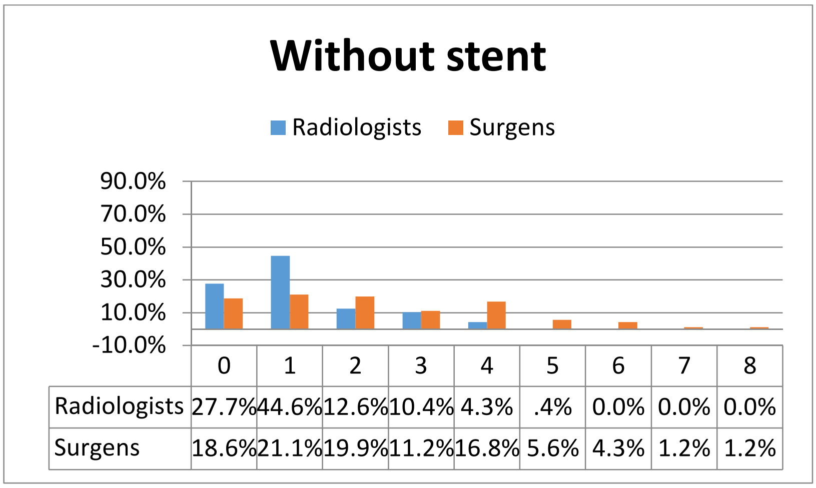

Figure 8:Frequency percentage of different cuts selected by the radiologists and surgeons based on distance(number of cuts) from the correct cut in absence of stent

DISCUSSION

Malaligned dental implants have much more complicated laboratory procedures for the fabrication of superstructure than regular implants and may result in unfavorable esthetics. Moreover, in such cases, stress concentration increases due to improper load distribution and causes trauma to the implant supporting structures. The bone-implant interface may be adversely affected as well [20,21]. A radiographic stent can be fabricated to enhance radiographic assessment of the available bone in terms of height and width prior to treatment planning for implant placement. These stents can also help in surgical procedures performed to provide a suitable implant placement site [21]. Vaccumform or acrylic templates can be adapted to the duplicated dental casts of diagnostic wax-ups to prepare radiographic or surgical stents [13]. The stents with radiopaque markers are easy to make in the clinical setting and enhance accurate placement of implants. Also, they eliminate the need for surgical elevation of a flap. Implant holes are directly drilled through the stent. This way the soft tissue is better preserved, minimal trauma is applied to the supporting structures and the operation time would decrease. Consequently, the patient would have less post-operative pain and complications and healing would occur faster, resulting in higher patient satisfaction.

A total of 118 CBCT sections with and without radiographic stent from 10 quadrants of five patients were evaluated by seven observes including four oral and maxillofacial radiologists and three oral and maxillofacial surgeons. Our results showed that use of radiographic stent increased the accuracy of measurements; this finding was in line with the results of Pal et al, in 2010 who showed that surgical stent increased the accuracy of implant installation [19].
In the current study, the ICC was found to be 0.997 and 0.925 among radiologists for scans taken with and without radiographic stent, respectively. Also, the ICC of surgeons was found to be 0.988 and 0.967 for scans taken with and without stent, respectively. The total ICC was 0.993 and 0.898 with and without stent, respectively. As seen, all ICCs were over 90%, which shows high agreement in each group of radiologists and surgeons and between both of them with regard to the selection of correct cut for different teeth with and without radiographic stent. We also compared the selected cuts by radiologists and surgeons with the gold standard and found that radiologists were more accurate than surgeons in selection of the correct cut with and without radiographic stent. This finding is probably due to the higher skills acquired by radiologists in this respect. In our study, observers (both surgeons and radiologists) provided interpretations very much similar to the gold standard using CBCT scans taken with radiographic stent ($P<0.001$) compared to scans without radiographic stent. This finding highlights the important role of radiographic stent as a guide for proper reading and interpretation of the sections by the observers irrespective of their specialty.

In the current study, the selected cuts by the radiologists among CBCT scans taken without stent had a maximum of four cuts distance from the correct cut while in the group of surgeons, the selected cuts had a maximum of eight cuts distance from the standard correct cut. This is probably attributed to the greater experience of radiologists in interpretation of CBCT scans. Radiologists and surgeons had the lowest error in determining the first premolar site on CBCT scans taken without stent; this may be due to the mental foramen serving as a guide in this area. The correlation of type of tooth and right/left quadrant with selection of correct cut was not significant. To the best of authors' knowledge, no previous study is available on the role of radiographic stent in implant measurements made on CBCT scans to compare our results with. However, many previous studies have shown optimal efficacy of radiographic and surgical stents for proper installation of implants [22].

CONCLUSION

Based on the results of the current study, fabrication of radiographic stent is recommended prior to all implant placement surgeries.

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