East African Scholars Journal of Medical Sciences
Abbreviated Key Title: East African Scholars J Med Sci
ISSN: 2617-4421 (Print) & ISSN: 2617-7188 (Online)
Published By East African Scholars Publisher, Kenya

OPEN ACCESS

Volume-3 | Issue-4 | Apr-2020 | DOI: 10.36349/EASMS.2020.v03i04.012

Review Article

Novel Adjuncts in Diagnostic Aids in Endodontics

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Article History
Received: 01.04.2020
Accepted: 25.04.2020
Published: 29.04.2020

Journal homepage:
https://www.easpublisher.com/easjms

Quick Response Code

Abstract: Management of any problem starts with an accurate diagnosis and this is not different in the field of endodontics. The diagnosis of dental pulp status should be seen as a synthesis of history, clinical examination, special tests and radiological examination, and not as the outcome of any one specific test. With the advent of technologies in our day to day life we need the help of technologies in dentistry also. 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 review paper seeks to clarify the recent advances and three-dimensional imaging techniques that have been suggested as adjuncts to conventional diagnostic techniques. Few of these include tuned aperture computed tomography (TACT), magnetic resonance imaging (MRI), ultrasound, computed tomography and cone beam computed tomography (CBCT).

Keywords: Transillumination, Cone Beam Computed Tomography, Imaging Technique, Endodontics, Magnification, Laser System

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INTRODUCTION

An accurate and confident treatment planning is an essential part of endodontic practice. The purpose of diagnosis is to determine what problem the patient has and why does he have that problem (Ingle, J.I., *et al.*, 2008). Right treatment starts with a correct diagnosis Before starting any treatment one should initially collect data in regards to signs, symptoms, manifestations and the history. The data is then joined with the outcomes from clinical assessment and tests. This procedure is characterized as diagnosis. In this way diagnosis is fundamentally a methodology of accepting a patient, perceiving that he has an issue, deciding the reason for the issue and building up a treatment plan that will settle or mitigate the problem (Ingle, J.I. *et al.*, 2002).

Conventional diagnostic aids include visual and tactile inspection, palpation, percussion; periodontal evaluation, sinus tract tracing, thermal tests, occlusal pressure test, electric pulp vitality testing, test cavity, anesthetic test, caries detector dyes, dental radiographs, microbiological diagnosis, etc. To aid in the conventional diagnostic techniques and to overcome their shortcomings, new modifications and advancements are constantly being made in the field of diagnosis. In the modern world, there are so many recent advances in endodontic diagnosis that are enhanced by newer technologies. These improvements are targeted towards increasing the objectivity, sensitivity, and reproducibility of the diagnostic techniques while decreasing the patient's discomfort. Several aids like pulse oximetry, laser doppler flowmetry, ultrasound doppler, dual wavelength spectroscopy, photoplethysmography have being developed and evolved to get adapted to the current clinical situations which may be of great use to the operator. Also, these new methods fulfil the necessity of choosing the best tools for a good diagnosis (Gopikrishna, V. *et al.*, 2009)

Transillumination is a technique of viewing decay, fractures, endodontic orifices and their clinical entities by passing an intense light through them (Friedman, J. *et al.*, 1970). It works on a principle that if an intense light is placed in direct proximity to a tooth and other overall light is reduced, the clinical entities such as fracture line or endodontic orifices, will appear as distinct dark areas in the otherwise bright structure (Friedman, J. 1972). Reason behind this appearance is based on the fact that any healthy tooth structure has an index of light transmission greater than that of decay, canal or fracture.

How to place a Trans illuminator?

For an anterior tooth the transilluminator is placed on the labio-cervical region and the tooth is then viewed from the lingual aspect via direct or indirect vision.

For a posterior tooth the transilluminator is placed on the cervical portion of the tooth which is nearest to the root under investigation. For example, if one has to locate the mesio-buccal canal, the transilluminator should be placed as close as possible to the mesio-buccal root. The floor of the access opening is then viewed for the appearance of the endodontic orifice via direct or indirect vision.

To diagnose the fracture line, transilluminator is placed on the buccal gingival area of the suspected tooth and the intensity of the overhead lighting is reduced. The transilluminator is then moved slowly from mesial to distal side. When observing from occlusal surface, presence of a dark line will indicate a fracture crown (Taylor, R.C. 1967).

Fiber optic transillumination (FOTI)

Fiber optic device is used to examine the carious tissues by placing it over the tooth to be examined. A dark shadows along the dentinal tubules is observed as it has lower light transmission index compared with the sound tooth structure. The best utilization of the FOTI device is for evaluating the depth of occlusal and proximal lesions.

However, Neuhaus *et al* in 2009 has shown that FOTI diagnosis by naked eye can be subjected to great inter and intra examiner variation (Neuhaus, K.W. *et al.,* 2009)

Digital Fiber Optic Transillumination Imaging (DIFOTI)

DIFOTI is developed to overcome the shortcoming of variability in FOTI. This method employs digital image processing for quantitative diagnosis and prognosis in dentistry.

It utilizes fiber-optic transillumination of safe visible light to capture the image of the tooth. In this system, light is delivered by a fiber-optic that gets collected on the other side of the tooth by a mirror system and is recorded via charge couple device (CCD) imaging camera, simultaneously. Thus, by maintaining adjustment of a number of imaging control parameters, DiFOTI images can be acquired in repeatable fashion and the information is then sent to a computer for analysis with dedicated algorithms, which produces digital images (Shuwaish, M.B. *et al.,* 2008).

The images obtained by this method can be saved and viewed later by the patients or a dentist. Also, the properties of the lesions can be examined by increasing the contrast of the image. This method is useful in detecting physiological and pathological like fractures, caries and fluorosis (Yilmaz, H. *et al.,* 2018).

Young *et al*. explained that DIFOTI presents higher sensitivity in detection of early lesions when compared to the conventional radiographic examination and also has potential for quantitative monitoring of selected lesions over a period of time (Young, D.A. *et al.,* 2005).

LASER DOPPLER FLOWMETRY (LDF)

Vascular supply is considered as the most accurate marker of pulp vitality. LDF is a noninvasive, painless, objective and an electro optical technique, which allows the semi-quantitative recording of pulpal blood flow (Samraj, R.V., *et al* 2003). This technology employs a beam of infrared (780-820)nm or near infrared 632.8nm light directed into the tissues by using optical fibers.[11] This technique depends on the doppler principle whereby light from a laser diode, when incident on the tissue gets scattered by the moving RBC's and as a result, the frequency is broadened (Evans, D. 1999). The frequency broadened light, along with laser light scattered from static tissue is photo detected and the resulting photocurrent is then processed to provide a blood flow measurement.

Advantages-

- Over the past decade, LDF technology has been used experimentally to monitor blood flow in the pulps of both, animals and human beings, to test the pulp vitality.
- LDF has been shown valuable in monitoring revascularization of immature incisors followed by severe dental trauma.

Disadvantage comes up with the limitation in detecting radicular blood flow. The assessment of coronal blood flow may be highly susceptible to environmental factors, hypersensitive drugs, and nicotine or technical factors. It is impossible to completely eliminate the contamination of the scattered light from the periodontal issues. LDF lacks its usefulness in teeth with crown and large restorations (Gzelius, B. *et al.,* 1993 & Polat, S. *et al.,* 2005).

PULSE OXIMETRY

Pulse oximetry has been the most commonly used technique for the measurement of oxygen saturation in medicine because of its ease and affordability. Recently it has been adapted for the use in dentistry.This is an oxygen saturation monitoring device broadly utilized in clinical practice for recording blood oxygen saturation levels during the administration of intravenous anaesthesia. The term 'oximetry' is defined as oxygen saturation determination in the circulating arterial blood (Radha, K.S. *et al.*, 2002).

It utilizes red and infrared wavelengths so as to transilluminate a tissue and recognizes absorbance peaks due to pulsatile circulation and uses this data to calculate the pulse rate and oxygen saturation. This technology is based on a modification of Beer Lambert's law: "the absorption of light by a solute is related to its concentration at a given frequency." Pulse Oximetry additionally utilizes the qualities of hemoglobin in the red and infrared range. 'Oxy' hemoglobin absorbs more light in the red range than 'deoxy' hemoglobin and the other way around in the infrared range.

The tooth to be tested is sandwiched between a photoelectric locator and a light transmitting diode of red (640 - 660 nm) and infrared (940 nm) lights held in a sensor holder. The connection between the pulsatile change in the absorption of red light and the pulsatile change in the infrared light absorption is analysed by the pulse oximeter to decide the arterial blood saturation. The basic necessity of utilizing pulse oximeter in dentistry is that the sensor should fit with the size, shape, and anatomical forms of teeth. Besides, the sensor holder should keep the light-emanating diode sensor and the photoreceptor as parallel as conceivable to one another so that the photoreceptor sensor gets the light transmitted through the tooth. This sensitivity test can be a perfect chair side screening test for pulp vitality (Tomer K.A. *et al.*, 2019).

Despite of having surrounding insulation of the enamel and dentine hindrances to the detection of a pulse in the pulp, it has proven to be a successful method in 70% of the clinical trials. Pulse Oximeter have been found to be very useful in cases of impact injury with intact blood supply but damaged nerve supply (Gazelius, B. *et al.*, 1986).

CONE BEAM COMPUTED TOMOGRAPHY (CBCT)

Within the last 20 years diagnostic digital imaging modalities in dentistry, including periapical, bitewing, panoramic and cephalometric imaging, have been replacing conventional (film-based) radiography. CBCT imaging is a 3D method to visualize an individual tooth or the dentition in relation to the surrounding skeletal tissues. This imaging is nowadays an increasingly used diagnostic tool in endodontic practice (Abella, F. *et al.*, 2015).

In contrast to traditional radiographic methods, which reproduce the 3D anatomy as a two-dimensional (2D) image leading to inherent magnification, distortion and overlap of anatomy (Nakajima, A. *et al.*, 2005), CBCT allows the observation of an individual tooth or teeth in multiple views, rather than in predetermined 'default' views.

Ranging in duration between 8.9 and 40 seconds, as the source and receptor rotate around the patient, many exposures are made. The software "reconstructs" the sum of these exposures into as many as 512 axial slice images. These images are in the Digital Imaging and Communications in Medicine (DICOM) data format which is a standard for storing, printing, holding and transmitting information in medical imaging. During a single rotation of the source and receptor, the entire volume of anatomy within the field of view is captured by the receptor.

Thus, CBCT allows clinicians to evaluate the area of interest in 3 dimensions with visualization of anatomy without superimposition of adjacent structures. The capacity to traverse through a tooth using sub-millimeter slices before, during, and after treatment results in better diagnosis and greater endodontic precision and produces higher predictability.

Mobile CBCT(New Tom Vg Mobile)

With one button calibration and a simple, fast warm up period the new Tom VG Mobile, also known as mobile CBCT, is having one button calibration and a simple, fast warm up period which is in contrast with some sensitive CBCT machines that often require extensive calibration processes and timely warm up periods making mobile applications difficult.. It also adjuncts the radiation dosage based on patients size.

Despite the obvious advantages that are offered by CBCT in dentistry, the technology has several drawbacks and limitations. A significant problem is the scatter and beam hardening caused by high-density neighboring structures and materials, resulting in the CBCT images of low quality that could be of minimal diagnostic value. Also, crowns, bridges, implants, fillings and intracanal posts can hide the endodontic complications or mimic the existing ones.

DIGITAL SUBTRACTION RADIOGRAPHY (DSR)

When compared with the conventional radiographic interpretation, the DSR technique is almost twice sensitive at detecting lesions and also capable of providing more accuracy in the assessment of bone formation or resorption during or after endodontic treatment. DSR with specific software has ability to detect extremely small bony changes, so considered as a valuable tool for the evaluation of periapical lesions.

DSR includes tools that allow image manipulation and measurement and utilizes specialized software that allows the digital subtraction of two superimposed images. After subtracting the unchanged structures, these are displayed in neutral gray shade in the subtraction image; while the regions that had changed are displayed in lighter or darker shades of gray (Reddy, M.S. *et al.*, 1993). It is used to suppress the background features and to compare standardized radiographs taken at sequential examination visits.

For a successful DSR, reproducible exposure geometry along with identical contrast and density of serial radiographs are essential. But, DSR is very technique sensitive and even minor changes leads to large errors in the result (Jain, V. *et al.*, 2017). Despite the development of newer systems, there is no definite and accurate simple solution to control the projection geometry and to correct the discrepancies (Vannier, M.W. 1996).

Cholesteric Liquid Crystals

Cholesteric crystals are a type of 'liquid' crystal. These are ordered fluids that have a helical structure ordered along the long axis; this phase is known as chiral-nematic liquid crystals. These are easily influenced by temperature or pressure due to their fluidity. The pitch of the every structure of the crystal varies when there is alteration in pressure or temperature thus changing their color i.e. they are thermochromic. Howell *et al*. in Lexington used them in their study in 1970 and found that nonvital teeth have lower temperature than vital teeth (Tyagi, S.P. *et al.*, 2012). For endodontic application of this method, the tooth to be evaluated is isolated and coated thinly with petroleum jelly to prevent saliva contamination. Then a thin black plastic strip is coated with the liquid crystals on one side, and the uncoated surface is placed directly in contact with the tooth. The colour changes that result are then matched against a asset temperature range. The major benefit of cholesteric liquid crystal thermography is its simplicity of use. Beside the interference of the measurement by temperatures of oral tissues, the method suffers a setback of doubtful vitality until the teeth are opened.

Diagnodent Laser System

Diagnodent Laser system is a laser fluorescence system that is used to detect changes in the tooth structure as a result of demineralization. These changes in the tooth structure cause an increase in the fluorescence at specific excitation wavelengths of different intensity depending upon the condition of hard tissues. Diagnodent comes up with a laser diode that generates a pulsed 655 nm laser beam through a central fiber, which is transported onto the tooth from the tip of the device. When the incident light interacts with tooth substance, it stimulates fluorescent or luminescent light at longer stokes of shifted wavelengths. The intensity of fluorescence is a function of the bacterial concentration in the probed region or the degree of demineralization. A high level bacterial reading indicates the probability of having a decalcified enamel structure. Advantage of this system include quantitative nature of its readings that give a basic guideline for "when to intervene". False positive readings is possible with this instrument that may arise from the various factors such as the presence of bacterial plaque, dental prophylactic pastes, fissure sealants, and composite resin materials (Jindal, D. *et al.*, 2014). Therefore, one demerit of this technology is that all bacteria other than a caries-related bacteria, also produce fluorescence.

According to studies carried on permanent teeth, Diagnodent has shown high sensitivity that makes it suitable for caries detection but also has low specificity that results in higher rate of false positive results. Therefore other adjunct tests are needed to be done for final diagnosis.

Diagnocam: This technology uses a laser diode of wavelength 780 nm for transillumination of teeth. Carious tissues absorb lighter wavelength than their surroundings and appear as dark spots. A digital camera is used for monitoring the images. According to a recent study, the results obtained by diagnocam were far better in terms of clinical outcomes when compared with diagnodent alone.

Diagnodent Pen: Diagnodent pen (KaVo Dental, Biberach, Germany) is a device that works with the same principle as diagnodent. It comes with two different sapphire fiber tips - i) A cylindrical tip; and ii) a conical tip. In a study comparing diagnodent and diagnodent pen in detecting occlusal caries it was found that this new device gives comparable results with diagnodent.

Quantitative Light Induced Fluorescence (QLF)

QLF uses a non-invasive blue-violet light for illumination of the oral cavity that is transmitted at a wavelength of 405 nm. It is designed to quantify mineral changes in the very early stages of caries lesions with the help of dedicated QLF software. It can take a digital image which can be stored for future follow up measurements. An intraoral camera charge coupled device (CCD) camera lens is used in combination with a low cut-off filter at a wavelength of 520nm that only detects the fluorescent light and leave the red and green parts of the spectrum. The blue-violet light energizes the discharge of green and red fluorescence. The green fluorescence is the natural fluorescence of the dental hard tissue bone, dentine and veneer. Sound tooth tissue discharges a splendid green fluorescence whereas diseases of tooth tissue, for example, decalcifications or white-spot injuries are obvious as dull spots brought about by alleged fluorescence misfortune. Intra-oral camera is helpful in capturing and analyzing the green fluorescence loss and presence of red fluorescence. Green fluorescence is an intrinsic property of hard dental tissue and it is the first type of fluorescence observed. Any white spots lesions that appear are visible as dark areas. This permits the discovery of decalcifications around multiple times sooner than with regular visual material investigation and x-beam photos (Alammari, M.R. *et al.*, 2013).

CARBON DIOXIDE LASER

Lasers have come indicated far since Albert Einstein depicted the hypothesis of invigorated outflow in 1917. Today lasers innovation has and is affecting our life from numerous points of view. Its progressions in the field of medication and dentistry are assuming a significant job in quiet consideration and prosperity. Since the subsurface of the carious lesion has more organic compounds than the adjacent sound tissues, the application of carbon dioxide laser as a diagnostic tool is considered helpful. It is used for caries prevention and pulp coagulation.

At the point when carbon dioxide laser is applied to an incipient carious lesion, the natural organic substances evaporates leaving a dark carbonized buildup behind while the inorganic substance of sound enamel containing least amount of water is less influenced by the laser pillar. Increasingly clinical examinations ought to be done so as to comprehend the viability of carbon dioxide laser.

ULTRASONICS (ULTRASOUND CARIES DETECTOR)

Utilization of ultrasound to identify dental caries has been proposed for as far back as 30 years; however the system has gotten restored intrigue especially in the previous 10 years. It was presented for distinguishing early carious injuries on smooth surfaces. Demineralization of natural enamel is evaluated by ultrasound pulse-echo technique. It is seen that there is a definite connection between the mineral substance of the body of the lesion and the relative echo amplitude changes.

Ultrasound utilizes sound waves with frequency which are are longitudinal or pressure h waves and travel through gasses, fluids, and solids. Ultrasound interacts distinctively with various tissues and has a frequency of >20,000 Hz, They have all the properties of waves, in that they might be reflected, dissipated, refracted, or consumed. Measure of sound reflected gives data about the structure of reflecting interface, while the time taken for sound to be reflected gives data about the position of the reflecting interface (Mohanraj, M. *et al.*, 2016).

OPTIC COHERENCE TOMOGRAPHY (OCT)

In 1991 at the Institute of Technology of the University of Massachusetts, Optical coherence tomography (OCT) was first presented. OCT is practically identical to ultrasound imaging yet here light is utilized rather than sound. Cross-sectional pictures are produced by estimating the echo time deferral and light intensity that is reflected or backscattered from internal tissue structures. On the grounds that the speed of light is very high, the echo time delay can't be estimated directly. One technique for estimating the echo time delay of light is to utilize low coherence interferometry. Light from a source is coordinated onto a beam splitter, and one of a beam is incident on the imaging sample, while the subsequent beam travels a reference way with a variable way length. The backscattered light is interfered and detected with a photodetector at the interferometer output. OCT can be used to perform cross-sectional imaging. The optical shaft is focused on the imaging sample, and the echo time delay and intensity of the backscattered light are estimated to yield an axial backscattering profile which is estimated at a few transverse positions to yield a two dimensional information index. The axial resolution in OCT is dictated by the coherence length of the light source. In this way high resolution can be accomplished free of the beam focusing conditions (Machoy, M. *et al.*, 2017).

Its application in the field is to diagnose the carious lesions. OCT imaging has also been found to be effective in getting detailed microscopic images of wet canal showing cementum and dentin. Intraoperatively, OCT imaging of root canals can indicate unclean fins, transportation of the canals, hidden accessory canals and measurement of the apex.

FIBER-OPTIC FLUOROSCENT SPECTROMETRY

Utilizing fiberoptics and the principles of reflectance and fluorescence, marked differences in spectral ssignatures among different dental tissues under investigation have been observed via fiberoptic fluorescent spectrometry. Brilliant scope for endodontic microflora evaluation likewise exists. Incident ultra violet light has the ability to actuate fluorescence from certain objects. Foreman in an study revealed this wonder in the teeth. He detailed that teeth with vital pulps fluoresced regularly but the teeth with necrotic or missing pulps didn't fluoresce when presented to ultraviolet light. Contrasts in characteristic sound dentin and carious dentin fluorescence, spectra at excitations of 405 nm and 440 nm were seen as statistically significant. Sound dentin had characteristic peaks at 494 nm and 530 nm after excitation at 405 nm, while infected dentin showed characteristic peaks at 498, 533, 545, and 568 nm. After excitation at 440 nm, sound and decayed dentin both indicated a peak around 545 nm, with decayed dentin showing an optional peak around 570 nm. The differences in fluorescence spectra were attributed to the loss of mineralized tissue parts and expanded organic presence as well as water in decayed versus sound dentin. Fluorescence from the pulp was seen as generously lower than the sound and decayed dentin fluorescence. The emission from the enamel is unique and can be distinguished from that of sound and decayed dentin patterns giving a premise for differentiating between tissue classifications (Tyagi, S.P. *et al.*, 2012).

MAGNIFICATIONS

Endodontics demands higher visual acuity due to its confinement to narrow operating space as it deals with miniscule anatomy. Over the years, many magnification devices have been introduced that act as a bridging tools between the naked eyes and the magnifying microscope. Endoscope, magnifying glass, and intraoral camera are such tools that have largely been superseded by contemporary devices and seem to be more practical and convenient for application, such as loupes dental operating microscope (DOM), Orascope, etc (Held, S.A. *et al.*, 1996, Erten, H. *et al.*, 2006 & Brüllmann, D. *et al.*, 2011).

Orascope

An orascope is a fiber optic endoscope that works directive with a camera, light source and a screen, alike the rod-lens endoscope. Fiber optics are made of plastics, and in this way, are little, lightweight, and adaptable. Note that the picture quality from fiber optic amplification has an immediate connection to the quantity of fibers and size of the focal point utilized and is intended for intracanal visualization. The orascope has a 0.8 mm tip diameter, 0° lens and 15 mm in long working portion. Before the placement of the 0.8 mm fiber optic scope, it is suggested that 2- 2.5 × loupes or a SOM be utilized for regular endodontic perception to get to the canal(s). An adequate canal preparation is necessary before the placement of an orascope, as under instrumented canal may lead to wedging of the orascope and damage some of the fiber optic bundles within the scope. In spite of the fact that, the scope will see through sodium hypochlorite, the canal should likewise be dried before the 0.8 mm fiber optic scope is put. Like the endoscope, the endodontist holds the orascope while seeing the picture from the screen. Temperature and humidity contrast between the dental operatory and the canal can make moisture tovcondense on the fiber optic focal point, in this manner bringing about fogging. The utilization of a lens anti- fog solution to fog arrangement can help wipe out this lens condensation buildup (Bahcall, J.K. 2018).

Microscope-Endoscope Combination

In conventional and surgical endodontic treatment, there are different parameters for visualizing each kind of treatment, when there is requirement beyond magnification. Both the microscope and rod-lens endoscope have advantages in magnification and can be used for either type of endodontic treatment. The favorable circumstances for utilizing a microscope for ordinary endodontic treatment and a rod lens endoscope for surgical visualization prompted the development of a magnifying instrument coupler (JEDMED, Inc. St. Louis, MO) that empowers the endodontists to join the two innovations. The blend unit likewise takes into account the utilization of the orascope and advanced digital documentation (Bahcall, J.K. 2018).

CONCLUSION

Diagnosis forms the basis of treatment. The problem of incorrect, delayed, or inadequate endodontic diagnosis and treatment planning places the patient at risk and could result in unnecessary or inappropriate endodontic treatment. The vistas of endodontic diagnosis are ever evolving. Careful attention to diagnostic aids and an understanding of both their usefulness and limitations is essential if they are to be employed most effectively in clinical dentistry. To conclude one could say that the determination of exact pulpal status i.e. vital or necrotic is complex and is dependent on a number of factors like patient history, clinical examination and various diagnostic tests conducted. However with the advent of newer diagnostic techniques, such as pulse oximetry, LDF and radiovisiography, these provide a quicker, easier and precise diagnostic means. The results of newer diagnostic tests should never be relied upon individually, but on the contrary they should be utilized in combination in order to arrive at a correct final diagnosis. Equipping ones natural diagnostic instinct with knowledge of contemporary advances would ensure that a 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.

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