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Radiographic diagnostic Aids: A review

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Abstract
Presently diagnosis has shown a major growth in the field of Endodontics. Newer technologies have evolved in a way that human elements are being enriched in a much better way to ensure proper and correct diagnosis. Therefore, for a successful diagnostician, a necessity arises to keep abreast of all the new methods for correct diagnosis and treatment. The aim of this review therefore is to assess the usefulness of some radiographic diagnostic aids and techniques used in endodontic therapy to make the correct pulpal diagnosis.

Keywords: Radiographic diagnostic, aids, endodontics

Introduction
Diagnosis is arguably the most critical component of all dental treatment, and Endodontics is no exception. Stedman's Medical Dictionary describes clinical diagnosis as ''the determination of the nature of a disease made from a study of the signs and symptoms of a disease.'' The diagnostic process therefore is an essential part of treatment as well as treatment planning. Collection of information, history, signs and symptoms, a thorough clinical examination, and objective testing are mandatory prior to recommending and initiating treatment. Only after collecting this information can one come up with a diagnosis that benefits the patient. ''Providing the wrong treatment for a patient could not only intensify a patient's symptom but make it even more difficult to arrive at the correct diagnosis. Knowledge of endodontic disease, radiographic interpretation, and clinical manifestations is an integral and important part to achieving the correct diagnosis [1].

The oldest diagnostic tests were the simple percussion and palpation. In the early 1900s, the following tests were considered essential- roentgenograms (in particular, bitewings for children and adolescents), Transillumination (noting the color changes between a tooth with a vital and nonvital pulp), percussion and palpation, thermal vitality tests (use of ice or hot water), electric pulp tester, mobility tests, test cavity and the anesthetic test. Although these have served the dental clinician well over the many decades, these come with their share of limitations-putting the patient through any more pain than already is in or invading the irreplaceable tissues, being not free from doctor and patient bias, along with the lack of correlation with the histological status of the pulp and dubious accuracy and therefore the need arose for newer methods to detect pulp vitality [2].

Recently, various diagnostic aids for assessing the dental pulp vitality have been reported. These include Caries Diagnostic Advances, Radiographic methods like Xeroradiography, Radiovisiography, Digital Subtraction Radiography, Micro CT, Magnetic Resonance Imaging, Ultrasound, etc.

Various diagnostic aids
Radiographic methods
- Xeroradiography
- Radiovisiography
- Digital subtraction radiography
- Micro computed tomography

- Cone beam computed tomography
- Optical coherence tomography (OCT)
- Tuned aperture computed tomography (TACT)
- Spiral computed tomography
- Magnetic resonance imaging
- Ultrasound imaging in Endodontics
- Orascope
- Endoscope
- Computerized expert system

Xeroradiography

Xeroradiography is an electrostatic process which uses an amorphous selenium photoconductor material, vacuum deposited on an aluminium substrate to form a plate. the plate enclosed in tight cassette, may be linked to films used in halide based intraoral technique. The key functional steps in the process involve the sensitization of the photoconductor plate in the charging station by depositing a uniform positive charge on its surface with a corona emitting device called scorotron. That is the uniform electrostatic charge placed on a layer of selenium is in electrical contact with a grounded conductive backing. In the absence of electromagnetic radiation, the photoconductor remains non-conductive uniform electrostatic charge when radiation is passed through an object which will vary the intensity of radiation, observed by Rawls and Owen. The photoconductor will then conduct its electrostatic charge into its grounded base in proportion to the intensity of the exposure. After charging the cassette is inserted into a thin polyethylene bag to protect the cassette and plate from saliva [3].

Advantages

- Elimination of accidental film exposure,
- High resolution,
- Simultaneous evaluation of multiple tissues,
- Ease of reviewing,
- Economic benefit,
- Reduced exposure to radiation hazards,
- Cephalometrics analysis.

Disadvantages

- Technical difficulties,
- Fragile selenium coat,
- Transient image retention,
- Slower speed,
- Technical limitations [4]

Radiovisiography

The RVG system is capable of rapidly displaying a digital radiographic image on a monitor which results in a lower patient radiation. The "Radio" component is the conventional x-ray generator with a timer, capable of very short exposure time, along with image receptor. The "Visio" portion converts the output signal from a CCD to a digital format and displays it on a monitor. The "Graphy" component consists of data storage unit connected to a video printer. The most significant advantages of digital imaging, therefore, are computer aided image interpretation and image enhancement, in addition to the obvious options of standardized image archiving and image retrieval. The CCD is a solid-state detector composed of an array of X-ray or light sensitive pixels on a pure silicon chip. A pixel or picture element consists of a small electron well into which the X-ray or light energy is deposited upon exposure. The individual CCD pixel size is approximately 40µ with the latest versions in the 20µ range. The rows of pixels are arranged in a matrix of 512 x 512 pixels.

There are two types of digital sensor array designs: area and linear. Area arrays are used for intraoral radiography, while linear arrays are used in extra oral imaging [5].

Applications

a. Dental Caries Detection
b. Intrabony defects
c. Periapical pathologies detection
d. Detection of root fractures
e. Detection of root canal lengths
f. Application in mentally retarded/developmentally disabled individuals
g. Telemedicine [11]

Disadvantages

a. Previous disadvantages of the system included limitations caused by the relatively small sensor size and its greater thickness than conventional film.
b. To date, only limited clinical studies have been reported regarding the RVG technique. The possibilities of the technique’s unique ability of image ‘enhancement’ have still to be explored to the full.
c. As the technique is so different from the conventional, it is important for the observer to view the image produced without the constraints imposed by conventional radiography.
d. The technique is simple to use, but assessment of images may require a certain degree of familiarization as the image is different from a conventional radiograph [6].

Digital Subtraction Radiography

Digital subtraction of images: has been applied to dental radiography for more than 20 years. Film subtraction was the established standard method for cerebral angiography and was widely used until digital subtraction fluoroscopy became available in the late 1970s. Nowadays, filmless' photoelectronic imaging systems, specially video fluoroscopy, are used to subtract diagnostic images [12].

It improves the detection of density changes in bony structures, and significantly, the sensitivity and accuracy of the evaluations.

a. With conventional radiography, a change in mineralization of 30-60% is necessary to be detected by an experimented radiologist, also the lesions restricted to cancellous bone could not be detected because of it's less mineral contents than the cortical bone, but with DSR the alveolar bone changes of 1-5% per unit volume and significant differences in crestal bone height of 0.78 mm can be detected
b. This technique is used in periodontal diagnosis because of its potentially high sensitivity to detect of bone changes as little as 1% and changes in the third dimension (bone density, bone thickness).
c. Also defects of at least 0.49 mm in depth of cortical bone can be detected whereas a lesion must be at least three times larger to be detectable with the conventional radiography techniques.
d. Furthermore, it can be used to assess the bone at each of three phases of implant treatment, evaluation, and maintenance.
e. Another application of DSR is in Temporo-Mandibular Joint (TMJ), imaging, especially with panoramics. TMJ

imaging programs allowed imaging of the right and left mandibular condyles in the open and closed positions on a single film, but the condylar head and intra-articular space were not depicted clearly because of the superimposition of surrounding structures and the oblique projection of the joint. So, elimination of the superimposed structures with digital subtraction technique improves the visualization of condyle [7].

DSR: has also been used in the evaluation of the progression, arrest, or regression of caries lesions. The caries lesions are not well-defined radiolucencies, thus the measurement of their extent is difficult in conventional radiography. Subtraction consists of subtracting the pixel values of the baseline image from the pixel values of the second image. When nothing has happened, the result is zero. When caries regression or progression has occurred in the meantime, the result will be different from zero. When there is caries regression, the outcome will be a value above zero. in case of caries progression, the result is opposite and the outcome will be a value below zero. Because the negative values cannot be displayed on the screen, usually an offset of 127 is added to the outcome of the subtraction process. In addition it is used for evaluation of endodontically treated teeth and has the ability to detect root resorption as low as 0.5mm 6and when underexposed radiographs are used, it can detect even soft tissue changes. So any lesion (including bony cysts or tumors) with potential of change over time can be studied in this technique [7].

Micro Computed Tomography

The X-ray micro-computed tomography (micro-CT) was developed in the early of 1980s. It is a non-invasive, non-destructive method for obtaining two- and three-dimensional images.

Principle of the technique is based on multiple X-ray converging on the sample and captured by a sensor. The projected X-ray is converted into digital images. The volumetric pixel (voxel) provided by micro-CT range in 5-50 µm. Smaller the voxel size higher is the resolution of image, also the decrease in the distance between scanning steps demand longer time of X-ray exposure. Depending on the material to be scanned, scanning time varies [7].

Cone Beam Computed Tomography

Cone beam computed tomography (CBCT) is a relatively new method to visualize an individual tooth or dentition in relation to surrounding skeletal tissues and to create three-dimensional images of the area to be examined (Cotton *et al*. 2007, Patel 2009).

The use of CBCT in Endodontics is rapidly increasing worldwide. Compared with traditional radiographic methods, which reproduce the three-dimensional anatomy as a two-dimensional image, CBCT is a three-dimensional imaging method that offers the possibility to view an individual tooth or teeth in any view, rather than predetermined 'default' views. Therefore, CBCT can be a powerful tool in endodontic diagnosis, treatment planning and follow-up. At the same time CBCT has limitations, and radiation dose to the patients must always be taken into consideration when selecting the modes of diagnostics. There is a need for evidenced-based guidelines on when to use CBCT in Endodontics, thus aiding the decision on when it is appropriate to take a CBCT scan [8].

Optical Coherence Tomography (OCT)

OCT is a new diagnostic imaging technology that was first introduced in 1991. OCT is an attractive non-invasive imaging technique for obtaining high-resolution images.

OCT combines the principles of an ultrasound with the imaging performance of a microscope, although ultrasound produces images from back-scattered sound echoes.

OCT uses infrared light waves that reflect off the internal microstructure within the biological tissues. OCT is based on low-coherence interferometry (LCI) and achieves micron-scale cross-sectional image.

LCI has evolved as an absolute measurement technique which allows high resolution ranging and characterization of optoelectronic components. Using the principle of LCI it achieves depth resolution of the order of 10 µm and in a plane resolution similar to the optical microscope.

By scanning the probe along the imaged specimen while acquiring image lines, a two dimensional or three-dimensional image is built up. Due to the high potential of the low coherence interferometer to provide thin section slices from the tissue, the technology was termed as optical coherence tomography [9].

Advantages

a. Real time imaging
b. Sub surface resolution
c. No radiation exposure
d. No site preparation before taking image
e. Incomparable spatial resolution [9].

Thus OCT can be aptly be called as "Optical Biopsy" without any excision requirement in comparison to the conventional biopsy.

Tuned Aperture Computed Tomography (TACT)

Tuned aperture computed tomography works on the basis of tomosynthesis.

A series of 8-10 radiographic images are exposed at different projection geometries using a programmable imaging unit, with specialized software to reconstruct a three-dimensional data set which may be viewed slice by slice [9].

Advantages

1. The images produced have less superimposition of anatomical noise over the area of interest.
2. The overall radiation dose of TACT is no greater than 1–2 times that of a conventional periapical X-ray film as the total exposure dose is divided amongst the series of exposures taken with TACT.
3. It includes the absence of artifacts resulting from radiation interaction with metallic restorations. The resolution is reported to be comparable with two dimensional radiographs [16].

Spiral Computed Tomography

Existing diagnostic methods such as the computerised transverse axial scanning (CT) greatly facilitates access to the internal morphology of the soft tissue and skeletal structures. Recently, a newer CT technique, Spiral Computed Tomography (SCT) or volume acquisition CT has been developed that has its inherent advantage. By employing simultaneous patient translation through the X-ray source with continuous rotation of the source detector assembly, SCT acquires raw projection data with a spiral-sampling locus in a relatively short period. Without any additional scanning time, these data can be viewed as conventional trans axial images, such as multiplanar reconstructions, or as three dimensional reconstructions. With SCT, it is possible to reconstruct overlapping structures at arbitrary intervals and thus the ability to resolve small objects is increased [10].

Endodontic Applications

1. Potential endodontic applications include diagnosis of endodontic pathosis and canal morphology
2. Evaluation of root fractures
3. Assessment of pathosis of non-endodontic origin
4. Analysis of external and internal root resorption and invasive cervical resorption
5. Presurgical planning
6. Treatment of aberrant and extra root canals, developmental anomalies like dens invaginatus, C-shaped canals [10]

Magnetic Resonance Imaging

Nuclear magnetic resonance, also called MRI, has been available as an imaging technique since 1984 which does not use ionizing radiation. MRI combines the use of a magnetic field and some radio frequency antennas called coils. 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 [11].

Advantages of MRI

1. No Ionizing Radiation: RF pulses used in MRI do not cause ionization and have no harmful effects of ionizing radiation. Hence can be used in child bearing ladies and children.
2. Non-invasive: MRI is non-invasive.
3. Contrast resolution: It is the Principle advantage of MRI, i.e. ability of an image process to distinguish adjacent soft tissue from one another. It can manipulate the contrast between different tissues by altering the pattern of RF pulses.
4. Multiplanar image: With MRI, we can obtain direct, sagittal, coronal and oblique image which is impossible with radiography and CT.
5. It could differentiate between acute and chronic transit and fibrous phases parallel with histopathological changes.
6. Absence of significant artifact associated with dental filling.
7. No adverse effect has yet been demonstrated.
8. Image manipulation can be done.
9. Useful in determining intramedullary spread [11].

Disadvantages of MRI

1. Claustrophobia i.e. morbid fear of closed places because the patient is within the large magnet up to one hour.
2. MRI equipment is expensive to purchase, maintain, and operate. Hardware and software are still being developed.
3. Because of the strong magnetic field used in patient electrically, magnetically or mechanically activated implants such as cardiac pacemakers, implantable defibrillators and some artificial heart valves may not be able to have MRI safely.
4. The MRI image becomes distorted by metal, so the image is distorted in patients with surgical clips or stents, for instance.
5. Bone does not give MR signal, a signal is obtained only from the bone marrow. Long scanning time and requires patient's co-operation.
6. The very powerful magnets can pose problems with sitting of equipment although shielding is now becoming more sophisticated.
7. MRI scanners are noisy.
8. Patient could develop an allergic reaction to the contrasting agent, or that a skin infection could develop at the site of injection.
9. MRI cannot always distinguish between malignant tumors or benign disease, which could lead to a false positive result.
10. Facilities are not widely available, but with the development of small open systems suitable for district general hospitals.
11. Bone, teeth, air and metallic objects all appear black, making differentiation difficult [12].

Ultrasound Imaging In Endodontics

Ultrasound is sound energy with a frequency above the range of human hearing, which is 20 kHz. There are two basic methods of producing ultrasound. The first is magnetostriction, which converts electromagnetic energy into mechanical energy. A stack of magnetostrictive metal strips in a hand piece is subjected to a standing and alternating magnetic field, as a result of which vibrations are produced. The second method is based on the piezoelectric principle, in which a crystal is used that changes dimension when an electrical charge is applied.

Deformation of this crystal is converted into mechanical oscillation without producing heat. Piezoelectric units have some advantages compared with earlier magnetostrictive units because they offer more cycles per second, 40 versus 24 kHz [20].

The application of echographic examination to the study of endodontic disease has been attempted with success. The technique is easy to perform and may show the presence, exact size, shape, content and vascular supply of endodontic lesions in the bone.

The echographic probe, covered with a latex protection and topped with the echographic gel, should be moved in the buccal area of the mandible or the maxilla, corresponding to the root of the tooth of interest. The regular probe, so far, has been performing well even if a more specific instrument for dental use should be made available [12].

Advantages [13]

It is a dynamic and readily available technique. It is particularly useful in the examination of superficial structures. It is widely available and relatively inexpensive. It is a non-invasive technique. Images are rapidly acquired. Images are simple to store and retrieve. It can be performed without heavy sedation. It has no known cumulative biological effects. Its ability to detect non-calcified pathological entities such as sialoliliths.

Disadvantages [22]

The technique is very operator- and equipment dependent. Clinically only the bone surfaces and not the whole cortex or spongiosa can be visualized in intact done due to ultrasound frequencies. It has to be performed by experienced investigators. Images when archived they may be difficult to orientate and to interpret unlike CT and MR scans, which have acquired in standard reproducible scans. The difficulty of picturing the TMJ using ultrasounds depends on the limited accessibility of the deep structures, especially the disc, due to absorption of the sound waves by the lateral portion of the head of the condyle and the zygomaticus process of the temporal bone. Ultrasound images are affected by inherent noise accompanying the signal returned to the transducer which makes interpretation of the static images, and sometimes the dynamic ones as well and a non-moving object will vary in appearance because of this noise. Ultrasonography waves do not visualize bone or pass through air, which acts as an absolute barrier during both emission and reflection.

Orascopy or Endoscopy

The art of dentistry is based on precision. The human naked eye is capable of distinguishing fine detail, but it is no match for what can be accomplished when an image is sharpened and enlarged. The microscope and other forms of magnification fill that need, especially for accomplishing endodontic procedures. Enhanced magnification and illumination opened the eyes of endodontic surgeons to the intricate and complex root canal system. This advancement resulted in miniaturization of the endodontist's armamentarium. Today`s innovative and high-tech optical systems can deliver amazing depths-of-field and wide fields of view that enable the dentist to view a complete oral cavity in focus without having to move. The use of optical magnification instruments such as endoscopes, orascopes, loupes and microscopes enables the endodontist to magnify a specified treatment field beyond that perceived by the naked eye [13].

Endoscope

The flexible and semi-flexible endoscopes can be very valuable addition to the armamentarium. The endoscope is flexible due to special Nitinol coating. The optical part which is 0.9 mm of diameter, is a piece of equipment that enables the practitioner a magnification of up to 20X with clear picture with wide angle. A 2.7mm lens diameter, a 70º angulation, and a 3 cm long rod-lens are recommended for surgical endodontic visualization and a 4mm lens diameter, a 30º angulation, a 4 cm long rod-lens are recommended for non-surgical visualization through an occlusal access opening. The rod-lens endoscope provides clinicians greater magnification, greater clarity as compared to the microscopes and the loupes and the non-fixed field of vision. Non-fixed field of vision is the ability to view treatment field at various angles and distances without losing depth of field and focus. The Modular endoscope system (Sialotechnology Ltd., Ashkelon, Israel) being based on modern technology of micro endoscopes is used in small channel organs (salivary gland ductal system, tear canals) and is designed to enable the practitioner to work inside the root canal with magnification and instrument access [14].

The system includes three parts

- Endoscopic compact system,
- Optical part that includes ocular part and the endoscope, and
- Handpiece with a disposable part [14].

Uses of dental endoscope

a. **Diagnosis:** The dental endoscope viewing system (Dental View) is currently available as a diagnostic and therapeutic adjunct to the restorative dentist, endodontist, periodontist, oral pathologist, oral surgeon, otolaryngologist, and dental hygienist. Enhances Visualization: This dental endoscopic viewing system provides high magnification (24X to 50X) and a light source via a fiber-optic illumination that allows to detect new carious lesion, recurrent caries, inadequate restorations in proximal boxes or class V restorations, intrafurcal fractures, anatomic aberrations, (eg, a palatal groove on maxillary lateral incisors), residual crown and bridge cement, oral pathologic lesions, and root fractures/perforations.

b. **Transillumination:** In cases of tooth infraction, the endoscope can provide trans illumination as a diagnostic aid. As a fiberoptic light source, it is an excellent tool for fracture detection as light may refract along fracture line.

c. **Apical Surgery:** The surgical procedure is performed under the inspection of the endoscope with intermittent irrigation of isotonic saline and suction. The curvature of the hand-piece enables the practitioner to visualize the hidden parts of the cavity preparation, and to inspect for cracks and root fractures in the apical retrograde preparation.

d. **Endoscopic Observations during Endodontic Treatment:** The endoscopic observation and treatment usually leads to detection and removal of the remaining dental pulp tissue following cleaning and shaping of the root canal walls. Lateral canals and microscopic root cracks are usually detected with high accuracy, providing better intraoperative judgment and facilitating adequate treatment [14].

Computerized Expert System

The diagnosis of dental pain that results from pulpal pathosis may prove to be confusing and complex issue for both dental students and clinicians alike. Comendex, a computerized diagnostic expert system was developed to aid in clinical diagnosis of pulpal pathosis and to provide a rapid, accurate second opinion when the human consultant is not readily available. The vast majority of diagnostic expert system uses a single reasoning methodology as their interference mechanism.

It is believed that the system will prove useful both as a diagnostic aid and an educational tool. The system is capable of providing second opinion. The second opinion is a valuable one because although both clinician and Comendex receive similar initial case information, they render a diagnosis through two significantly different cognitive processes. It is a method of consulting opinion by a way of totally different method of reasoning that makes diagnostic expert systems a valuable asset to health professionals. Appropriate diagnostic case facts are obtained and this data is entered into the computer. The computer checks and gives out the diagnosis. With rapid advances being made in the field of computers, we may get many more programmes for efficient endodontic diagnosis [13].

Conclusion

Diagnosis forms the basis of treatment. The vistas of endodontic diagnosis are ever evolving. Equipping one's natural diagnostic instinct with knowledge of contemporary advances would ensure that the clinician chooses the best possible diagnostic tools for his toolkit to help him and his patient along a safer and surer path of endodontic treatment [1].

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