# Comparison of Virtual Dental Implant Planning Using the Full Cross-Sectional and Transaxial Capabilities of Cone Beam Computed Tomography vs Reformatted Panoramic Imaging and 3D Modeling

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***Purpose:*** *To compare the choice and placement of virtual dental implants in the posterior edentulous bounded regions using the full cross-sectional and transaxial capabilities of cone beam computed tomography (CBCT) vs reformatted panoramic images and three-dimensional (3D) virtual models.* ***Materials and Methods:*** *Fifty-two cases with posterior bounded edentulous regions (61 dental implant sites) were identified from a retrospective audit of 4,014 radiographic volumes. Two image sets were created from selected CBCT data: (1) a combination of reformatted panoramic imaging and a 3D model (PIref/3D), and (2) the full 3D power in CBCT image volume analyses (XS). One virtual implant was placed by consensus of three prosthodontists in each image set: PIref/3D and XS. The choice of implant length and the perceived need for ridge augmentation were recorded for implant placement in both test situations. All the virtual implant placements from both PIref/3D and XS image sets were inspected retrospectively using virtual 3D models, and the number of exposed threads on both the buccal and lingual/palatal aspects of the virtual dental implant was evaluated. The chi-square and paired t tests were used with the level of significance set at* $\alpha = .05$. ***Results:*** *Shorter implants were chosen more often using XS than PIref/3D (P = .001). Fewer threads were exposed when placed with XS than with PIref/3D (P = .001). The use of XS reduced the perceived need for ridge augmentation compared with PIref/3D (P = .001).* ***Conclusion:*** *The use of the full 3D power of CBCT (including cross-sectional images in all three orthagonal planes and transaxially) provides supplemental information that significantly changes the choice of virtual implant length and vertical position of the implant, and reduces the frequency of perceived need for ridge augmentation before implant placement.* Int J Oral Maxillofac Implants 2015;30:xxx–xxx. doi: 10.11607/jomi.3992

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An important goal of dental imaging for implant site assessment is to facilitate placement based on prosthetic restoration considerations.[1–6] Conventional imaging techniques including periapical, lateral cephalometric, and panoramic imaging, along with clinical examination and diagnostic stone casts have long been considered necessary for preoperative planning of dental implants.[7] In cone beam computed tomography (CBCT), volumetric data from moderate width, curved planar transaxial imaging along the dental

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arch can be used to simulate panoramic images (PIref). Unlike conventional panoramic images, PIrefs are considered to be very accurate with constant known magnification and minimal distortion.[8] Cross-sectional images resulting from CBCT can demonstrate the topography of edentulous spaces and important internal features such as the location of anatomic structures limiting the placement of dental implants (eg, inferior alveolar canal). Several professional organizations have published opinions or recommended clinical guidelines on the use of cross-sectional imaging for implant planning and assessment, ranging from very limited usage of CBCT to endorsing CBCT as the modality of choice.[7,9–13] Some authors argue that only specific clinical situations may benefit from CBCT imaging and that two-dimensional (2D) imaging is usually adequate in most cases for presurgical assessment and planning of dental implants in posterior regions.[14] Specifically for dental implant treatment in molar regions, Vazquez et al[15] suggest that panoramic imaging in conjunction with periapical radiography is satisfactory for preoperative assessment when the calculated vertical magnification factor of panoramic radiographs correlates well with values listed by the manufacturer.[16] Conversely, others contend that CBCT provides additional information for dental implant placement and reduces inaccuracies in presurgical assessment and planning.[17] CBCT offers superior visualization of anatomical structures in the mandibular posterior region, specifically the lingual concavity, inferior alveolar nerve, and mental foramen.[18,19]

There is a lack of clear evidence on the clinical efficacy of cross-sectional imaging compared with panoramic imaging in combination with diagnostic stone casts in presurgical implant assessment and planning. However, ethical problems exist in designing and executing an in vivo clinical study in which both panoramic and CBCT imaging is performed for a patient and either one of the modalities is withheld from planning or actual treatment. Practical issues also present at institutions where CBCT imaging alone is performed for all patients presenting for implant site assessment. Therefore, to address this issue, studies are often designed to use simulated data as a surrogate. The combination of PIrefs and three-dimensional (3D) modeling is used as the surrogate for conventional panoramic imaging and study models in this study. The purpose of this study was to compare the choice and placement of virtual dental implants, exposed threads, and perceived need for ridge augmentation after placement of virtual dental implants, in the posterior edentulous bounded regions using the full 3D capabilities of CBCT vs PIref and 3D virtual models from the same CBCT image volumes.

## MATERIALS AND METHODS

### Sample

This study was approved by the institutional review board (IRB) of the University of Louisville (Louisville, Kentucky) on December 5, 2012 (IRB # 12.0534). A retrospective audit was performed of a database of radiographic reports on patients referred for CBCT dental imaging and reports available from a period spanning installation of the equipment (May 13, 2004) to a convenient date (September 30, 2012). A total of 4,014 radiographic reports were audited. All CBCT images of these patients had been acquired using an i-CAT Classic CBCT unit (Imaging Sciences). The device operated at 1 to 3 mA and 120 kV using a high-frequency, constant potential, fixed-anode with a nominal focal spot size of 0.5 mm. Scans were performed at one of three volume sizes: 13.2 cm, 8 cm, or 6 cm heights. The diameter of the image volume was invariably 16 cm.

Specific data fields were exported from the records to a spreadsheet (Excel, Microsoft). These included the age of the subject, the date the scan was performed, the field of view of the scan, the reason for referral, and the radiologic findings. To identify a sample of subjects who presented for assessment of a residual alveolar ridge in a bounded posterior edentulous space before implant placement, the following inclusion criteria were applied to the spreadsheet:

- Specifically referred for preoperative implant site assessment
- Posterior edentulous spaces involving only one or two missing teeth from the first premolar, second premolar, and first molar sites
- No presence of pathology in the posterior maxilla or mandible
- No history of previous ridge augmentation at the potential implant site
- Absence of systemic disease, concurrent infections, or illnesses

A total of 52 subjects who met all inclusion criteria were identified as having 61 potential dental implant placement sites. The most common missing tooth site (based on the Universal Tooth Numbering System) was at the first molar on the mandibular left side (20 cases) followed by the mandibular right molar (12 cases). The maxillary left first molar and mandibular right second molar were involved in six cases each, followed by the maxillary right first molar and mandibular left second molar (n = 2 each), and finally the maxillary right second molar, maxillary left and right first premolar, and maxillary left second premolar (n = 1 each).

Table 1 provides details of the number of missing teeth in each jaw. Of these sites, 76.9% were in the mandible with most edentulous spaces only missing a single tooth (82.7%).

## Image Sets

The CBCT data for each subject was retrieved from the archive and DICOM data imported into a proprietary dental DICOM viewer (Invivo Dental, Version 5.2.4, Anatomage). Using this software, two image sets, PIref/3D and XS, were created for each subject.

***PIref/3D.*** After standardized reorientation of the skull position,[20] a curved reformatting spline was drawn along the dental arch in the "Super Pano" screen of the axial plane at the level of the cementoenamel junction on the mesial aspect of the right second molar. The spline acted as the center of a virtual panoramic focal trough, producing a standard 15-mm-thick PIref. A volumetric surface rendering was then created and cropped inferiorly just above the level of the mental foramen. The PIref/3D combination was used as a surrogate for conventional panoramic imaging and study models for implant preoperative planning.

## Full CBCT Cross-Sectional and Transaxial Capabilities (XS)

Using the same procedure as described before, a curved panoramic spline was constructed in the "Arch Section" screen, generating both a PIref and contiguous 1-mm-thick transaxial and XS images at 1-mm increments along the spline. This combination represents the most common image sequence used for implant site assessment based on cross-sectional imaging using the full CBCT 3D capability.

## Virtual Implant Placement

All protected health information was stripped from the data set before the virtual implant placement process, data collection, and analysis. The clinicians (three prosthodontists) in this study were blind to the subjects' identification during the virtual implant placement process to eliminate bias.

A virtual dental implant was first inserted (Straumann Bone Level Regular CrossFit design, Institut Straumann) in the PIref/3D image set created from each subject (Fig 1). The final implant placement was reviewed, assessed, and verified by the three prosthodontists. The prosthodontists reached a consensus on the final placement of the dental implant. To ensure implant choice uniformity, choice of virtual implants was restricted to a specific implant design (Straumann Bone Level Regular CrossFit). Molars and premolars were replaced with bone-level implants of 4.8 mm and 4.1 mm diameter, respectively. Three implant length choices were available: 8, 10, and 12 mm. The implants were placed following the International Team for Implantology (ITI) implant treatment guidelines.[21] The distance between the implants was recommended to be at least 1.0 to 1.5 mm in buccolingual dimension. A distance of at least 2 mm was recommended from the inferior alveolar nerve and minimum of 1.5 mm of bone existing in any dimension of dental implant. The final virtual implant placement and selection were then saved in the PIref/3D image set created from each subject.

**Table 1 Number of Missing Teeth in Maxilla and Mandible**

| | No. of missing teeth | | |
|---|---|---|---|
| Arch | 1 | 2 | Total |
| Maxilla | 12 | 0 | 12 |
| Mandible | 31 | 9 | 40 |
| Total | 43 | 9 | 52 |

After a 1-month interval, following the same implant selection and placement principles, a virtual dental implant was then inserted (Straumann Bone Level Regular CrossFit) in the XS image set created from each subject's CBCT image (Fig 2). The final virtual implant placement and selection were then saved in the XS image set created from each subject.

## Data Collection and Analysis

Based on the consensus-derived implant position, the following decisions were recorded using each image set independently:

- Choice of implant length (8 mm, 10 mm, and 12 mm).
- The perceived need for ridge augmentation to the alveolar crestal bone during the virtual implant placement. Three options are possible including (*1*) no perceived need for ridge augmentation, (*2*) simultaneous ridge augmentation needed at the time of implant placement, and (*3*) prior grafting required for implant placement as a separate procedure.

All virtual implant placements from both the PIref/3D and XS groups were inspected on the virtual 3D models. Any bony perforations or fenestrations were inspected as well as the number of exposed threads on both the buccal and lingual/palatal aspects of the virtual dental implant.

The descriptive statistics for the edentulous space of the sample included dental arch (maxilla or mandible), site location (left or right/first or second premolar or first molar), number of missing teeth, and patient age. Differences between image sets (PIref/3D and XS) for clinical decisions (choice of implant length and the perceived need for ridge augmentation during the

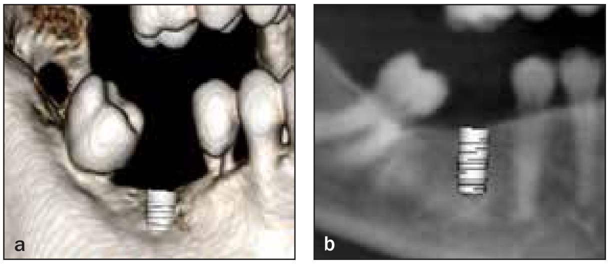

**Fig 1** Implant placed using PIref/3D information based on consensus of prosthodontists. (*a*) Virtual 3D model showing perceived need of simultaneous ridge augmentation. (*b*) Cropped reformatted panoramic image showing virtual implant of 10 mm/4.8 mm in place at edentulous site no. 46.

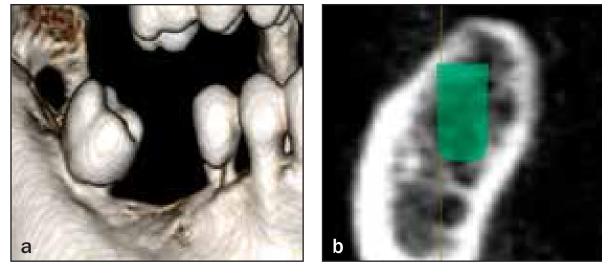

**Fig 2** The same case seen in Fig 1, in which the implant was placed using XS information. (*a*) Virtual 3D model showing no perceived need for ridge augmentation at site no. 46. (*b*) Parasagittal XS image showing shorter 8 mm/4.8 mm implant at site no. 46.

planning process) and number of exposed threads of the virtual implant on the buccal and lingual aspects were determined using the chi-square test and paired *t* test, respectively, at a significance level of $\alpha = .05$. The assessment of intrarater variability was unnecessary because the treatment decisions were made by consensus among three prosthodontists.

## RESULTS

Table 2 shows the frequency of implant length choice for each modality. The 10-mm virtual implant was the most commonly chosen length for both image sets (PIref/3D, 44.3%; XS, 41%). The second most common choice was 12 mm for PIref/3D (37.7%) and 8 mm for XS (36.1%).

Table 3 shows agreement and differences in decisions of implant length for each image set. For 50% of sites, the choice of implant length was the same for both image sets. The Yates corrected chi-square test indicated a difference between image sets for implant choice, with shorter implants being selected for 39% of sites when XS was used.

Table 4 shows significant differences between the image sets in the perceived need for ridge augmentation (Yates corrected chi-square = 27.76, $P = .001$) for 65% of sites. Using XS imaging to place the virtual implant, ridge augmentation was considered necessary for only 21% of sites (n = 13), whereas using PIref/3D, 70.5% of sites (n = 43) were perceived to need ridge augmentation.

Table 5 shows the differences between image sets in the perceived timing of the augmentation procedure. Simultaneous ridge augmentation was recommended only when XS imaging was used. Using PIref/3D, a small proportion of the augmentations (6.55% or four sites) were considered for prior grafting.

Table 6 shows the difference in number of exposed threads with virtual implant positioning using PIref/3D and XS image sets independently. Placement of virtual implants using PIref/3D exposes significantly more implant threads (approximately two) on both the buccal and lingual/palatal aspects compared with using the XS image set.

## DISCUSSION

Preoperative bone evaluation and prosthetically driven virtual implant placement are important steps for the success of implant therapy.[22,23] Both steps are facilitated using 2D (eg, periapical, lateral cephalometric, and panoramic imaging) or 3D radiographic imaging (eg, CBCT). The evidence for increased efficacy of 3D techniques for dental implant diagnosis and treatment simulation for all clinical situations is currently equivocal. Some authors suggest that the use of conventional panoramic imaging and clinical examination is adequate for dental implant preoperative planning,[7, 14] including the molar region 15, whereas others affirm that CBCT is a more reliable and beneficial imaging modality for implant planning.[9,24,25] Concern has been raised by some that because of the additional radiation burden associated with CBCT imaging, a clear clinical benefit of cross-sectional imaging for specific clinical situations should be demonstrated.[26] The recent ITI consensus statement supports the use of CBCT for dental implants but highlights a strong need for standardized methodologic research in the development of future guidelines.[13]

The purpose of this study was to compare the differences in virtual implant length and placement for posterior bounded edentulous regions of no more than two teeth, using XS images and PIrefs from CBCT. This is a specific use scenario not reported in previous studies.[27,28] In this study, a specific implant planning software was used, which was previously found to be reliable for CBCT image analysis.[29] In this study, conventional panoramic images were not available, so

**Table 2 Comparative Choice of Implant Length Decision for Each Modality**

| Implant length (mm) | PIref/3D | XS |
|---|---|---|
| | Frequency (%) | Frequency (%) |
| 8 | 11 (18) | 22 (36.1) |
| 10 | 27 (44.3) | 25 (41) |
| 12 | 23 (37.7) | 14 (23) |
| Total | 61 (100) | 61 (100) |

**Table 3 Comparative Cross-Tabulated Analysis of Implant Length Decision for Each Image Set**

| | | XS | | | | |
|---|---|---|---|---|---|---|
| | | 8 mm | 10 mm | 12 mm | Total | *P* |
| PIref/3D | 8 mm | 10 | 1 | 0 | 11 | .001 |
| | 10 mm | 11 | 12 | 4 | 27 | |
| | 12 mm | 1 | 12 | 10 | 23 | |
| Total | | 22 | 25 | 14 | 61 | |

**Table 4 Ridge Augmentation for Each Image Set**

| Ridge augmentation | PIref/3D (%) | XS (%) | *P* |
|---|---|---|---|
| No ridge augmentation | 18 (29.50) | 48 (78.68) | .001 |
| Ridge augmentation | 43 (70.49) | 13 (21.31) | |
| Total | 61 (100) | 61 (100) | |

**Table 5 Comparative Cross-Tabulation of Ridge Augmentation for Each Image Set**

| Level of ridge augmentation | | XS | | | |
|---|---|---|---|---|---|
| | | No ridge augmentation (%) | Simultaneous- ridge augmentation (%) | Prior grafting (%) | Total (%) |
| PIref/3D | No ridge augmentation | 13 (21.31) | 5 (8.19) | 0 (0) | 18 (29.5) |
| | Simultaneous ridge augmentation | 31 (50.81) | 8 (13.11) | 0 (0) | 39 (63.9) |
| | Prior grafting | 4 (6.5) | 0 (0) | 0 (0) | 4 (6.6) |
| Total | | 48 (78.7) | 13 (21.3) | 0 (0) | 61 (100) |

**Table 6 Comparative Analysis Showing Number of Exposed Implant Threads for Each Image Set**

| Aspect of Implant Surface | Modality (Mean ± SD) | | 95% Confidence Interval | | Significance | | |
|---|---|---|---|---|---|---|---|
| | PIref/3D | XS | Lower | Upper | T | df | *P* |
| Buccal | 3.11 ± 2.58 | 0.92 ± 1.31 | 1.59 | 2.80 | 7.25 | 60 | .001 |
| Lingual | 1.51 ± 2.24 | 0.11 ± 0.48 | 0.84 | 1.94 | 5.08 | 60 | .001 |

surrogate panoramic images and PIrefs were generated from CBCT data. PIrefs provide potentially greater diagnostic accuracy than conventional panoramic images because of less distortion and magnification[2;0] therefore, the authors expect that in clinical practice, decision discrepancies between conventional panoramic images and XS images could be greater than those seen in the present study.

The placement of virtual implants at edentulous sites in both image sets was based on ITI treatment guidelines for optimal implant positioning in the posterior region.[21] These included the following: 1.5-mm distance between the implant and adjacent tooth, at least 1.5 mm of bone in both the buccal and lingual/palatal dimensions, and at least a 2-mm distance from the inferior alveolar nerve and maxillary sinus.

In the present study, it was found that the use of CBCT XS imaging for virtual implant placement changed the choice of implant length in almost 50% of the subjects compared with the use of PIref/3D alone. Most changes resulted in the selection of a shorter implant than that planned using PIref/3D (39%), almost all being one size (2 mm) shorter. Correa et al[28] reported similar findings, but in their study the implant length decision was made using automated software based on measurements performed by three observers.

It was also found that the use of cross-sectional imaging significantly reduced the degree to which virtual implant threads were exposed on both buccal and lingual aspects compared with the use of PIref/3D alone. Using cross-sectional imaging, no thread exposure occurred for 62% of virtual implants on the buccal and

93% of virtual implants on the lingual aspect. Using PIrefs/3D, no thread exposure only occurred for 24.6% on the buccal and 54.1% on the lingual aspect. Similar results in this study suggested that using PIref/3D results in a significantly higher (57.4%) perceived need for these procedures compared with when XS is used for virtual planning.

The use of XS CBCT imaging with full 3D power significantly influences the choice of dental implant length and reduces the frequency of interpreting need for ridge augmentation compared with PIref/3D and virtual study models alone when used for virtual implant simulations in posterior bounded edentulous regions with up to two missing teeth. Following prosthetically acceptable criteria, the use of shorter implants can reduce the possibility of encroachment on adjacent anatomical structures, thus reducing the perceived need for ridge augmentation, and potentially reducing the surgical time, complexity, and cost of treatment.[30,31]

## CONCLUSIONS

Within the limitations of this study, it is concluded that virtual implant planning using XS imaging significantly changes the choice of implant length and the perceived need for ridge augmentation in posterior bounded edentulous regions of limited span compared with PIref/3D models alone. Although the current results support the concept that XS imaging provides valuable information in preoperative planning of dental implantation in this case scenario, prospective studies are needed to confirm these findings.

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