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# Cone beam analysis of the buccal bone associated with a dental implant: A tridimensional assessment case report

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**Objective:** This case report presents cone beam computed tomography (CBCT) three-dimensional (3D) assessment of the buccal bone associated with an implant. **Method and Materials:** A patient who had immediate implant replacement of a maxillary incisor received a CBCT examination after 6 months. The scanned volume was then subjected to segmentation of the buccal bone associated with the implant and to its three-dimensional rendering. **Results:** Virtual reconstruction allowed volumetric assessment of the buccal plate, and of the buccal marginal bone level. **Conclusion:** Creating a 3D virtual volume permits a comprehensive evaluation of the anatomical information contained in the CBCT dataset. *(Quintessence Int 2017;48:339–344; doi: 10.3290/j.qi.a37798)*

**Key words:** bone quantity, bone volume rendering, cone beam computed tomography

Evaluation of buccal bone thickness is a topic that receives much attention because it can influence the esthetic outcome of implants placed in the anterior region.[1,2] Various studies have investigated changes of the buccal plate thickness following a tooth extraction and its replacement with an implant. Strategies considered included immediate, early, or delayed implant placement, in combination with flapless or conventional surgical techniques. Such studies were performed in animals or humans. Typically, the evaluation of buccal bone thickness had been based on either direct measurement after flap elevation or histologic examination. Animal models allow thickness evaluation at planned time-points and regardless of the surgical protocol adopted.[3] Conversely, studies on humans have to limit observations to at placement and eventually at stage-two surgery.[4-7] It is also clear that possibilities to evaluate buccal bone volume at implants placed without a flap are very limited. In addition, measurements with caliper and probes may present questionable reproducibility because of the frequency of bone irregularities, and they are usually confined to measurement of changes at the top of the crest. Finally, a common restriction of both histologic and clinical examinations is that they are usually limited to evaluation of the bone thickness associated with the maximum implant diameter. As yet, the body of data has been considered insufficient to set a threshold for minimal bone thickness to ensure an optimal esthetic outcome.[1,2]

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A new possibility for investigating bone volumes associated with implants in a minimally invasive way is cone beam computed tomography (CBCT). Depending on the scanner employed, it has been shown that CBCT can produce measurements of buccal bone thickness greater than 0.8 to 1 mm that have a good resolution and accuracy.[8,9]

The aim of this case report is to demonstrate how CBCT can be used to evaluate buccal bone thickness associated with implants. CBCT single slice evaluation and a novel approach based on three-dimensional (3D) reconstruction are shown and discussed.

## METHOD AND MATERIALS

A Caucasian 50-year-old man presented seeking replacement of a single maxillary incisor. He was enrolled in a larger study on immediate implant placement approved by the institutional review board of the University of Pennsylvania (Protocol number 809472), as part of an observational prospective investigation on immediate implant placement. Following explanation of the study, the patient signed informed consent. Immediate implant placement was performed according to a protocol described previously.[10] In brief, an implant was placed into the fresh extraction socket and the provisional restoration placed immediately. Adequate stability was ensured by undersizing the apical portion of the osteotomy. The patient was scheduled for postoperative check-ups, and follow-up visits were planned every 6 months.

### Radiographic examination

CBCT examination of the anterior maxilla was performed after 6 months of follow-up. The equipment used (Kodak 9000 3D, Kodak) was set to 74 KV, 10 mA, 76 µm voxel resolution, a scanning time of 10.68 seconds, and to a 50 x 37 mm field of view (FOV). A radiologist aware of the aim of the study performed the examination.

### 2D bone thickness evaluation

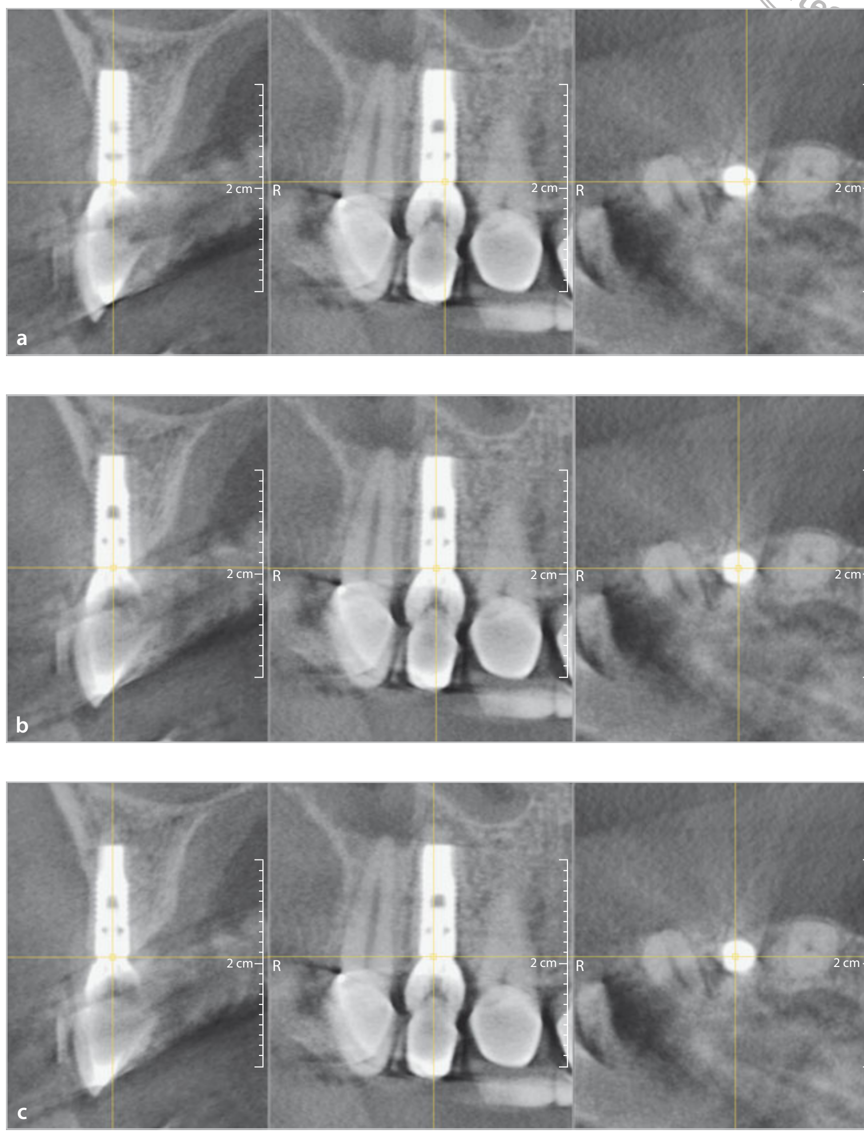
The CBCT dataset, as exported from the radiologic machine, was imported as 15 bit DICOM files into the MevisLab programming environment (MeVis Research; Fig 1). Using this software, the slices were reformatted so that the implant appeared perpendicularly reoriented and with the cortical bone plate perpendicular to the implant axis (Fig 1b). The volume was then displayed in axial, sagittal, and coronal viewing directions. In addition, a cross-hair instrument (in yellow in Figs 1 and 2) allowed selection of the same voxel on all the three displayed sections. One cross-section was taken at the implant midline and two slightly off center towards the left and the right (Fig 1). Cross-sections were then used to evaluate buccal bone dimension. Two additional cross-sections were obtained with different orientations of the scanned bone volume.

### 3D bone volume evaluation

The above-mentioned reformatted slices were then imported into software for image segmentation (ITK-Snap).[11,12] A region of interest was then created whose boundaries were the implant-abutment interface, the implant apex, and the implant diameter parallel to the buccal bone plate (Fig 3). This region of interest was subjected to semi-automated segmentation of the buccal bone. Image segmentation refers to a process of examining cross-sections of a volumetric dataset and outlining the structures of interest visible in these cross-sections. After segmentation, a 3D graphical rendering of the volumetric object was obtained and saved to an .STL file (Fig 3). This .STL file was imported into inspection software (Qualify, Geomagic) where the volume was divided into apical and coronal halves and also into distal, medial, and mesial thirds. For each of these six portions the corresponding bone volume was computed using Geomagic software (Fig 4). In addition, the whole buccal bone plate of the anterior alveolar process was segmented as above along with the associated dental implant (Fig 5).

## RESULTS

The implant was permanently restored 6 months following implant placement. It remained in function and symptom-free through a 24-month follow-up period. No complications were reported and the patient was

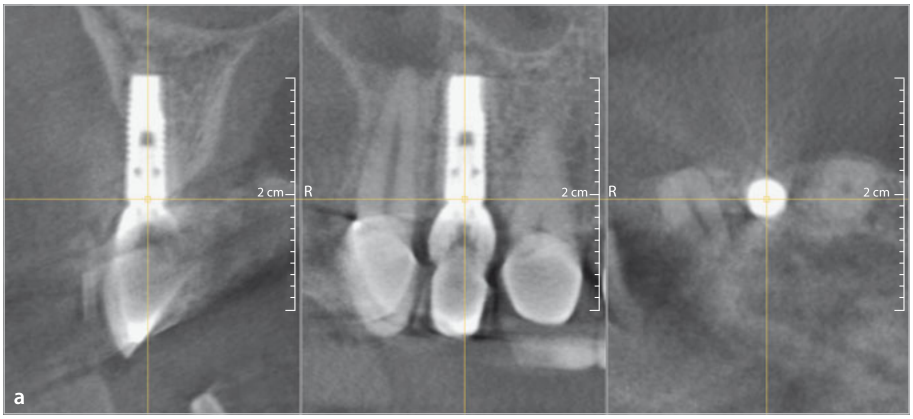


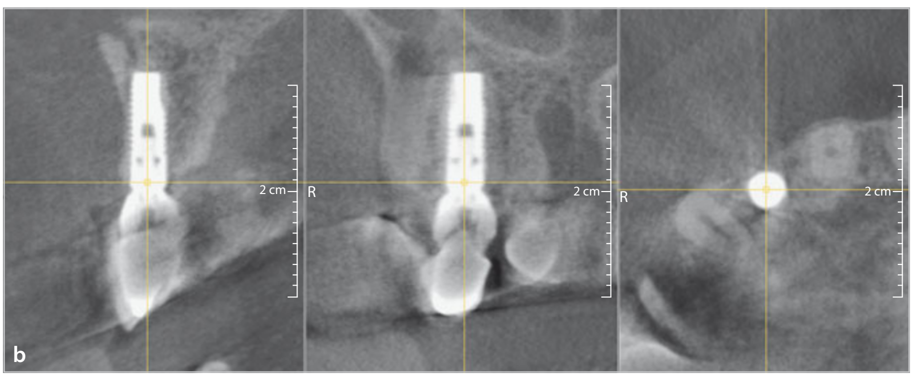

**Figs 1a to 1c** A 2D cross-section was made perpendicular to the buccal bone plate *(b)*. When this cross-section is correctly placed in the implant center, it may seem that the fenestration affects the whole bone plate associated with the implant. However, the fenestration affects only a narrow area and disappears when moving the cross-section mesially *(a)* or distally *(c)*. Yellow lines represent cross-hairs focusing all the three slide views onto the same location in the image volume.

satisfied with the treatment outcome. The CBCT examination, 6 months after placement, showed a narrow buccal bone fenestration that was located at the midline of the implant. When using the 2D analysis, the defect varied in appearance depending on the selected slice (Fig 1) and on the orientation of the scanned bone volume (Fig 2). Conversely, when using the 3D analysis, the bone associated with the dental implant could be assessed in detail and evaluated volumetrically (Fig 4). The 3D volume also allowed comprehensive observation of the buccal marginal bone level and evaluation of the extent of the defect in the context of the whole buccal bone plate (Fig 5).

## DISCUSSION

Evaluation of buccal bone thickness associated with dental implants using CBCT is a subject that is receiving increasing interest from researchers.[1,2] Nonetheless, a recent literature review on studies employing CBCT to evaluate the fate of maxillofacial bone grafts, pointed out how, despite the diffusion of the new imaging tech-




**Figs 2a and 2b** Effect of different orientations of the scanned bone volume (compare the right third of the two images) on the 2D cross-sections (left third). Although the cross-section lies in the implant center in both cases, the fenestration disappears in *(b)* because of the different bone volume orientation.

nique, the reproducibility and scientific impact of the investigations has not increased.[13] At present, CBCT data are most often used after reformatting in 2D images that can be scrolled in any plane and direction. However, it has been shown that the choice of contrast, the orientation of the plane used for cross-sections, and the slice thickness could influence the appearance of these 2D reconstructed images.[13] This is in agreement with the present report where the slice choice (Fig 1) and dataset orientation (Fig 2) influenced the 2D appearance of the buccal bone associated with an implant. It was also advocated that an ideal method should allow for visualization of the full bone profile for evaluation of the whole bone volume.[13] The present novel protocol for CBCT data analysis was set up with the aim of whole bone volume evaluation and it could be helpful in the investigation of the remodeling pattern and the dimensions of buccal bone at implants. An increased understanding of these aspects could aid optimization of the treatment strategy and outcome of implant-supported prostheses.

From the present case report, it appears that an effective way to exploit the new technology is through the use of software for segmentation and creation of a 3D model of the whole buccal plate associated with the implant. In this way, visualization and quantification of any dehiscence or fenestration that could develop following the initial period of bone remodeling would be possible. In addition, whenever serial CBCT images are available, it would be possible to quantitatively compare changes of the bone volume associated with the implant. Results from a series of studies on skeletal changes due to growth and orthodontic treatment suggest that the reproducibility of the segmentation process to create 3D models is good.[14,15] It should, however, be kept in mind that dental implants will generate artifacts when imaged with CBCT scanners. These artifacts will depend on the type of the scanner and also on the

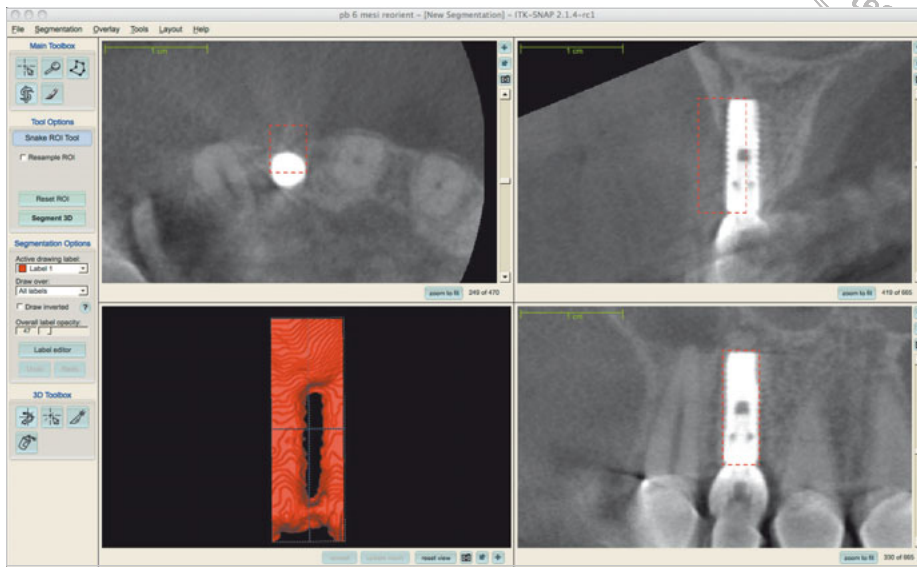


**Fig 3** Selection of the volume of interest undergoing segmentation for virtual volume creation (red dotted rectangles). Its boundaries are: implant-abutment interface; top of the implant, mesiodistal implant dimension. The resulting virtual bone volume (in red) shows the extent of the fenestration, and the morphology of the marginal bone level.

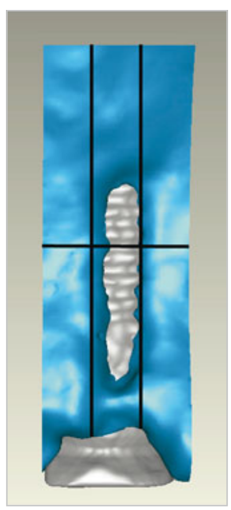


**Fig 4** A 3D rendering of the segmented implant and its associated buccal bone volume. An analysis of the bone volume was performed. From top left segment clockwise: apical distal: 14.6 $mm^3$; apical medial 7.86 $mm^3$; apical mesial 11.05 $mm^3$; coronal mesial 9.06 $mm^3$; coronal medial 1.79 $mm^3$; coronal distal 8.36 $mm^3$.

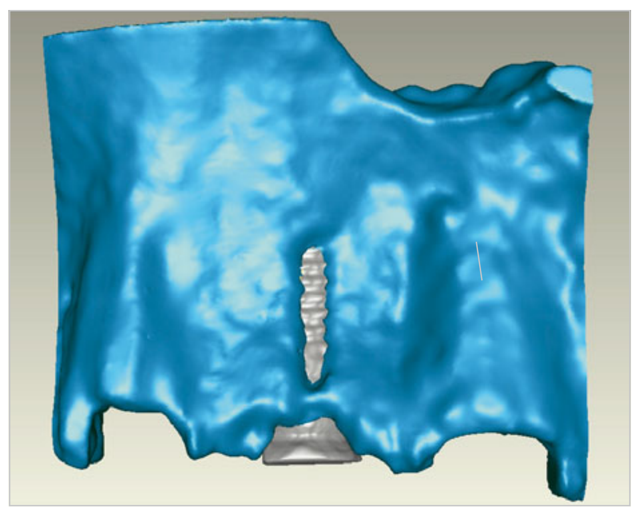


**Fig 5** A 3D rendering of a wider portion of the buccal bone plate and the associated dental implant. It is possible to assess the location of the fenestration and also the buccal marginal bone level.

thickness of the associated bone.[8,9] At present, therefore, very thin bone structures associated with a dental implant may not be visible on CBCT images and this would constitute a limitation regardless of the methodology for the analysis of the scanned CBCT volume.

A positive aspect of the ITK-Snap software employed is the possibility to allow for regional semi-automatic segmentation employing user-initialized deformable implicit surfaces that evolve to the most appropriate border between neighboring structures. The segmentation process, although started by the operator, is completed by the software.

Compared to conventional CBCT viewers that only allow the analysis of 2D slices, creating a virtual 3D model allows the clinician to analyze the bone volume of interest at a glance.[14] From a set of more than 300 axial cross-sectional slices, it is possible to build 3D virtual models.

The first step in image processing is to outline the shape of structures visible in the cross-sections of a volumetric data set, a process called segmentation. After the segmentation, a 3D graphic rendering of the volumetric object allows navigation between voxels in the volumetric image and the 3D graphics with zooming, rotating, and panning. Consequently, it is possible to easily evaluate the amount of bone volume associated with the implant. In addition, it is possible to assess the extent of fenestrations or dehiscences that otherwise would change in appearance in a 2D-viewing modality according to the selected cross-section (Figs 1 and 2).

In case dehiscences or fenestrations are present, their surface can be easily calculated by exporting the 3D virtual bone model into software for digital shape analysis. Also, marginal bone resorption at the implant can be evaluated in its extension and topography. Given the low bone volume associated with the implant, its segmentation and volumetric processing is not too time consuming. In addition, the software for volume segmentation and rendering is freeware and thus easily accessible.

In contrast, conventional 2D analysis of cross-sections, while easily performed with software associated with the CBCT equipment, relies on manual selection of the cross-sections, which is likely to make the process less accurate. Conventional 2D analysis, which is usually limited to a single cross-section, probably gives rise to a loss of information regarding bone morphology.

The present methodology would be of utility if evaluation is required of changes in bone thickness associated with the implant over time. Two-dimensional methodology relies on precise repositioning of the cross-section planes between scans at different time-points, and it also requires identical repositioning of the scanned bone volume. In contrast, when the bone volume is evaluated in 3D rendering, the above-discussed risk is not present because the whole buccal plate associated with the implant can be analyzed.

The principles of this technique of analysis have already been applied to some extent in two recent studies to assess the changes in buccal bone after extraction and the amount of buccal bone at dental implants.[16,17] It is foreseeable that a volumetric 3D CBCT method of analysis similar to the method presented in those studies will be useful in the assessment of bony portions subjected to remodeling related to pathology, post-extraction healing, or surgical augmentation.

## CONCLUSION

In conclusion, creation of 3D virtual volumes from CBCT could be useful in the evaluation of buccal bone morphology, and could help the understanding of its remodeling, stability, and its association with clinically relevant outcomes.

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