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Review Article

A New Era in Diagnosis and Treatment: 3-D Imaging in Endodontics

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Abstract: The three dimensional dental imaging allows endodontists to see more anatomy, and with more clarity than traditional film-based dental x-rays. The focused x-ray beam reduces scatter radiation, resulting in better image quality and a lower dose of radiation. With an enhanced visualization of your teeth, bones, and surrounding hard and soft tissue, endodontist will understand more about diagnosis and treatment plan. The three-dimensional imaging has made the complex dento-facial structures more accessible for examination and early and accurate diagnosis of deep seated lesions. This paper is to review current advances in imaging technology and their uses in different disciplines of dentistry.

Key words: CBCT, Dental imaging, Endodontist, Radiograph.

INTRODUCTION

Dental imaging of the dental and alveolar structures has enabled endodontists to visualize structural changes that provide the information used to derive the proper diagnosis and create the treatment plan which can be applied immediately or in stages, depending on the situation. The use of oral radiographs enables visualization of the bone and supporting structure around the roots of the teeth, therefore resulting in successful root canal therapy [1]. It very important for successful diagnosis of pulpal and periapical pathosis, treatment of the pulp chamber and canals of the basis of a compromised tooth via intracoronal access, biomechanical instrumentation, final canal obturation, and assessment of healing [2].

Preoperatively, Imaging achieves visualization and assessment of dental and alveolar hard tissue morphology to help correct diagnosis. It provides information on the morphology of the tooth including location and number of canals, pulp chamber size and degree of calcification, root structure, direction and curvature, fractures, iatrogenic defects, and therefore the extent of cavity. The consequences of periradicular and periapical disease are often determined, including the degree of root resorption and characteristics of periapical osteolysis. Larger lesions, only determined by imaging, may necessitate adjunctive surgical procedures additionally to plain intracanal therapy. Diagnostic radiographs can be used to forecast the likelihood of problems, detect root fractures, and show periapical abnormalities [2].

Intraoperatively , during the therapy intraoral periapical images could also be performed., as radiological and anatomic root apexes are virtually never coinciding, the working length is determined by inserting a metallic file(s) into the basis canal(s) to a length that approximates that of the basis.This ensures that mechanical cleaning and shaping of the intracanal contents extends to the apical terminus of the canals and before final obturation, a conefit radiograph is made to assure proper fitting of the master cone. A postoperative radiograph immediately after passage obturation is made to assess the sealing condensation within the canal system. Most dental radiographic needs can be met using 2-D conventional radiographs. Eventually it results in collapsing 3-D structural information onto a 2-D image, which leads to loss of spatial information in the third dimension. However, there are certain limitations of two dimensional radiographs, which can be overcome by three-dimensional, imaging techniques such as cone beam computed tomography, magnetic resonance imaging and ultrasound [3].

Dental radiographs

The first dental radiograph was taken 14 days after Roentgen's by Otto Walkhoff, a German dentist. In his mouth, he put a glass photographic plate coated in black paper and rubber and exposed himself to X-rays for 25 minutes. C. Edmund Kells, In 1896, a dentist from New Orleans performed the first intraoral radiograph on a patient. Kells exposed his hands to X-rays every day for years by holding the plates and trying to adjust the quality of the beam in order to achieve clear images. Unfortunately, this exposure led to the development of cancer in his hand which resulted in the amputation of his arm, demonstrating the potential risk and harmful effects of X-rays. Later kells in 1899 used the X-ray to determine tooth length during root canal therapy.

Techniques for advanced imaging in use

Computed tomography
Cone beam computed tomography
Tuned aperture computed tomography
Spiral computed tomography
Micro computed tomography
Fine aperture computed tomography
Ultra sound
Magnetic resonance imaging

Computed tomography

"CAT" scanning is another name for computed tomography (CT) imaging (Computed Axial Tomography). Tomography is derived from the Greek words "tomos" and "graphia," both of which imply "slice" or "section." It is an imaging technique that uses a sequence of two-dimensional segment X-ray scans to create three-dimensional views of an item. Computed tomography technology has been applied to the management of endodontic problems.

Applications in endodontics

One of the earliest papers on the use of CT technology in endodontics was published by Tachibana & Matsumoto. Using rebuilt axial slices and three-dimensional reconstruction of CT data, they were able to learn more about root canal architecture and its connections to critical structures like the maxillary sinus [4].

Cone beam com puted tomography

Cone beam computed tomography, also known as digital volume tomography, is an extra-oral imaging technique that was created in the late 1990s to provide three-dimensional scans of the maxillo-facial skeleton at a lower radiation dose than CT scans [5, 6].

Emergence of cbct over conventional ct

i. CBCT differs from CT imaging in that it acquires the complete three-dimensional volume of data in a single sweep of the scanner, utilising a straightforward, direct method. The X-ray source and detector spin between 180° and 360° around the patient's head, depending on the CBCT scanner utilised.
ii. Unlike CT relationship between sensor and source which rotate synchronously around the patient's head. Scanners, most CBCT scanners either scan the patient sitting or standing up. The X-ray beam is cone-shaped, thus the technique's name, and it takes data in a cylindrical or spherical volume.
iii. Compared to CT scanners, it has a significant reduction in radiation exposure. Because of the fast scan times, pulsed X-ray beams, and advanced image receptor sensors .The image quality of CBCT scans is superior to helical CT for assessing the dental hard tissues and provides higher resolution for detecting small high-contrast structures such as 'nerve canals' carrying neurovascular bundles[7-9].

Applications in endodontics

There are many reports in the literature of the benefits of CBVT, particularly in endodontics. Broken instrument localization and detection, non-healing root canals requiring retreatment, root resorption, root fractures, understanding canal shape, trauma, identification of periapical diseases, and the extent of extruded root canal material are all endodontic uses. The technique has gained widespread acceptance and is now being used in clinical and research settings.

Tuned aperture computed tomography (tact)

Tomosynthesis is the foundation of tuned aperture computed tomography. Using programmable imaging equipment and appropriate software, a sequence of 8–10 radiography images are exposed at multiple projection geometries and then reconstructed into a three-dimensional data set that can be seen slice by slice.

Applications in endodontics

Webber & Messura compared TACT with conventional radiographic techniques in assessing patients who required minor oral surgery. They concluded that TACT was 'more diagnostically informative and had more impact on potential treatment options than conventional radiographs [10]'.

Barton et al. concluded that TACT did not significantly improve the detection rate of MB2 canals in maxillary first molar teeth when compared with two conventional radiographs taken using the parallax principle. The detection rate of MB2 canals using either technique was approximately 40%; the true incidence of MB2 canals was confirmed with the aid of a dental operating microscope to be much higher at 85%. It may be concluded that the complex nature of the adjacent anatomy around posterior maxillary molar teeth limits the use of TACT [11]. In a study conducted by Nair et al. 2001, oblique/vertical root fractures were induced in the mid- third of endodontically treated mandibular single- rooted extracted teeth. These teeth were then radio- graphed using TACT and conventional digital sensors. It was concluded that the diagnostic accuracy of TACT was superior to conventional two-dimensional radiog- raphy for the detection of vertical root fractures. However, these results should be viewed with caution as these artificially created fractures may have been confirmed from a basic clinical examination [12].

Spiral computed tomography

Spiral computed tomography is a type of computed tomography that involves moving in a helical pattern to improve resolution. Spiral CT scanners are now used in the majority of modern hospitals. Helical (or spiral) cone beam computed tomography is a type of three-dimensional computed tomography (CT) in which the source (usually of x-rays) describes a helical trajectory relative to the object while a two-dimensional array of detectors measures the transmitted radiation on part of a cone of rays emanating from the source.

In practical helical cone beam x-ray CT machines, the source and array of detectors are mounted on a rotating gantry while the patient is moved axially at a uniform rate. Previously, x-ray CT scanners imaged one slice at a time using a rotating source and a one-dimensional array of detectors while the subject remained stationary. The helical scan approach minimizes the x-ray exposure to the patient while scanning more quickly for a given resolution. However, this comes at the cost of increased mathematical complexity in the image reconstruction from measurements.

Micro computed tomography

Micro-computed tomography with high resolution is a cutting-edge technique with numerous uses in endodontic research and education. Using CT, the investigators were able to demonstrate anatomical configuration of teeth, but the spatial resolution of 0.6 mm was found to be insufficient to allow for detailed analysis of root anatomy and structures. The authors concluded that conventional CT offered only limited application in endodontics due to its high radiation dose, time consumption, cost, insufficient resolution, and inadequate computer software capability.

In 1988, technological breakthroughs allowed kak and Stanley to introduce a tiny type of traditional CT, the micro-CT, for use in nonclinical situations. 60 Micro-CT works on the same principles as traditional CT, but the three-dimensional reconstructions of small objects, such as teeth, are generated to a resolution of a few microns (2m). The three-dimensional images gather considerable data, allowing for both qualitative and quantitative evaluation of the sample. These characteristics make micro-CT a desirable tool for in vitro studies that evaluate root canal morphology and procedures of root canal preparation and obturation. As a result, a scanned tooth can be studied throughout its whole length in order to provide data for estimating areas and volumes before to and after endodontic treatment.

ULTRASOUND (Real Time Ultrasound Imaging)

In 1912, the first use of acoustic echoes for object localization took occurred underwater in the hunt for the Titanic's wreckage. Seventy years ago Dussik introduced the use of ultrasounds as a diagnostic tool in the medical field to evaluate a cerebral pathosis. Since 1942, diagnostic ultrasounds have grown in importance, and there is no diagnostic specialty in medicine where ultrasonic imaging does not find a specific indication today [13].

Applications in endodontics

The echo mCDP reveals the vascular map around and within a lesion, as well as the direction of blood flow, in the field of endodontics. For the diagnosis, evaluation, and followup of bone lesions in the jaws, US real time imaging has been used in the endodontic profession.

The technique is relatively easy to perform: the patient is sitting on the echographic bed, and the operator moves the probe (protected with a latex/plastic cover and topped with the echographic gel) inside the buccal area of the mandible or the maxilla which corresponds to the periapical area of the tooth of interest (as previously assessed with a radiograph). Extraorally, by placing the probe on the skin's exterior surface, the same evaluation can be conducted. The operator stands in front of the computer, gently moving the probe about the area of interest to collect enough scans to define the lesion in real time.

Each moving sequence or single image can be selected and stored in the computer. Multifrequency high-resolution transducers in the form of linear probes or intraoperatory probes (smaller probes suited for intraoral examination) are used to evaluate bone lesions in the jaws, and they work with a digital US apparatus.

Magnetic resonance imaging

Magnetic resonance imaging is a specialized imaging technique which does not use ionizing radiation. It involves the behaviour of hydrogen atoms (consisting of one proton and one electron) within a magnetic field which is used to create the MR image.

In 1973, PAUL LAUTERBUR described the first magnetic resonance image, and PETER MANSFIELD advanced the use of magnetic fields and mathematical signal analysis for picture reconstruction. Since 1984, MRI has been available.

Applications in endodontics

The application of MRI to dentistry has more often involved the temporomandibular joints and salivary glands [14]. Its use has also been reported on the assessment of the jaw bones prior to implant surgery, and on the differential diagnosis of lesions in the mandibular and maxillary bones [15, 16]. When using MRI to study dental tissues, it was discovered that adequate imaging of the maxillary bones, teeth, and periapical tissues could be obtained; it was also discovered that the pulp space could be better observed using a contrast medium and that edoema in the periapical region could be detected [17, 18].

CONCLUSION

Recent advances in imaging technologies have revolutionized dental diagnostics and treatment planning. Correct use of appropriate imaging technology and their correct interpretation and cost-effectiveness, newer radiography techniques can aid in the detection of diseases at an early stage, lowering morbidity and mortality and improving patient quality of life.

Images acquired using conventional intra-oral radiographs reveal information in two-dimensions only height and width limiting the valuable information in the third dimension. Aside from that, the inherent difficulties of positioning image receptors in the ideal position in relation to the anatomical area of interest, anatomic noise, and under or overestimation of actual healing or failure of endodontic treatment limit the assessment of the true nature of endodontic lesions. CBCT technology is rapidly improving due to increased diagnostic data and, as a result, proper decision making for the management of complex endodontic disorders. But it is also essential to remember that it uses ionizing radiation and therefore it is not without risk. As a result, endodontic cases should be appraised on its own merits, and CBCT should only be used when traditional imaging technologies fail to provide enough information to allow effective care of endodontic difficulties.

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