Cone Beam Volume Tomography: An Imaging Option for Diagnosis of Complex Mandibular Third Molar Anatomical Relationships

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Abstract

Complex impacted third molars present potential treatment complications and possible patient morbidity. Objectives of diagnostic imaging are to facilitate diagnosis, decision making, and enhance treatment outcomes. As cases become more complex, advanced multiplane imaging methods allowing for a 3-D view are more likely to meet these objectives than traditional 2-D radiography. Until recently, advanced imaging options were somewhat limited to standard film tomography or medical CT, but development of cone beam volume tomography (CBVT) multiplane 3-D imaging systems specifically for dental use now provides an alternative imaging option. Two cases were utilized to compare the role of CBVT to these other imaging options and to illustrate how multiplane visualization can assist the pretreatment evaluation and decision-making process for complex impacted mandibular third molar cases.

The potential treatment complications and resultant patient morbidity associated with complex impacted "wisdom teeth" are well known. This reality was recently reiterated by a dental liability carrier, which indicated that claims for extractions rate highest in severity and frequency. When emphasizing prevention they indicated that recognizing the difficulty of the proposed extraction is paramount and one of the most important steps is to obtain appropriate radiographs.[1] What are appropriate radiographs or in current terms is appropriate imaging for impacted molars?

The intent of radiographic imaging is to provide an intraosseous view of related structures. Important for assessing

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the treatment complexity, prior to extracting impacted third molars, is its location and position to other structures such as the mandibular canal, adjacent teeth, sinus walls, and cortical borders. In addition, the assessment determines the presence or absence of pathologic conditions and can be beneficial for predicting treatment outcomes.[2] Failure to adequately determine these relationships leaves both the dental surgeon and the patient uninformed of the associated risks, a situation which is well documented by a variety of undesirable treatment outcomes such as nerve damage, bleeding, sinus perforations, and jaw/tooth fractures.

Therefore, proper interpretation of acquired images is essential for treatment success. Unfortunately, interpretation of complex 3-D anatomical relationships is sometimes difficult due to inherent limitations associated with 2-D conventional imaging systems. Valmaseda-Castellon and associates[3] studied the correlation between interpretation of panoramic radiographs and treatment outcomes of 1,117 mandibular third molar post-extraction cases. They found that inferior alveolar nerve damage increased with patient age, deflection of the molar roots when approaching the mandibular canal, proximity of root apices to the mandibular canal, and the need to perform a distal ostectomy. Their assessment criteria are similar to those described by several other current studies.[4-6] While such criteria can be useful to the treating surgeon, actual pretreatment visualization is still lacking.

Tomography is the imaging method use to overcome the limitations of 2-D interpretation. It can be simple film tomography, which provides images made at right angles to one another or complex as with computed tomography (CT) scanners. Although better than the traditional intraoral/panoramic 2-D view, the simple methods still have some inherent film imaging problems such as blurring, appropriate exposure techniques, imprecise site location, varying magnification and image data is limited to the film. This is adequate for routine cases but limiting for the complex cases where the potential for volume analysis and patient modeling could enhance the diagnostic process. Use of CT overcomes these limitations. The computer-generated image better portrays 3-D anatomical truth and as a result, spatial relationships of anatomical structures can be measured, tissue densities evaluated, and image models made. Because of this, CT has become increasing more common for dental imaging.

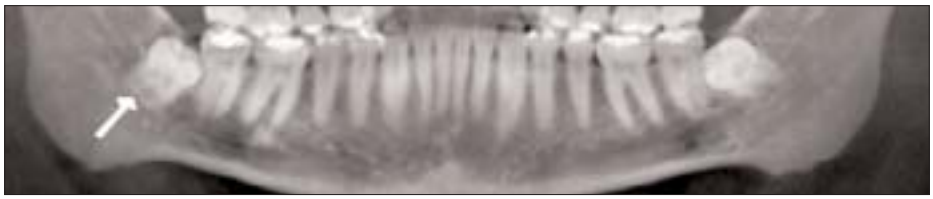

Figure 1a. Mandibular panoramic reconstructed (12 mm thick) from volume imaging. Right third molar is area of interest. Arrow shows superimposed image of nerve canal upon the root apices.

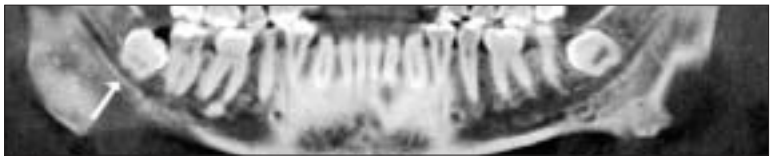

Figure 1b. Similar mandibular reconstruction as 1A, but image thickness is only 1 mm. Nerve canal outline is more pronounced and roots seem to have disappeared (arrow).

Figure 1c. Enlargement of right third molar ROI. Nerve canal highlighted white.

Despite these advantages, there have been some drawbacks to CT use in dentistry such as access to medical imaging centers, examination costs, and radiation dose to the patient. Because of these limitations and drawbacks, a technology "gap" exists between these tomography options. Recently, several new 3-D imaging systems using cone beam volume tomography (CBVT) have been developed specifically for dental use. These systems appear to bridge the technology gap providing alternatives to film radiography and CT. More common in the European and Asian mar-

Figure 1d. Sagittal (distal-mesial) views of right molar ROI. A composite of noncontiguous selected 1 mm imaging layers moving from most buccal (left image) to most lingual (right image). Nerve canal observation begins as root apices start to disappear (short arrow) and is most delineated in next more lingual image (large arrow).

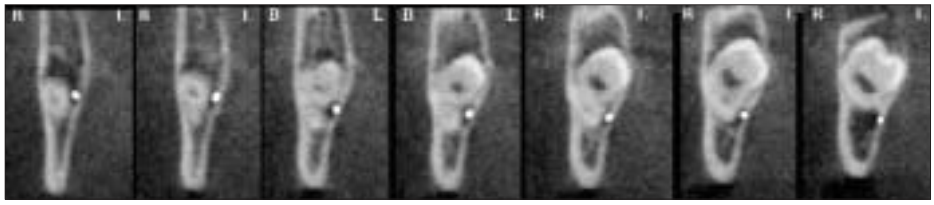

Figure 1e. Coronal/cross-sectional (buccal-lingual) views of right molar ROI. A composite of noncontiguous selected 1 mm layers moving from most posterior (left image) to most anterior (right image). Nerve canal (white dots) show canal lingual to root apices, but in mid-region the roots curve to the lingual somewhat enveloping the passing canal.

kets, some are now commercially available in the U.S. and others will be soon. Purchase price ranges from $200,000 to $300,000. Although a few have been installed in private dental offices, most are in dental imaging centers or dental schools. Current use suggests CBVT imaging will play a major role in the future of dental imaging.

The intent of the article is to present two case reports as examples of how one of these devices (Newtom 9000, Aperio Services Inc., Sarasota, Fla.) is currently being used in the diagnosis and treatment planning of impacted third molars.

CBVT Examination Procedures

Patients were referred to the dental imaging center for the scanning procedure. The Newtom 9000 performs a 75-second scan to obtain patient image data for a maxillofacial volume extending approximately from the lower orbit to just below the inferior border of the mandible. Images are reconstructed without magnification, size or shape distortion from a full maxillofacial volume scan made with a 0.3 mm voxel size and eight-bit grayscale resolution. Once the raw data is reconstructed, patient 3-D multiplane images or image models can be viewed and image data is transferred to the referring dental office. Patient effective dose per examination has been measured to be 50 μSv[7] similar to that for a standard complete-mouth intraoral periapical survey.[8]

Illustration Case I

The patient was a 24-year-old man who went to the oral surgeon for possible removal of his unerupted right mandibular third molar. He had been suffering with chronic pericoronitis for the past year. At the consultation appointment, a panoramic radiograph was made and it showed the mandibular nerve to disappear at the apical one-third of the impacted molar. This raised an immediate concern that the nerve canal may be encased within the root apices presenting a significant risk for nerve damage during the extraction of the tooth. The decision to extract the tooth was postponed until the patient could receive a 3-D volume imaging examination.

Image Analysis of the Impacted Right Mandibular Third Molar

Concern focused upon whether or not the nerve canal passed through the root bifurcation. **Figure 1a**, a 12 mm-wide/thick reconstructed mandible panoramic image, confirmed (white arrow) the findings of the initial panoramic radiograph. The effect of using a narrower tomographic image can be seen with **Figure 1b**. This image is 1 mm in width and while delineation of the nerve canal had become more pronounced, the roots seem to have disappeared or become shorter. Since the anatomical volume of the molar and nerve are much greater than 1mm, the entire region of interest (ROI) required evaluation of multiple image layers/slices in various planes to construct an accurate 3-D view for determining the actual relationship of the nerve canal to the root apices. **Figure 1c** is an enlargement of this area, showing the use of the machine's software program paint tool to mark

areas of interest with color identification. In this case, the nerve canal had been color marked (red original, white for this article) and this marker is then carried to any other image reconstruction so that anatomical relationship can be accurately determined regardless of the plane of viewing.

3-D Reconstruction of ROI

A series of 1 mm thick image layers were made by the computer in a "step-by-step" approach to reconstruct the ROI into a 3-D view. The images are generally made at 90 degrees to each other. **Figure 1d** is a composite example of multiple sagittal (distal–mesial) plane images which displayed the anatomical changes that occurred as viewing moved from the buccal surface (left images) to the lingual (right images). Following the images from left to right, showed the root apices appeared first and started to disappear as the nerve canal came into view suggesting that the roots apices were buccal to the canal. The best view of the nerve canal (large arrow) lacked the apical half of the molar supportive of the previous image interpretation. While these views were similar to the panoramic in **Figure 1a**, the ability to see individual incremental layers resulted in a completely different interpretation.

This interpretation was support by the cross-sectional/coronal images of **Figure 1e**. These images were made at 90 degrees to the previous sagittal views and were similar to what is done for dental implant imaging of the mandible. In this case, the diagnostician started the review from the posterior/distal segments (left image) and followed the nerve canal (white dot) anterior as it passed the molar to the final image (most right). It was observed that the nerve canal remained lingual to the molar in all images but at the mid-range, it appeared that the molar roots curved to the lingual and partially enveloped the canal. Such a visual finding was not available with any form of panoramic imaging. In this case, beside the 90-degree cross- sectional/coronal images being supportive to the imaging seen in **Figure 1d**, it was also additive because the lingual hook of the root apices was clearly seen.

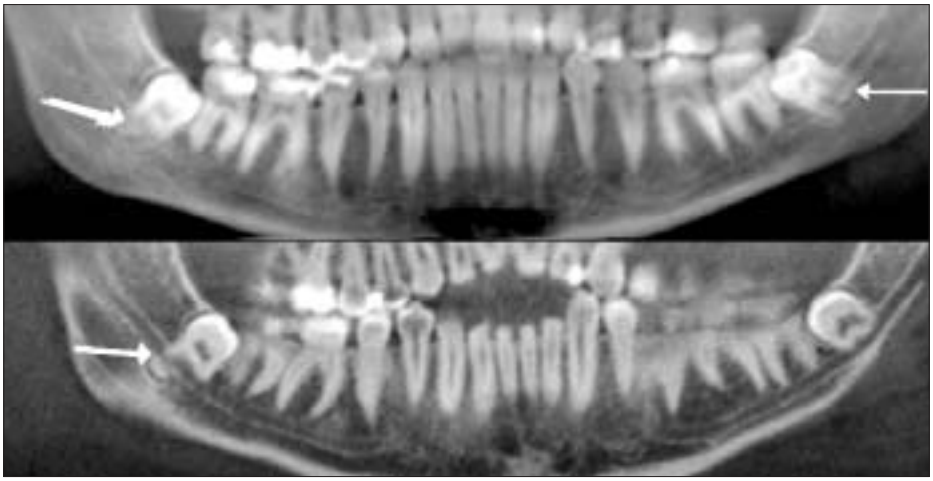

Figure 2a. Mandibular panoramic reconstructed from volume imaging (image layer top-12 mm thick, lower, 1 mm). Right third molar is selected ROI. Left arrows show superimposed image of nerve canal upon the root apices and distal curve of root.

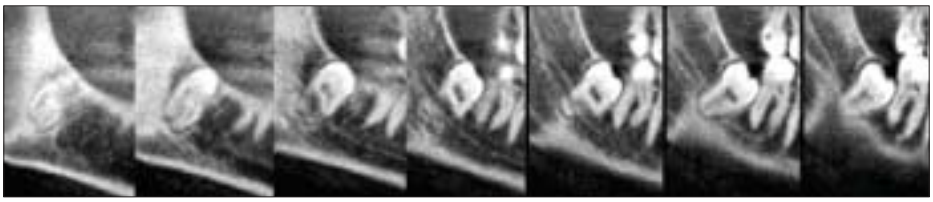

Figure 2b. Sagittal (distal-mesial) views of right molar ROI. A composite of contiguous selected 1 mm imaging layers moving from most buccal (left image) to most lingual (far right). Nerve canal seen (arrow) show a slightly altered pathway and appears partially encased by root apices.

Surgical Observations

After reviewing the images, the decision was made to proceed with the extraction to resolve the chronic pericoronitis problem. A cautious conventional surgical protocol was used enabling the tooth to be successfully removed without damaging the mandibular nerve canal and as a result, the patient did not sustain any neurological defect. Upon inspection of the extraction site, the nerve canal was located exactly as it was shown by the volume scan examination.

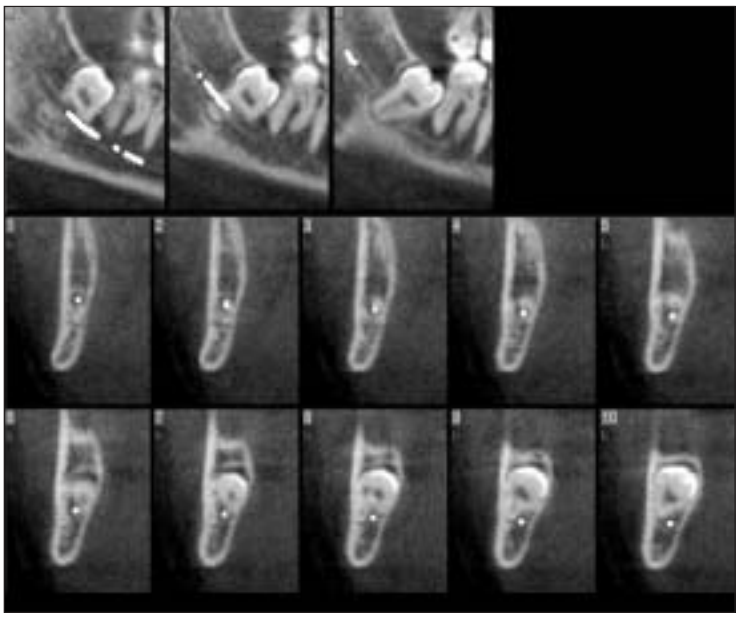

Figure 2c. Selected sagittal views with paint tool (top) and contiguous 1 mm coronal/cross-sectional views (frames 1-10). Nerve canal (white dot) appears partially encased by root apices (frames 3-6).

Illustration Case 2

A 23-year-old female patient was referred to the oral surgeon for extraction of all four third molars. Her chief complaint was about pressure from the maxillary molars, which she claimed occasionally gave her headaches. Although the mandibular third molars were asymptomatic, she wanted all of the thirds molars removed since she was relocating and dental benefits might not be available. A panoramic radiograph made at the consultation appointment showed the mandibular nerve passing through the middle of the third molar roots, raising concern that the nerve was encased with the roots posing significant risk for damage if the teeth were extracted. Although there was no immediate plan for removing these teeth, the patient agreed to a volume imaging scan to better understand the nerve and root relationship for future reference in case the teeth became symptomatic.

Image Analysis of the Impacted Right Mandibular Third Molar

The patient was referred for a 3-D volume imaging examination when the initial panoramic radiograph indicated that the mandibular nerve canal might go through the root bifurcation of both the right and left impacted mandibular third molars. **Figure 2a** (top) was the 12 mm reconstructed mandible panoramic image which confirmed (white arrows) the findings of the initial panoramic radiograph. The lower 1 mm image further defined the problem when it can be seen that the nerve canal appeared surrounded by the right molar root apices (arrow, lower). The right molar was selected as the ROI for 3-D evaluation.

3-D Reconstruction of ROI

Selected contiguous 1mm sagittal views can be seen in **Figure 2b**. The most buccal image (far left) showed that the apical portion of the root came into view first. As viewing moved more lingual to the right, the complex relationship of the nerve canal and the root apices could be seen in image frames 3-5. The root appeared curved and there was deviation of the nerve canal in frame 3. In frame 4, the canal was better delineated, but still had a superior portion covered by the root. Frame 5 best showed the apparent "grip" (arrow) the root had upon the nerve canal as it passed through the molar. The last two frames indicated that most of the coronal portion of the molar was lingual to the nerve canal. **Figure 2c** was a composite of selected sagittal views, which showed the color identification marker of the nerve canal and a series of 1 mm contiguous cross-sectional/coronal views (images 1-10). The first image frame was the most posterior and showed only the tips of the distally inclined root. As the view moved more anterior toward frame 10, the outline of the root apices and position of the nerve canal became more complex. This was best seen with frames 3-6 where the nerve canal seemed almost encased by the root apices. Finally, as the canal exits past the molar (frames 7-10), it can be seen inferior and somewhat centrally positioned to the coronal portion of the tooth.

Scan Consultation

The volume scan validated the panoramic concerns that indeed the nerve was encased with the roots of the third molars. The patient appreci-

ated having done the scan imaging and made an informed decision to postpone extraction of the mandibular molars.

Discussion

CBVT is an emerging technology for dentistry that offers alternative imaging options between standard film radiography and tomography, and medical CT. The case examples illustrate how computer-assisted imaging provided multiplane viewing and tracking of the mandibular canal through various image planes. Such imaging capabilities not possible with standard film radiography or tomography are available with CT, but at a higher patient dose and examination fees. The patient effective dose from a CT dental implant scan measured specifically for the mandible is most comparable to that for a full volume Newtom 9000 scan. Several studies report the mandibular effective dose for dental implant CT to range from 123 µSv to 528 µSv.[9-12] This is several times greater than the 50 µSv[7] reported for the Newtom 9000 full volume scan. Fees for a CBVT examination may vary from $250 to $350. Generally, this would be slightly higher than for a film tomography examination (estimated range $150 to $250) and less than CT (about $300 to $800).

The Newtom 9000 CBVT imaging proved beneficial for both pretreatment evaluation and surgical risk assessment. Based upon the imaging, the first patient made an informed decision to proceed with the surgery, which was successful and verified the interpretation of the images. The second patient postponed extraction determining the surgical risk was greater than the benefit of removing the asymptomatic impacted molar.

Conclusion

CBVT is a an emerging technology that provides computer-assisted multiplane imaging for complex mandibular third molar surgical cases and is a lower dose alternative option to medical CT. CDA

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