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Personal Computer-Based Three-Dimensional Computed Tomographic Images of the Teeth for Evaluating Supernumerary or Ectopically Impacted Teeth

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ABSTRACT

This study describes the use of personal computer (PC)–based three-dimensional computed tomographic (3D CT) images in the evaluation of supernumerary and ectopically impacted teeth. Three selected cases were presented as examples of the more complex cases in which 3D CT imaging added information not readily available from periapical, occlusal, or panoramic radiographs. Patients were CT scanned from the occlusal plane to the periapical region of the impacted teeth. Digital Image and Communications in Medicine CT data were transferred to a personal laptop computer using a network line. 3D volume rendering was performed using PC-based volumetric analysis software. 3D CT–reformatted imaging of the teeth is a useful way to investigate and localize supernumerary or impacted teeth. Newer software that enables this investigation using a PC provides a relatively inexpensive way to carry out such investigations, making it easier for dental practitioners to request such investigations and to view the results in real time in their own offices.

KEY WORDS: 3D CT, Diagnostic imaging, Image processing, Computer-assisted imaging.

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INTRODUCTION Return to TOC

Supernumerary teeth and ectopically impacted teeth are not rare anomalies of the maxillofacial complex.[1] Associated complications that have been reported include interference with the eruption of adjacent teeth, crowding and displacement of these teeth, formation of diastemata, root resorption, dentigerous cyst formation, and loss of vitality of the adjacent teeth associated with severe root resorption.[2–5] Most cases of supernumerary and ectopically impacted teeth are asymptomatic and are found during routine clinical or radiological investigations. Indeed, radiographs are important in assessing the location and nature of these anomalies. Usually, the required information can be obtained from periapical, occlusal, or panoramic radiographs (or all), but sometimes these cannot provide complete information on the three-dimensional (3D) relationship of the supernumerary and ectopically impacted teeth to associated teeth and adjacent structures or about the associated complications.

Computed tomography (CT) has been used to obtain more detailed information about these anomalies.[6–10] Although conventional two-

dimensional (2D) CT offers more useful information for diagnosis and treatment planning than conventional radiographs, sometimes it is difficult to see the entire extent of the impacted tooth root and its relationship to adjacent teeth. 3D CT images using newer software can overcome this limitation of 2D CT. Conventional 3D CT images, such as surface rendered 3D CT jaw images, do not show the roots of the teeth in 3D because they are masked by the outer bony structures.

Recently introduced 3D CT software enables 3D visualization of the root portion of the teeth through use of a differential in the threshold level of bone and the teeth. Additionally, recent developments in computer hardware and software have enabled the dental practitioner to view, postprocess, and rotate the 3D images of the teeth using a personal computer (PC) in the dental office.

This study describes the use of PC-based 3D CT images in the evaluation of supernumerary and ectopically impacted teeth.

MATERIALS AND METHODS Return to TOC

Three cases of supernumerary or ectopically impacted teeth (or both) from our Dental Hospital are presented. These were selected as examples of the more complex cases in which 3D CT imaging added information about possible resorption of adjacent teeth or relationships of the teeth to neighboring structures not readily available from periapical, occlusal, or panoramic radiographs.

CT scans were obtained in a high-speed CT system (CT HiSpeed Advantage, GE Medical Systems, Milwaukee, Wis), at 200 mAs and 120 kV, using the helical (spiral) scanning mode with 1:1 pitch, the high-resolution bone algorithm, a 9.6-cm field of view, and 1 mm scanning slice thickness. Patients were scanned in the supine position, from the occlusal plane to the periapical region of the impacted teeth.

The acquired 2D CT DICOM (digital image and communications in medicine) data were sent to a personal laptop computer (Toshiba Satellite 3000, Tokyo, Japan) with an Intel Pentium III 1.13 GHz CPU, 512 MB RAM, a 20-GB hard drive, the Microsoft Windows XP OS, and a GeForce2 Go graphic card (Nvidia Co., Santa Clara, Calif) installed. Reformatted 3D images of the jaw and teeth were created using Vworks™ 4.0 3D software (CyberMed Inc., Seoul, Korea).

RESULTS Return to TOC

Case 1

A 13-year-old male patient presented at our Dental Hospital with a chief complaint of delayed eruption of the right central incisor. The panoramic radiograph requested by the examining practitioner revealed two horizontally impacted permanent maxillary right teeth, a faciopalatally impacted central incisor, and an anteroposteriorly impacted canine (Figure 1).

CT images were requested to assist in localization of the markedly abnormally positioned teeth (Figure 2). To assist in localization and orientation of the teeth, reformatted 3D CT images were created and viewed interactively on a laptop computer (Figure 3).

3D CT images clearly showed the location of the impacted teeth, as well as the 3D relationship of the two impacted teeth to the adjacent teeth. In addition, they revealed a markedly superolaterally orientated dilaceration in the apical third of the root of the central incisor, which had not be seen on the panoramic and periapical radiographs because of superimposition of the two teeth. This information allowed us to modify the treatment plan.

Case 2

An eight-year-old female patient with a diagnosis of a supernumerary tooth, found on a routine radiographic examination without any previous signs or symptoms, was referred from a local clinic for CT investigation. The accompanying panoramic and periapical radiographs showed an inverted and impacted maxillary right permanent central incisor and an adjacent unerupted supernumerary tooth (Figure 4). The actual 3D relationship of the teeth was difficult to appreciate. Axial CTs, made for the definitive localization of the impacted tooth and supernumerary tooth, showed that the follicular spaces of the central incisor and the supernumerary tooth were somewhat enlarged (Figure 5).

3D CT–reformatted images created and viewed on a laptop computer clearly showed not only that the inverted impacted right central incisor and supernumerary tooth were located to the palatal side of the impacted central incisor but also showed the relationship of the teeth to each other (Figure 6).

Case 3

An 11-year-old female patient presented at our Dental Hospital with a chief complaint of delayed eruption of a permanent tooth. The panoramic and periapical radiographs requested by the examining practitioner revealed multiple supernumerary teeth associated with

crowding in both the maxillary and mandibular anterior tooth-bearing areas (Figure 7). To clarify the exact location of the supernumerary teeth and their relationships to the adjacent permanent incisors, as well as the relationships of the adjacent teeth to each other, CT images were acquired for 3D reformation (Figure 8).

3D CT–reformatted images, viewed interactively on a PC, revealed four supernumerary teeth located in the anterior portion of maxilla (Figure 9). Two were unerupted and malformed supernumerary teeth located to the palatal side of the labially positioned permanent central incisors. The remaining two supernumerary teeth were inverted and located to the palatal side of the two permanent lateral incisors. In the mandible, there was crowding in the area of the four permanent incisors, and two supernumerary teeth were seen in the permanent canine region (Figure 10). The 3D CT images allowed exact location of the supernumerary teeth and adjacent permanent teeth.

DISCUSSION Return to TOC

One of the most important causes of delayed eruption and impaction of teeth is supernumerary teeth in their eruption path. Before treatment planning, it is necessary to both accurately locate the supernumerary teeth and determine their relationship to the teeth of the normal dentition and anatomical structures in the area. Then, if the treatment plan indicates the necessity to extract the ectopically impacted teeth or supernumerary teeth, or to intervene orthodontically, it is important to determine the best surgical approach causing the least harm to adjacent tooth roots while minimizing trauma to surrounding tissues. Traditionally, periapical, occlusal, and panoramic radiographs have been used to make these determinations. However, in some cases, it is difficult to determine the exact buccolingual relationships of teeth and surrounding structures using these views alone.

CT is an imaging method that has proven to be superior to other radiologic methods in visualizing bone tissue. Comparisons among imaging techniques have shown that CT yields more detailed information than conventional radiography.[6–10] The image on a panoramic view consists largely of the anatomic structures located within the focal trough. Supernumerary or ectopically impacted teeth outside the focal trough are blurred, magnified, or reduced in size, sometimes to the extent of not being recognizable. Also, slumping of the cervical spine may cause a large radiopaque shadow to be superimposed on the midline region, the most common location of supernumerary teeth.[11] On some periapical and occlusal radiographs, assessment of the facial or lingual position of impacted teeth is possible using a tube-shift (parallax) technique. In others, a true occlusal (cross-sectional) view may provide this information. However, in cases of severe overlapping and superimposition of impacted teeth, or with multiple-impacted teeth, it may be impossible to determine the accurate location of the teeth relative to surrounding structures.

In contrast, CT clearly shows the intraosseous location, inclination, and morphology of impacted or supernumerary teeth, as well as distances from adjacent roots and teeth and between impacted teeth and cortical bone. Ericson and Kurol,[12] using conventional CT, compared the extent of root resorption of teeth adjacent to an impacted tooth and found it to be nearly identical to that on the actual specimen. Although, conventional 2D CT images offer more useful information for diagnosis and treatment planning than conventional radiography, sometimes, as in case 1, it is still difficult to see the entire extent of the impacted tooth root and its relationship to adjacent teeth. Reconstructed cross-sectional images in various planes, either from conventional CT data or spiral CT may be helpful,[13] but the limitations of 2D imaging remain.

Conventional 3D CT images, such as surface rendered 3D CT jaw images are useful for visualization of the entire structure under consideration and understanding of the anatomical relationships of associated structures. However, in the cases of impacted teeth in the jaws, it is difficult to see inside the jaws three-dimensionally. Recently introduced 3D image software that allows adjustment of the threshold level of the CT images, makes it is possible to subtract the teeth from the surrounding bony structures using the different attenuation coefficients of structures. However, one hindrance to its being widely used has been the fact that the workstation system was connected to the CT scanner with the special software for 3D imaging, making this type of reformatting and subtraction very expensive and limiting the time for routine access to the workstation by the clinician.

Continuous technological development of computers and software has allowed the use of PC-based 3D image software to produce subtracted 3D CT images of the teeth. The CT data can be sent to a PC using a direct connection, Internet line, or storage devices such as CD-ROM.

In the present cases, the 2D CT data were transferred in the DICOM image format to the GE Advantage Workstation (GE Medical Systems) through a network for further processing or data saving. Then these DICOM CT data were transferred to a personal laptop computer using a network line. Next, 3D volume rendering was performed using a PC-based volumetric analysis tool, Vworks™ 4.0 (CyberMed Inc.). Finally, the threshold level of the 3D image was adjusted to remove the surrounding bony structures, permitting the remaining images of tooth structures to be evaluated. What cannot be shown in the static images of this paper is that the 3D tooth images could be rotated in any direction, making possible a more thorough investigation (Figure 9). For example, in case 1, the entire figure of the severely dilacerated root of the impacted central incisor could be detected only on the rotated 3D tooth images. In case 2, 3D tooth images permitted orientation of the direction of the impaction, and in case 3, rotation of the 3D images of the teeth was helpful in differentiating supernumerary teeth from the normal dentition and localizing them within the crowded dentition.

One of the limitations of routine use of CT scanning is the possible increased radiation exposure of patients, compared with standard radiography, although this depends upon the protocols used in each type of imaging. This means that for any case where this CT imaging

is used there must careful consideration of the benefit–risk ratio.

The basic CT imaging protocol in this study was the same as the established imaging protocol of the middle ear CT examination requested by ENT specialists. However, the standard CT examination of middle ear consists of serial axial and coronal images, whereas in this 3D examination of the teeth only axial images are made, thereby reducing the patient's exposure to radiation. The CT scanning for this study was performed using a helical (spiral) scanning mode, 120 kV and 200 mAs. The total numbers of axial slices in case 1 was 27, in case 2 was 23, and in case 3, 30 for the maxillary teeth and 32 for the mandibular teeth. However, if the scanning were to be restricted to the impacted teeth and adjacent dental areas, the total number of scanning slices could be reduced even more. According to Dula et al,[14] the effective dose in CT scanning of 40 axial slices at 120 kV and 165 mAs is 0.58 mSv in the maxilla and 0.48 mSv in the mandible. According to Hong et al,[15] the effective dose in CT scanning at 120 kV and 240 mAs of 35 slices for maxilla is 0.452 mSv and 40 slices for mandible is 0.448 mSv. Although this gives an estimate of the magnitude of the effective dose for this study, the actual number would be much less because the total number of slices in this study was less than those used in either of those studies. As spiral or helical CT becomes widely used, there will be a further reduction in examination time and thus radiation dose (up to 75%).[16] There may be some limitations on dose reduction. It has been reported that various scanning protocols in CT can affect the quality of the reformatted images of the jaws.[17,18] Therefore, further study is needed to evaluate the effects of such variables as slice thickness, scanning mode, and mAs on the quality of 3D image of the teeth to find the most appropriate imaging protocol that balances clinically acceptable image quality with the lowest radiation exposure, to the patients, achievable.

CONCLUSIONS Return to TOC

3D CT–reformatted imaging of the teeth is a useful way to investigate and localize supernumerary or impacted teeth. Newer software that enables this investigation to be carried out using a PC provides a relatively inexpensive way to carry out such investigations, making it easier for dental practitioners to request such investigations and to view the results, including rotation of the images in real time in their own offices.

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FIGURES Return to TOC

Click on thumbnail for full-sized image.

FIGURE 1. Case 1. The panoramic radiograph shows an ectopically impacted maxillary right permanent central incisor (I) and canine (C), mesial tilting of the lateral incisor (L), and a retained deciduous canine (D)

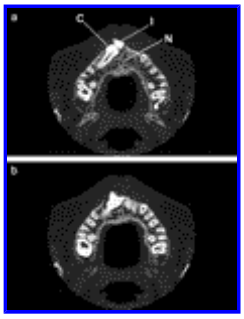

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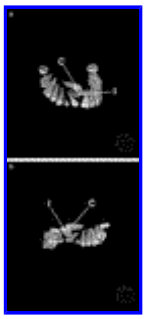
FIGURE 2. (**a**) and (**b**) Case 1. Axial CT scans show horizontal impaction of the maxillary right permanent central incisor (I) and canine (C) in close proximity to the nasopalatine canal (N). The coronal portions of these teeth are in intimate contact



Click on thumbnail for full-sized image.

FIGURE 3. Case 1. (**a**) anterosuperior and (**b**) posterior 3D CT images of the teeth show the spatial relationship of the impacted canine

(C) and dilacerated root of the horizontally impacted maxillary right permanent central incisor (I)

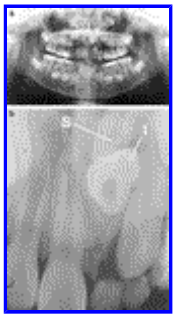


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FIGURE 4. Case 2. The ectopically impacted maxillary left permanent central incisor (I) and a supernumerary tooth (S) are seen on (**a**) the panoramic radiograph and (**b**) periapical radiograph. Dens invaginatus of the right permanent lateral incisor is also noted

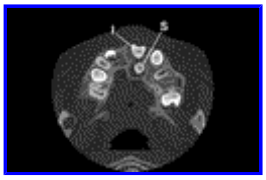

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FIGURE 5. Case 2. The axial CT scan shows an enlarged follicular space of both the impacted maxillary left permanent central incisor (I) and the palatally located supernumerary tooth (S) in proximity to the displaced nasopalatine canal (N)

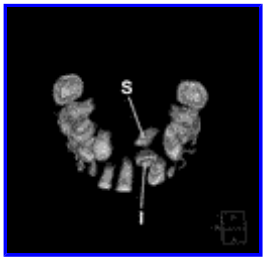

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FIGURE 6. Case 2. The 3D CT–reformatted image of the maxillary dentition shows an ectopically impacted maxillary left permanent central incisor (I) rotated at 90 degrees and a palatally located supernumerary tooth (S)

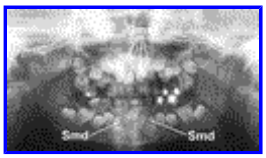

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FIGURE 7. Case 3. The panoramic radiograph shows multiple supernumerary teeth in the maxillary anterior area (Smx) and two supernumerary teeth, one in each mandibular canine region (Smd)

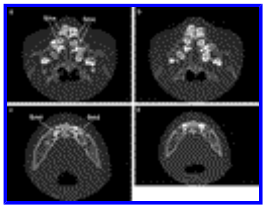

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FIGURE 8. (**a**), (**b**), (**c**), and (**d**) Case 3. The axial CT scans also show four supernumerary teeth in the maxillary anterior area (Smx) and

two supernumerary teeth, one in each mandibular canine region (Smd)

Click on thumbnail for full-sized image.

FIGURE 9. Case 3. The rotated 3D CT images of the maxillary dentition, right lateral, right lateral anterosuperior, anterosuperior, left lateral anterosuperior, left lateral, superior, and anterosuperior, anterior, anteroinferior, and inferior views, which are representative examples of images seen in real time rotation on the computer, show the exact location of the supernumerary teeth (S) as well as the degree of rotation and the eruption path of these teeth

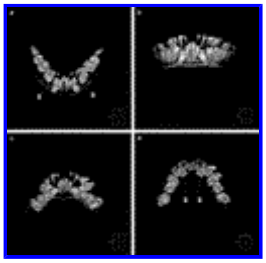

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FIGURE 10. (**a**), (**b**), (**c**) and (**d**) Case 3. Selected rotated 3D CT images of the mandibular dentition, anterosuperior (a), anterior (b), anteroinferior (c), and inferior (d) views of the mandibular dentition show the exact location of the supernumerary teeth (S) as well as adjacent permanent teeth

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