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Diagnostic Aids: A means of establishing treatment plan

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Abstract
The importance of proper diagnosis in formulating a treatment plan need not be emphasized as it is the most important part in treating a patient. The right diagnosis comes from the use of proper diagnostic aids and identifying the exact problem underlying the presenting complaint. Addressing the patient's complaint and relieving it will provide adequate relief to the patient and also will provide the best treatment outcome. This article tries to put together various diagnostic aids in accurately identifying the presenting complaint. Most of the diagnostic methods are enlisted starting from the conventional methods to the recent developments in the field to enhance the knowledge of the clinician.

Keywords: electric pulp test, laser Doppler flowmetry, liquid crystal test, thermal tests, tuned aperture computed tomography

Introduction

A key element of a definitive treatment planning approach is arriving at an accurate diagnosis [1]. An improper diagnosis can lead to an inappropriate treatment modality and there by a bad prognosis [2]. Endodontic diagnosis cannot be arrived just by the examination of the patient. It requires both examination and other investigations. The clinician should gather all information from the patient by taking a detailed case history, should subject the patient for various clinical, microbiological and other modified tests. The diagnosis can vary depending on the stage of the dental caries, patient's health scenario and various other factors [3].

Case history and General examination

Sir William Osler has stated "Never treat a stranger, listen to your patient, patient will give you diagnosis". A detailed case history will help the clinician in treating a disease and will emphasize on the modification of the treatment modality based on patient's systemic health condition. The patient should be allowed to describe the complaint in their own words thereby giving the clinician clue about the onset, intensity, aggravating and relieving factors of patient complaint [4]. A proper demographic, medical and previous dental history should be taken. Dental history helps in assessing the etiology of the complaint, helps in understanding the patient motivation towards dental treatment, which can have an influence on the treatment approach.

There are several medical conditions which require utmost care during dental treatment including allergies, cardiovascular diseases, defects in immune system, diabetes, patients under medications [5]. Apart from general examination a detailed extraoral and intraoral examination has to be done. Extra oral examination includes checking for any facial asymmetry, lymph node assessment, tempero mandibular joint examination, amount of mouth opening, salivary gland swelling.

Intra oral examination hard tissue examination mainly includes examination of tooth for any decay, missing, mobility, crack, fracture, recession, discoloration and variation from normal anatomy. Soft tissue examination examines the buccal and vestibular mucosa, tongue, gingiva and alveolar mucosa, lips, oropharynx, floor of mouth [6].

The dental pulp has a unique feature that it's contained in a noncompliant environment of the root canal system that does not allow the direct vision of the pulp. This encapsulation affects the ability of pulp to respond to injury or any disease. If the rigid shell is disintegrated, the pulp is under the attack of foreign bodies [7].

Visual Examination

A thorough visual examination of the tooth and surrounding tissues has to be followed. The contour, consistency and colour should be assessed. A tunnel vision involving only the chief area of concern should be avoided. The surrounding areas must be thoroughly analyzed. Conventional examination includes the use of mouth mirror, dental explorer and dental probes are used. Few recent magnification aids include loupes, dental operating microscope, brynolf magnifier, endoscope, intra oral cameras and orascope [8, 9, 10].

Thermal Tests

The pulp is innervated by various myelinated and non-myelinated nerve fibres, namely A delta, A beta, C fibres. Ninety percentage of A myelinated fibres are A delta fibres located at the coronal portions and the pulp horns. C non myelinated fibres are located at the central core of the tooth or at the pulp proper. The A delta fibres have a smaller diameter, hence a faster conduction unlike the C fibres. Pulpal thermal tests extrapolate pulpal health from the sensory responses.

A delta fibres responds to the stimuli mainly by the hydrodynamic effect whereas the C fibres are stimulated mainly

by vasodilation. Thermal testing is influenced by the inward or outward movement of the dentinal fluid. A painful sensation is elicited on application of a thermal stimulus. A sudden change in the temperature excites the A delta fibres because of a change in the structural arrangement of cell membrane of A delta fibres and a gradual change of temperature is needed for C fibres to get excited.

Continuous application heat stimulus causes an inward fluid movement, vasodilation and an increase in intrapulpal pressure there by activating the C fibres. Application of cold stimulus causes outward movement of dentinal fluid, elicits a stronger response and activates the A delta fibres. On continuous application of cold, the blood flow is reduced because of its vasoconstrictive effect and thereby a state of anoxia or hypoxia occurs and A delta fibres stop to function but C fibres can still survive in hypoxic condition, which is why the cold test is sometimes refractory [11].

Cold Tests (Fig: 1)

The various aids used are Endo ice, Carbon dioxide snow, Pencil Ice, Ethyl chloride, Skin refrigerant, Spray, Ice cold water. Ice is the widely used cold test aid. The ice is made in an empty anaesthetic cartridges. Refrigerant spray is another widely used and easily available mode of cold test. Ethyl chloride and Dichlorodifluoromethane (DDM) can be used. Recently DDM is replaced by Tetrafluoroethane (TFE)- Endo ice. It can be dipped in cotton pellets and applied on the tooth. A pressurized CO2 liquid cylinder is commercially available known as the Carbon dioxide snow. Liquid pressurized carbon dioxide when forced through small openings and on contact with the atmospheric pressure it converts to ice.

Fig 1: Cold Test

Heat tests

The various aids used are hot water, hot air stream, heated gutta-percha (68 degree Celsius), hot impression compound, heated burnisher, rubber disk, brew wheel, laser beam mainly Nd Yage, System B Sybron endo (pulp tester tips) [12].

Electric Pulp Test

An electric stimulus can elicit an action potential and hereby cause a change in the ionic balance across the neural membrane. The electric pulp tester works on this principle. The electric signal is released from the probe tip to the dentinal tubule which is transferred to the pulpal organ [13]. The patient wears a lip clip or can touch the probe handle. On stimulation the patient experiences a tingling sensation. The results cannot be completely relied upon since false results are produced in various cases like immature healthy teeth, teeth subjected to orthodontic forces, patients having systemic disease, anxiety, hyperemia and immediate trauma [11].

Dyes

Caries detector dyes stain the organic matrix of infected dentine. The various dyes used are methylene blue, Indiana ink, basic fuschin. propylene glycol. Recently a new approach, dye enhanced laser flourescence technique has been employed for caries detection [14].

Guttapercha tracing (Fig: 2)

A traditional gutta-percha is placed through the sinus opening which helps in localizing the source of infection. By radiologic examination and pulp vitality test further investigations can be done [15].

Fig 2: Gutta Percha Tracing

Test Cavity

It serves as a last resort in arriving at a diagnosis. The rotary movements in the dentine can evoke a sensory response among the patient. This method is an invasive and irreversible procedure and the cavity prepared can be restored further [12].

Bite Test

Bite test can be used to differentiate between a pulpal and a periapical pathology. It can be performed using orange wood sticks, cotton wool wheels, rubber abrasive wheel, cotton tip applicator. Tooth sloth, frac finder can also be used. A sense of pain on biting on the testing aid reveals the tooth is having a periapical pathology and a sense of pain on releasing the bite confirms a crack or fracture on the involved tooth [16].

Transillumination (Fig: 3)

Transillumination of a tooth helps to identify a cracked or fractured tooth. All other source of lights other than the transilluminator light source should not be used. The light source will illuminate an area of tooth and the other area across the

Fracture light appears to be dark. Recent approaches include fiber Optic transillumination (FOTI), digital imaging fiber optic transillumination (DIFOTI), photoplethysmography [17].

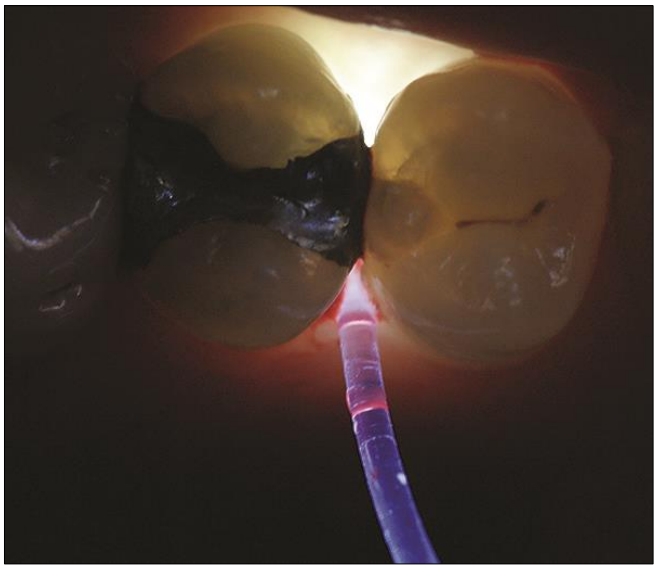

Fig 3: Transillumination

Selective Anaesthesia
The anesthesia is administered to the posterior segment of the oral cavity and the response for pain is checked for. If the pain still persists the mesial tooth is administered with anaesthesia [5].

Role of Radiographs
Radiography is an important aspect of dental diagnosis. Conventional radiographic techniques involve intra oral periapical radiograph (IOPA), bitewing radiograph, occlusal radiograph, orthopantogram (OPG). All the conventional radiographic techniques are 2 D image format. The two-dimensional image visualizes the anatomical structure in horizontal and vertical plane, but the sagittal plane is not evaluated. The angulations of anatomic structures, the thickness of the cortical plates is not evaluated in a two-dimensional image format. The anatomic noise and temporal perspective of periapical radiographs are yet another limitation of two-dimensional images. Because of all these limitations, digital radiographic techniques are employed which represent a three-dimensional image of the tooth.

Cone beam computed tomography (CBCT)
It provides a 3D image of an anatomical structure using an extra oral imaging technique. The radiation dose is much lower than all other radiographic modes. A cone beam x ray beam is directed to the area of interest. The anatomical structures are sliced into thin sections. CBCT can be combined with the periapical radiographs to arrive at better diagnosis and treatment plan.

Computed tomography (CT)
This involves an imaging technique which produce a three-dimensional image from a set of two-dimensional images. It eliminates anatomical noise and provides a better resolution. Micro CT is another alternative CT technique.

Tuned aperture computed tomography (TACT)
It creates a three-dimensional image from a set of eight to ten 2D images. The images are projected at different geometries and a 3D software is employed to provide an image [18].

Digital subtraction radiography (DSR)
A dental and a maxillofacial lesion progress in a gradual manner and it cannot be interpreted from the initial radiographs alone. Along with changes occurring in the due course of time the radiographic interpretation can vary according to the way in which clinician interpret it. The dental and structural noise can produce a change from the original image. Digital subtraction radiography concentrates on the change in radiographic images at each visit. All the radiographs taken at regular appointments are analyzed. The areas where the changes have occurred are displayed in a darker or lighter shade of grey, whereas the unchanged areas are displayed in a neutral shade of grey [19].

Computerized expert system
Expert system assists a clinician in arriving at a diagnosis. Expert system is a branch of computer science research called the Artificial Intelligence. All the necessary inputs regarding the patient must be entered to the database management software. Fuzzy Inference Systems (FIS), Coactive Neuro Fuzzy Inference System are few important expert systems [20].

Laser Doppler Flowmetry (LDF)
A tooth is said to be vital when there is a blood supply is intact. Thermal and electric tests mainly assess the nerve supply inside the tooth. Laser Doppler Flowmetry measures the amount of blood flow and thereby is a reliable marker of vitality. LDF is based on Doppler effect which states that there is a frequency shift of a wave when it is hit by a moving object. Red blood cells represent the moving cells in the dental pulp. The LDF device has a fiber optic probe which is placed on the surface of the tooth through which the laser beam is radiated. The beams after intersecting with the red blood cells, either change in frequency if the blood cells are in a state of flow thereby ensuring vitality or there is no change in the frequency if it's a static cell. The reflected light signals are again received back by photodetectors and signals are produced.
The signal produced signifies the amount of pulpal flow also called as Flux. Flux is the concentration of red blood cells and their mean velocity. Helium Neon laser beams are mainly used at a range of 632.8nm, 780nm. It can be used for estimation of pulpal vitality, pulp testing in children, to detect non endodontic causes in periapical pathosis, understanding the age related changes, helps in comparing the reactions of thermal and electric signals, understanding the pulpal reactions during orthodontic treatment, orthognathic surgery, monitoring the revascularization of implanted tooth.
Few studies reported that probe angulation did not have much influence on the results influenced by LDF. Ramsay *et al* (1991) and Hartmann *et al* (1996) have concluded that probe position more towards the gingival margin elicited a higher flux rate. Ingolfsson *et al* (1994) in his study evaluated that lower value of flux rate is obtained at incisal edge and occlusal areas. Based on the application area, the probe design can be altered including the

fiber separation. The probe should be held at a constant area to avoid changes in the readings.
Hand-held probe holders are available for this purpose. Rubber dam clamp, custom fabricated jig, silicone splint, plastic splint polyurethane splint can also be used. The tooth has to be isolated properly and the pulpal blood flow can be also a signal produced from the nonpulpal signals from periodontium. The laser technology is expensive, technique sensitive and can vary because of extraneous noise [21].

Pulse Oximetry
Takuo Aoyagi developed the oximetry technique. This is an effective, noninvasive technique and measures the objective blood saturation. It is based on Beer Lambert Law, which states that an unknown solute (hemoglobin) in a known solution (blood) can be assessed by the light absorption of the solute. The probe emits beams of two wavelengths- red and infrared light. The oxygenated blood and de oxygenated blood absorb different amount of red and infrared beams. This absorbed light is detected on a photodetector. The pulsatile change in the blood flow influence the amount of absorbed beam and thereby signifying the amount of arterial oxygen saturation. The probe should be kept in place to avoid any interferences. A clamp can be used to place the probe at place. Gels are available for the efficient transfer of the beams. The sensors should be adaptable to the size of tooth and is placed on the palatal aspect of the tooth.
It can be mainly used during maxillofacial surgery, during endodontic diagnosis, to assess the vitality of a recent traumatized tooth, during endodontic treatments under sedation, monitor patients under general anesthesia. Increased acidity, increased carbon dioxide in blood stream, blood disorders, venous pulsations contribute to wrong reading [22].

Dual wavelength spectrophotometry (DWLS)
The pulp is surrounded by an encapsulated organ. DWLS measures the presence or absence of oxygen in capillary bed inside dentinal tissue. The wavelength of 760nm and 850nm are employed. Here visible light is filtered through the fibreoptics. The DWLS is a small, invasive, inexpensive, portable device [23].

Liquid Crystal Test
Thermal changes on the tooth surface can be used as a very efficient diagnostic test. Liquid crystal testing was introduced by Renitzer. The liquid crystals have a property of exhibiting various colours on heating through their mesophase. Cooling of the crystals back reverses the colour. A colour of blue, green or a combination of blue green signifies that the tooth is vital. Red and yellow colour signifies that the tooth is nonvital. A nonvital tooth has a lower surface temperature than the vital tooth [24].

Thermocouple
Thermocouples are used for measuring the tooth surface temperature. Brown and Goldberg *et al* using thermocouple found out that surface temperature decreased in an anterior direction. Palatal surface was found to be warmer than the labial surface. Periodontium is the heat source which is conducted through the pulpal tissues. A vital pulp is capable of circulation and thereby a source of temperature.

Thermistors
The thermistor is a temperature sensitive thermometer and it changes its electrical resistance according to the thermal energy received. For diagnosis, two thermistors are used a measuring thermistor and a resistor thermistor. The measuring thermistor was placed on the surface of tooth structures and the reference thermistor was held suspended in air.
The measuring thermistor recorded the temperature of the tooth and reference thermistor measured the temperature of the immediate atmosphere.

Infrared Thermography
Computer controlled infrared imaging system is a noninvasive sensitive method of measuring body temperature. Sir William Herschel and his son Sir J. F. W. Herschel were pioneers in the field of infrared thermography. Hughes probe eye thermal video system is based on this principle and it can detect changes as small as 0.1 degree Celsius. Vital and nonvital teeth have same temperature at rest, but once a stream of cold air is passed through the teeth, nonvital teeth take longer time to rewarm than the vital teeth. It was also found that temperature at the gingival or cervical areas were a bit higher than that at the incisal edges [25].

Fibre optic transillumination (FOTI) and digital imaging fibre optic transillumination (FOTI)
FOTI is a noninvasive, simple, sensitive technique. Fiber optics are flexible thin cylindrical fibres of high optical glass or plastics. Fiber optic transillumination is based on Total Internal Reflection and Snell's law. Individual fibres are grouped to bundle of fibres. Transilluminator light source can illuminate the translucent dentinal tissue thereby help in detecting the carious lesions. It can also help in the detection of fracture and crack lines. DIFOTI is based on FOTI principle and also allows for rapid capturing and recording the images. DIFOTI can detect very early caries, white spot lesions, inter proximal caries [26].

Photoplethysmography
It measures the blood volume changes in the pulpal tissue. It is an optical measurement in which a light source is directed through the tooth. A photodetector assesses the small variations in light intensity. It detects the change in the pulpal blood flow and circulation.

Ultrasound and ultrasound Doppler
The ultrasound apparatus incorporates a transducer, a coupling agent, and a software with electronic and digital signal processing units. When the probe is moved, a 3D image is formed. Ultrasound has the ability to penetrate biological tissues and can detect the discontinuities and pathosis. Once the sound waves intersect the biological tissues it gets scattered and reflected back which is called the echo. The echo signals are transferred to electrical signals which are converted to a light image of various grey shades.
Ultrasound Doppler allows for the detection of the rate and direction of the blood flow. It is represented on a graph (Doppler) and as a grey scale image (colour). Positive Doppler shift is caused because of the movement of RBC towards the transducer and Negative Doppler shift is caused because of the movement in

The opposite direction. In vital teeth a pulsating waveform is obtained and in nonvital or endodontically treated teeth a linear nonpulsative waveform is obtained [27].

Detection of interleukin 1 β

The immune system of our body releases various interleukin, cytokines, proinflammatory mediators in case of inflammation. During dental pathosis, the mediators are released. Detection of these inflammatory bodies helps in the detection of severe infection [28].

Caries Activity Test

Caries activity test helps in identifying the causative organisms for the pathosis. It helps in identifying the high-risk population for dental caries, helps in further researches, decreases the caries susceptibility at the individual level.

Various tests include Lactobacillus colony count test, Streptococcus mutans test, S. mutans screening test, Alban test, Dewar test, Swab test, Salivary buffer test, Snyder colorimetric test, Enamel solubility test, Salivary reductase test, Fosdick calcium dissolution test [29].

Quantitative light induced flourescence

It measures the percentage of change in fluorescence of demineralized and mineralized enamel and dentine. It helps in measuring the development of caries and remineralization of lesions. The chromophore in enamel and dentine has the property of auto fluorescence which is reduced in demineralized tissues. The fluorescence loss in the demineralized areas can be quantified [30].

Conclusion

Diagnosis is the corner stone in the treatment planning. A better understanding of the diagnostic aids is essential for an effective outcome. A lot many recent diagnostic aids have been developed for arriving at better conclusion. Clinician's thorough knowledge along with the technology should be used in the most appropriate way.

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