10.5005/jp-journals-10011-1132

REVIEW ARTICLE

Advanced Diagnostic Aids in Endodontics

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ABSTRACT

Conventional radiographs used for the management of endodontic problems yield limited information because of the two-dimensional nature of images produced, geometric distortion and anatomical noise. This newer review paper seeks to clarify three-dimensional imaging techniques that have been suggested as adjuncts to conventional radiographs. These include tuned aperture computed tomography, magnetic resonance imaging, ultrasound, computed tomography and cone beam computed tomography (CBCT).

Keywords: Cone beamed computed tomography, Endodontics, Imaging techniques, Magnetic resonance imaging, Tuned aperture computed tomography.

INTRODUCTION

Radiographic examination is an essential component of endodontic management aspects of diagnosis, treatment planning, intraoperative control and outcome assessment. Intraoral periapical radiographs are still most commonly exposed during endodontic procedures, providing useful information for the presence and location of periradicular lesions, root canal anatomy and the proximity of adjacent anatomical structures.

Despite their widespread use, periapical images yield limited information. The aim of this paper is to review these limitations before assessing alternative imaging techniques, which have potential to overcome some of these problems.

LIMITATIONS OF CONVENTIONAL RADIOGRAPHY FOR ENDODONTIC DIAGNOSIS

Compression of Three-dimensional Anatomy

Conventional images limit diagnostic performance.[1] Relationship of the root(s) to their surrounding anatomical structures and associated periradicular lesions cannot always be truly assessed.[2] The location, nature and shape of structures within the root under investigation become difficult to assess.[3] The relationship of the root to key adjacent anatomical structures should be understood.[4] However, it should be noted that multiple intraoral radiographs do not guarantee the identification of all relevant anatomy or disease.[5]

Geometric Distortion

Because of the complexity of the maxillofacial skeleton, radiographic images do not always accurately replicate the anatomy being assessed.[6] For accurate reproduction of anatomy, the image receptor (X-ray film or digital sensor) must be parallel to the long axis of the tooth.[7] The ideal positioning of solid-state digital sensors may be even more challenging as a result of their rigidity and bulk compared with conventional X-ray films and phosphor plate digital sensors.[8] But it should be noted that it is impossible to eliminate completely some degree of geometric distortion.[9]

Anatomical Noise

The more complex the anatomical noise, the greater the reduction in contrast within the area of interest with the result that the radiographic image may be more difficult to interpret,[10,11] because of which the relationship between histological features and radiographic appearances may be less clear.[12]

COMPUTED INFRARED THERMOGRAPHIC IMAGING

Several methods have been developed to assess pulpal blood flow, but none is presently suitable for routine use in clinical practice. Thermographic imaging (TI) is a noninvasive and highly accurate method of measuring the surface temperature of a body. Surprisingly, there have been very few reports concerning the usefulness of TI techniques in assessing the surface temperature of teeth as an indicator of pulpal blood flow. This technique is accurate and allows comparison of different areas of a tooth.

A suitable device for infrared thermographic imaging is Hughes Probeye thermal video system. This camera is capable of detecting temperature changes as small as 0.1°C over a wide temperature range at a range of distances from the subject. Using this device, Pogrel et al showed that the temperature of upper incisors decreased from gingival margin to the incisal edge by approximately 2.5°C. Teeth with vital and nonvital pulp were the same temperature at rest, but, after cooling with cold air, teeth with nonvital pulp were slower to rewarm than vital teeth.[13]

DIGITAL SUBTRACTION RADIOGRAPHY

Digital subtraction radiography (DSR) has made a significant improvement in detection of dental and maxillofacial lesions. With conventional radiography, a change in mineralization of 30 to 60% is necessary to be detected by a radiologist, also the lesions restricted to cancellous bone could not be detected because of its less mineral contents than the cortical bone, but with DSR the alveolar bone changes of 1 to 5% per unit volume and significant differences in crestal bone height of 0.78 mm can be detected.[14]

DSR is a method that can resolve deficiencies and increase the diagnostic accuracy. Subtraction methods were introduced by BG Zeides des Plantes in the 1920s. Subtraction imaging is performed to suppress background features and to reduce the background complexity, compress the dynamic range, and amplify small differences by superimposing the scenes obtained at different times.[15] This method provides more accuracy in the assessment of bone formation or resorption during or after root canal treatment.

LASER DOPPLER FLOWMETRY

Vascular supply is the most accurate marker of pulp vitality. Tests for assessing vascular supply that rely on the passage of light through a tooth have been considered as possible methods for detecting pulp vitality. Laser Doppler flowmetry (LDF), which is a noninvasive, objective, painless, semiquantitative method, has been shown to be reliable for measuring pulpal blood flow.

When used to assess the vitality of teeth, the size of the flux signal obtained from healthy vital control tooth can be compared with that of the suspected nonvital tooth. The flux signal from a tooth with a vital pulp should be greater than that of tooth with a nonvital pulp.[16]

LDF has been used in measurements for:

1. Estimation of the pulpal vitality: In treatment planning, it is important to assess the pulpal status of individual teeth when making a differential diagnosis of dental pain.
2. Pulp testing in children: Sensibility tests are not reliable in children, because they are subjective and rely upon the patient response.
3. LDF can help monitor age-related changes. Using this system, it has been shown that the hemodynamics in the human pulp is reduced with age.
4. Monitoring of reactions to local and systemic pharmacological agent.
5. LDF can be used for monitoring of reactions to electrical or thermal pulp stimulation.
6. Another indication of LDF is in monitoring pulpal reactions to orthodontic procedures.
7. Measuring of PBF after traumatic injuries.
8. Monitoring of revascularization of replanted teeth.

The major advantages of LDF are that it is noninvasive, and that measurements may be made continuously. The major disadvantages of LDF are that the measurements are sensitive to artefacts, such as movement or pressure, and that the equipment necessary for this procedure is bulky and costly.

PULSE OXIMETRY

Pulse oximeter is a noninvasive oxygen saturation monitoring device widely used in medical practice for recording blood oxygen saturation levels during the administration of intravenous anesthesia through the use of finger, foot or ear probes. It was invented by Takuo Aoyagi, a biomedical engineer working for the Shimadm Corporation in Kyoto, Japan, in early 1970s.

Pulse oximeter uses red and infrared wavelengths to transilluminate a tissue bed, detecting absorbance peaks due to pulsatile blood circulation and uses this information to calculate oxygen saturation and pulse rate.

Pulse oximetry takes advantage of absorption coefficient difference to monitor saturation and pulse rate with a single sensor placed on the patient's extremity, and a plethysmograph to measure arterial oxygen saturation in a pulsating vascular bed such as that of a finger. By using the two wavelengths, the difference between Hb and Hbo concentrations can be calculated. The expansion and relaxation of the pulsating vascular bed creates a change in the length of the light path modifying the amount of light detected.

Despite its advantages, limitations include background absorption associated with venous blood and tissue constituents, which should be differentiated. In addition to the absorption, refraction and reflection also occur as in Penumbra effect, which is seen in patients with strong tissue pulsations, where some of the light reaches the photodetector diode without passing through the tissue bed.

THREE-DIMENSIONAL IMAGING

Tuned-Aperture Computed Tomography

Tuned-aperture computed tomography (TACT) works on the basis of tomosynthesis.[17] Claimed advantages of TACT over conventional radiographic techniques is that the images produced have less superimposition of anatomical noise over the area of interest. The overall radiation dose of TACT is not greater than 1 to 2 times that of a conventional periapical X-ray film.

The resolution is reported to be comparable with two dimensional radiographs. Webber and Messura (1999) concluded that TACT was 'more diagnostically informative and had more impact on potential treatment options than conventional radiographs'.[17] Nance et al (2000) compared TACT with conventional radiographic film to identify root canals in extracted mandibular and maxillary human molar teeth. With TACT, 36% of second mesiobuccal (MB 2) canals were detected in maxillary molar teeth and 80% of third (mesiolingual) canals were detected in mandibular molars.[18]

It may be concluded that the complex nature of the adjacent anatomy around posterior maxillary molar teeth limits the use of TACT.[9]

The diagnostic accuracy of TACT is superior to conventional two-dimensional radiography for the detection of vertical root fractures. TACT appears to be a promising radiographic technique for the future.[19,20]

Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) scan is a specialized imaging technique which does not use ionizing radiation. It involves the behavior of hydrogen atoms within a magnetic field which is used to create the MR image.[21,22]

The accuracy of MRI was similar to CT. MRI scans are not affected by artifacts caused by metallic restorations (for example amalgam, metallic extracoronal restorations and implants) which can be a major problem with CT technology. MRI may be useful to assess the nature of endodontic lesions and for planning periapical surgery.[23,24]

MRI has several drawbacks. These include poor resolution compared with simple radiographs and long scanning times, in addition to great hardware costs and limited access only in dedicated radiology units. Different types of hard tissue (for example enamel and dentine) cannot be differentiated from one another or from metallic objects; they all appear radiolucent. It is for these reasons that MRI is of limited use for the management of endodontic disease.

Ultrasound

Ultrasound (US) is based on the reflection (echoes) of US waves at the interface between tissues which have different acoustic properties.[25] The greater the difference between tissues, the greater the difference in the reflected US energy and the higher the echo intensity. Tissue interfaces which generate a high echo intensity are described as hyperechoic (e.g. bone and teeth), whereas anechoic (e.g. cysts) describes areas of tissues which do not reflect US energy. Typically, the images seen consist of varying degrees of hyperechoic and anechoic areas as the areas of interest usually have a heterogeneous profile. US may be used with relative ease in the anterior region of the mouth, the positioning the probe is more difficult against the buccal mucosa of posterior teeth.[26,27]

In addition, the interpretation of US images is usually limited to radiologists who have had extensive training in the use and interpretation of US images.

Computed Tomography

Over the last three decades, there have been considerable advances in computed tomography (CT) technology. Current CT scanners are called multislice CT (MSCT) scanners and have a linear array of multiple detectors, allowing 'multiple slices' to be taken simultaneously, as the X-ray source and detectors within the gantry rotate around the patient who is simultaneously advanced through the gantry. This results in faster scan times and therefore a reduced radiation exposure to the patient.[28] The position and inclination of the root within the mandible could only be assessed using CT. CT should be considered before the surgical treatment of mandibular premolars and molars when on the dental radiograph the mandibular canal is not visible or in close proximity to the lesion/ root.[29] Information obtained from CT is essential for decision-making in surgical retreatment, for example, whether to approach the palatal root palatally or buccally.[30]

The uptake of CT in endodontics has been slow for several reasons, including the high effective dose and relatively low resolution of this imaging technique.[31] Other disadvantages of CT are the high costs of the scans, scatter because of metallic objects, poor resolution compared with conventional radiographs and the fact that these machines are only found in dedicated radiography units (for example hospitals).

Cone Beam Computed Tomography

Cone beam computed tomography (CBCT) or digital volume tomography is an extraoral imaging system which was developed in the late 1990s to produce three-dimensional scans of the maxillofacial skeleton at a considerably lower radiation dose than CT.[32]

The image quality of CBCT scans is superior to helical CT for assessing the dental hard tissues (Hashimoto et al).[33,34]

CBCT is a major breakthrough in dental imaging. For the first time, the endodontist is able to use a patient-friendly imaging system to easily view areas on interest in any plane rather than being restricted to the limited views available up to now with conventional radiography. CBCT technology is increasingly being used successfully in endodontics.

CONCLUSION

- Even with the best intentions and refined technique, images acquired using conventional intraoral radiographs reveal information in two-dimensions only (height and width). Valuable and relevant information in the third dimension (depth) is limited.
- Because of the inherent problems of positioning image receptors in the ideal position in relation to the anatomical area of interest, it may not be possible to obtain an accurate, undistorted view of the area of interest.
- The detection and assessment of the true nature of endodontic lesions and other relevant features may be impaired by adjacent anatomical noise. The effect of this anatomical noise is unique for each patient and is dependent on the degree of bone demineralization, size of the endodontic lesion and the physical nature of the anatomical noise (i.e. its thickness, shape and density of the overlying anatomy).
- Serial radiographs taken with the paralleling technique are not always consistently reproducible. This may result in under or overestimation of actual healing or failure of endodontic treatment.

REFERENCES

1. Webber RL, Messura JK. An in vivo comparison of digital information obtained from tuned aperture computed tomography and conventional dental radiographic imaging modalities. Oral Surg, Oral Med, Oral Pathol, Oral Radiol and Endod 1999;88: 239-47.
2. Cotti E, Vargiu P, Dettori C, Mallarini G. Computerized tomography in the management and follow-up of extensive periapical lesion. Endodontics and Dental Traumatology 1999;15:186-89.
3. Cohenca N, Simon JH, Roges R, Morag Y, Malfaz JM. Clinical indications for digital imaging in dentoalveolar trauma. (Part 1): Traumatic injuries. Dental Traumatology 2007;23:95-104.
4. Velvart P, Hecker H, Tillinger G. Detection of the apical lesion and the mandibular canal in conventional radiography and computed tomography. Oral Surg Oral Med Oral Path and Endod 2001;92:682-88.
5. Barton DJ, Clark SJ, Eleazer PD, Scheetz JP, Farman AG. Tuned-aperture computed tomography versus parallax analog and digital radiographic images in detecting second mesiobuccal canals in maxillary first molars. Oral Surg Oral Med Oral Path Oral Radiol and Endod 2003;96:223-28.
6. Grondahl HG, Huumonen S. Radiographic manifestations of periapical inflammatory lesions. Endodontic Topics 2004;8: 55-67.
7. Walker RT, Brown JE. Chapter 4, Radiography. In: Stock C, Walker R, Gulabivala K, (Eds). Endodontics (3rd ed). Philadelphia, PA, USA: Mosby 2005;77-92.
8. Wenzel A. A review of dentists' use of digital radiography and caries diagnosis with digital systems. Dentomaxillofacial Surgery 2006;35:307-14.
9. Lofthag-Hansen S, Huumonen S, Gröndahl K, Gröndahl HG. Limited cone-beam CT and intraoral radiography for the diagnosis of periapical pathology. Oral Surg, Oral Med, Oral Path, Oral Radio and Endod 2007;103:114-19.
10. Revesz G, Kundel HL, Graber MA. The influence of structured noise on the detection of radiologic abnormalities. Investigative Radiology 1974;6:479-86.
11. Morgan RH. Visual perception in fluoroscopy and radiology. Radiology 1965;86:403-16.
12. Pitt Ford TR. Radiographic detection of periapical lesions in dogs. Oral Surg, Oral Med, Oral Pathol 1984;57: 662-67.
13. The application of tooth temperature measurement in endodontic diagnosis. Journal of Endodontics 2008;34:12.
14. Hekmatian E, Sharif S, Khodaian N. Literature review digital subtraction radiography in dentistry.
15. Carvalho FB, Gonçalves M, Guerreiro-Tanomaru JM, Tanomaru-Filho M. Evaluation of periapical changes following endodontic therapy: Digital subtraction technique compared with computerized morphometric analysis. Dentomaxillofacial Radiology 2009;38:438-44.
16. H Jafarzadeh. Laser Doppler flowmetry in endodontics: A review. International Endodontic Journal, 2009;42:476-90.
17. Webber RL, Messura JK. An in vivo comparison of digital information obtained from tuned-aperture computed tomography and conventional dental radiographic imaging modalities. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology 1999;88:239-47.
18. Nance R, Tyndall D, Levin LG, Trope M. Identification of root canals in molars by tuned-aperture computed tomography. International Endodontic Journal 2000;33:392-96.
19. Nair MK, Gröndahl HG, Webber RL, Nair UP, Wallace JA. Effect of iterative restoration on the detection of artificially induced vertical radicular fractures by tuned aperture computed tomography. Oral Surg, Oral Med Oral Path Oral Radiol and Endod 2003;96:118-25.
20. Nair MK, Nair UP, Gröndahl HG, Webber RL, Wallace JA. Detection of artificially induced vertical radicular fractures using tuned aperture computed tomography. European Journal of Oral Science 2001;109:375-79.
21. Whaites E. Chapter 10, Periapical radiography. In: Essentials of Dental Radiology and Radiography (4th ed). (2007a) Philadelphia, PA, USA: Churchill Livingston Elsevier.
22. Whaites E. Chapter 19, Alterative and specialized imaging modalities. In: Essentials of Dental Radiology and Radiography (4th ed). (2007b) Philadelphia, PA, USA: Churchill Livingston Elsevier.
23. Goto TK, Nishida S, Nakamura Y, et al. The accuracy of three-dimensional magnetic resonance 3D vibe images of the mandible: An in vitro comparison of magnetic resonance imaging and computed tomography. Oral Surg, Oral Med, Oral Pathol, Oral Radiol and Endod 2007;103:550-59.
24. Eggars G, Ricker M, Kress J, Fiebach J, Dickhaus H, Hassfeld S. Artefacts in magnetic resonance imaging caused by dental material. Magnetic Resonance Materials in Physics, Biology and Medicine 2005;18:103-11.
25. Gundappa M, Ng SY, Whaites EJ. Comparison of ultrasound, digital and conventional radiography in differentiating periapical lesions. Dentomaxillofacial Radiology 2006;35:326-33.
26. Cotti E, Campisi G, Garau V, Puddu G. A new technique for the real study of periapical lesions: Ultrasound real time imaging. International Endodontic Journal 2002;35:148-52.
27. Cotti E, Campisi G, Ambu R, Dettori C. Ultrasound realtime imaging in the differential diagnosis of periapical lesions. International Endodontic Journal 2003;36:556-63.
28. Sukovic P. Cone beam computed tomography in craniofacial imaging. Orthodontic Craniofacial Research 6(Suppl 1) 2003; 31-36.
29. Tachibana H, Matsumoto K. Applicability of X-ray computerized tomography in endodontics. Endodontics and Dental Traumatology 1990;6:16-20.
30. Huumonen S, Kvist T, Grondahl K, Molander A. Diagnostic value of computed tomography in re-treatment of root fillings in maxillary teeth. International Endodontic Journal 2006;39: 827-33.
31. Ngan DCS, Kharbanda OP, Geenty JP, Darendeliler MA. Comparison of radiation levels from computed tomography and conventional dental radiographs. Australian Dental Journal 2003;19:67-75.
32. Arai Y, Tammisalo E, Iwai K, Hashimoto K, Shinoda K. Development of a compact computed tomographic apparatus for dental use. Dentomaxillofacial Radiology 2003;28: 245-48.
33. Hashimoto K, Yoshinori Y, Iwai K, et al. A comparison of a new limited cone beam computed tomography machine for dental use with a multidetector row helical CT machine. Oral Surg, Oral Med, Oral Pathol, Oral Radiol and Endod 2003;95: 371-77.
34. Hashimoto K, Kawashima S, Araki M, Sawada K, Akiyama Y. Comparison of image performance between cone-beam computed tomography for dental use and four-row multidetector helical CT. Journal of Oral Science 2006;48:27-34.