Recent Advancements in Pulp Testing Devices

Akansha Kishen[1], Anjaneyulu[2], N. P. Muralidharan[3]

[1]Research Associate, Dental Research Cell, [2]Reader, Department of Conservative Dentistry and Endodontics, [3]Professor, Department of Microbiology, Saveetha Dental College, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India

Abstract

Pulp vitality test is very crucial in monitoring and regulating the state of health of a dental pulp, especially after the case of traumatic injuries. The dental pulp is considered to be the innermost part of the tooth. It is surrounded on all sides with dentine except near the apical foramina. This hard dentine casting around the pulp protects it from infection by microbes present in the mouth. The traditional pulp testing methods involve thermal and electric pulp testing methods. This conventional method basically depends on the innervation and often yields or records either false positive or negative response. The newer pulp testing devices, some of which are still under developmental stage, detect the blood supply of the pulp, enumerate pulpal vasculature, check the vitality of the tooth etc. These newer technologies function by light absorption and reflection methods in. They are considered to be more accurate and non-invasive methods. The review article attempts to discuss the recent advancements in various pulp testing devices related to pulp vitality testing in clinical endodontic practice. It also describes the principle on which these newer pulp testing devices are basically based on its mode of working. The aim of this review paper is to highlight the difference between sensitivity testing and vitality testing.

Keywords: *Pulp vitality, pulse oximetry, laser doppler flowmetry, pulpal circulation, revascularization, light transmission.*

Introduction

One of the greatest diagnostic challenges in dental clinical practice is to accurately assess pulp status in different age groups of people. This may be further more complicated in many cases of pediatric dentistry where the practitioner is faced with a developing dentition, traumatized teeth, etc[1].

The dental pulp is considered to be an unmineralized oral tissue that is composed of certain soft connective tissue, vascular, lymphatic, and nervous elements that occupy the central part of the pulp cavity of each tooth of the dental pulp [2]. These nerve vessels enter and leave the tooth through this foramen. Dental pulpal testing devices are used in clinical as well as in diagnostic purposes in the field of dentistry to help establish the health of the dental pulp, within a pulp chamber and root canals of any tooth in the oral cavity [3]. These pulp testing devices can function in two manners as "Vitality testing" which assesses the blood supply to the tooth, while the "sensitivity testing" assesses the sensory supply to the tooth [4]. The assessment of pulp vitality is a very crucial diagnostic procedure in the practice of dentistry.

Current routine methods which include the conventional or the traditional practices are based on the stimulation of nerve fibers and thus giving no direct indication of blood flow within the pulp chamber [5]. These include certain constituents like thermal stimulation, electrical, or direct dentine stimulation. These testing methods are considered to have the potency to produce an unpleasant and occasionally painful sensation to the

Corresponding Author:
Anjaneyalu
Reader, Department of Conservative Dentistry and Endodontics, Saveetha Dental College,
Saveetha Institute of Medical and Technical Sciences
Saveetha University, Chennai, Tamil Nadu, India,
600077, Email id kanjaneyulu.sdc@saveetha.com
Phone no.: 9566151527

tooth. The main disadvantages revolve with inaccurate results which can be either false positive or even negative which can be obtained in many instances [6].

Recent studies have proved that blood circulation inside the pulpal chamber is the most accurate determinant in assessing pulp vitality [7]. This factor helps in providing an objective which enables to differentiate between necrotic and vital pulp tissue. This review article highlights tests depending on the passage of light through the control tooth to detect pulp vitality of that tooth with greater objectivity in the longer run. They also depend either on the detection of changes in case of light absorption as it passes through the tooth, as in photoplethysmography devices [8]. pulse oximetry and dual-wavelength spectrophotometry. Also if there is a shift in light frequency it gets reflected from a tooth which is in case of laser Doppler flowmetry [9]. This review paper attempts to illustrate various advancements in pulp testing devices. Ehrmann has proposed mainly three key uses of pulp testing in clinical practice[10]. They are-

BEFORE OPERATIVE PROCEDURES

Pulp testing may be indicated for a selected tooth before certain restorative or orthodontic interventions, particularly where pulpal health or pulpal vasculature may be in question. The absence of all the symptoms or radiographic changes alone may not be considered as conclusive evidence of pulp vitality in the case of teeth, because pulpal degeneration can occur without accompanying symptoms[11].

DIAGNOSIS OF PAIN

The origin of most oral pain is due to pulpal tissues. case reports have illustrated the value of pulp testing in identifying crucial pulpal pain from other conditions such as myofascial pain dysfunction syndrome and referred pain [12].

INVESTIGATION OF RADIOLUCENT AREAS

Radiolucent areas at the apices of teeth may be the result of any periapical extension of pulpal pathology, but may also arise due to certain pathological processes. If pulpal pathology is not responsible for the underlined lesion, the associated teeth would be expected to give a normal response to vitality testing. Periodontal lesions, cysts, fibrous lesions, congenital abnormalities, and even neoplastic processes may all produce periapical radiolucencies similar to those associated with pulp degeneration. The mental foramen and the incisive canal are two normal structures which may present as periapical radiolucencies.

Materials and Methods

All the articles collected have complete relevance to the topic, which is a recent advancement in pulp testing. They have been collected from search engines such as PubMed, Google Scholar, Elsevier, etc. All the articles collected had information about pulpal tissue, pulpal sensitivity, principles of newer pulp testing devices, pulpal vasculature, etc. All the articles which were irrelevant to the topic were excluded from the list. The results for this review article are based on previous studies done by other esteemed and honored authors and journals.

Ethical clearance is not essential as this is a review.

Result and Discussion

For this review, various articles from google scholar, PubMed and Elsivier were collected. The result of this review depicts the recent advancements and technologies in pulp testing devices. Majority of the article collected mainly emphasis on the dental pulp, pulpal vitality, pulpal vasculature, and different pulp sensibility tests as well as pulp vascularity tests. The data collected from different articles shows that there are still many pulp testing devices under developmental stage.

Previously our team had conducted numerous clinical trials [13 14 15], in vitro studies [16 17 18 19 20], surveyed [21 22] and reviewed [23 24 25 26 27] various aspects of endodontics and conservative dentistry over the past five years. Now we are focusing on review studies, the idea for which has stemmed from the current interest in our community. This review study was conducted acknowledging the importance of the pulp and enabling to differentiate between vital and non-vital pulp, also about different pulp testing devices which contributes as a factor to the outcome of endodontic therapy.

DENTAL PULP

The pulp is the part in the center of a tooth which is made up of living connective tissue and cells termed as odontoblast [28]. The pulpal tissue is the neurovascular bundle central to each tooth, in case of permanent or primary dentition. This dental pulp consists of a central pulp chamber along with the pulp horns, and radicular canals. Because of the continuous deposition of dentine, the pulp chamber starts becoming smaller with age[29]. This factor is not uniform throughout the coronal pulp but progresses at a faster rate on the floor than on the roof or sidewalls.

Radicular pulp canals start extending down from the cervical region of the crown to the root apex of a tooth. These canals are not straight most of the time but vary in different aspects like shape, size, and number. They are continuous with the periapical tissues through the apical foramen. The mean volume of a single adult human pulp is 0.02cc[30]. There are four layers of pulp from innermost to the outermost aspect of the tooth [31]. They are-

PULPAL CORE

This is present in the center of the pulp chamber with many cells and an extensive vascular supply.

CELL RICH ZONE

It consists of fibroblast and undifferentiated mesenchymal cells.

CELL FREE ZONE

Also termed as (zone of Weil) this zone is rich in both capillaries and nerve networks together.

ODONTOBLASTIC ZONE

It is an outermost layer that contains odontoblasts and lies next to the predentin and mature dentin.

Cells found in the dental pulp include fibroblast (that constitutes the principal cell), odontoblasts, defense cells like histiocytes, macrophages, granulocytes, mast cells, and plasma cells. The nerve plexus of Raschkow is located central to the cell-rich zone [32].

PULP INNERVATION

Within the coronal pulp, nerve bundles start diverging and branching out towards the pulpo-dentine border, and emerge from their myelin sheaths[33]. Nerve divergence keeps continuing until each bundle loses its integrity and smaller fiber groups travel towards the site of dentine. This course is relatively straight in the axis until the nerve fibers start to form a loop and result in the formation of mesh termed the nerve plexus of Rashow [34]. Terminal axons exit from their Schwann cell investiture and pass between the odontoblasts as free nerve endings. This nerve plexus is most well developed in the case of the peripheral pulp. Two types of sensory fibres are present in the pulp: the myelinated (A fibres) and unmyelinated C fibres[35] .

The A fibres predominantly innervate the dentine (entering the dentinal tubules) and are sub-grouped according to their diameter and conduction velocities into Aβ and Aδ fibres[36]. The C fibres innervate inside the body of the pulp. Aδ fibres mediate acute, sharp pain and are excited by hydromechanical events in dentinal tubules such as drilling or air-drying. C fibres have a high threshold value and can be activated by intense heating or cooling of the tooth crown. Once activated, the pain initiated by C fibres can start to radiate throughout the face and jaws. C fibre pain is associated with tissue injury and is modulated by inflammatory mediators, vascular changes in blood volume and flow, and increases in pressure result in a progressive increase in the sensory response [37]. It has been assessed that the highest concentration of neural elements was in the pulp horn region (pain sensation is felt more in this region). There is a progressive decrease in the number of nerve fibres in the cervical and radicular areas [38]. It is considered that the direction of dentinal tubules is also important in establishing pulp test responses in various parts of the tooth crown. The dentinal tubules have an almost straight course which extends from the incisal edge of anterior teeth in the oral cavity to the pulp horn. In multi-cuspal teeth, the course of tubules is somewhat curved and resembles an 'S' shaped structure [39]. It is principally the fluid that is present in the dentinal tubules that allow the conducting of electrical impulses from the pulp tester electrode to the pulp. If the distance is shorter between the electrode and the pulp, then there will be lower resistance to the flow of current [40].

TECHNIQUES OF PULP TESTING DEVICES

The accurate diagnosis of the true histological status of the pulp is of significant importance for treatment planning. This is indirectly done by assessing the neural sensitivity of the pulp. The more accurate method would be to assess the vascularity of the pulp. However, most common methods clinically employed assess neural sensitivity, while the recent researches and developments are trying to find a clinical method of vascularity assessment. Various methods for tooth vitality assessment are given below-

Pulp sensibility tests

- Thermal tests
- Heat testing
- Cold testing
- Electric pulp tester (EPT)
- Anesthetic test
- Test cavity

Pulp vitality/vascularity tests

- Pulse oximetry
- Laser Doppler flowmetry
- Recent technologies
- Dual-wavelength spectrophotometry
- Thermography
- Crown surface temperature
- Transmitted light photoplethysmography

PULP SENSIBILITY TESTS

Dental pulp testing is a very useful and essential diagnostic aid in endodontics treatment. Pulp sensibility tests investigate the extrapolate pulp health from the sensory response [41].

MECHANISM

Currently, the most widely used pulp vitality testers are able to assess the integrity of the Aδ nerve fibers inside the dentine–pulp complex. This can be done by briefly applying a stimulus to the outer surface of the tooth. If the Aδ nerve fibres are successfully stimulated, then the patient will respond by acknowledging a very short, sharp sensation/tingling from the tooth. A positive response indicates that the nerve fibres are functioning (to some degree), but does not give any indication of pulpal blood flow. If there is no vascular supply to the pulp, it will rapidly become anoxic and the Aδ fibres will cease to function [42].

THERMAL TEST

These tests involve the application of cold and heat stimuli to a tooth, to determine sensitivity to thermal changes in a tooth. Response to cold stimulus given to the tooth usually states about the vital pulp, regardless of whether that pulp is normal or abnormal in condition. In contrast to the context, an increased response to heat stimulus is suggestive in the case of pulpal or periapical pathology which may require endodontic intervention.

Thermal tests involve the application of cold and heat to a tooth to determine its sensitivity to thermal changes. The results of the thermal test should be correlated with the results of other tests to ensure validity[43].

HEAT TEST

By using different techniques which deliver different degrees of temperature. It uses-

- Electrical heat carrier
- Hot gutta-percha stick
- Others
- Hot water under rubber dam isolation
- Hot burnisher, hot compound
- Dry rubber polishing wheel

The heat test can be performed in the posterior as well as anterior tooth [44]. The area to be tested is isolated and dried and suitable lubricant (Vaseline) is applied and heat is directed to the exposed surface of the tooth, the patient's response is noted. A heat carrier instrument that can deliver a controlled temperature to the tooth is preferable, or a hot GP stick can be used.

Mechanism Of Heat Test

The mechanism of the heat test is explained in figure 1.

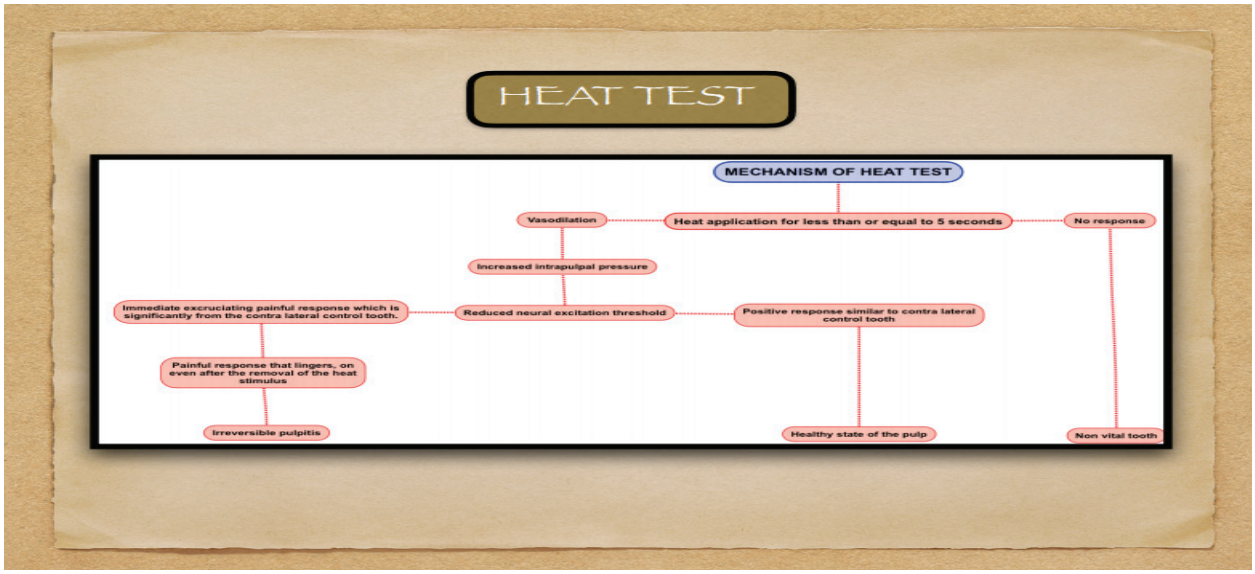

Figure-1: Mechanism of heat test, works by the process of heat application for less than or equal to 5 seconds to the affected tooth.

COLD TEST

Cold thermal testing results in contraction of the dentinal fluid within the dentinal tubules of the dentine, resulting in a rapid outward flow of fluid within the patent tubules [45]. This rapid movement of dentinal fluid inside the dentine results in 'hydrodynamic forces' acting on the Aδ nerve fibres within the pulp–dentine complex, leading to a sharp sensation lasting for the duration of the thermal test[46]. A variety of cold tests can be done; the major difference between all these is the degree of cold that is applied to the tooth. The most common pulp testing method employed by clinical practitioners is to seek a response to cold stimuli. Ideally, cold testing should along with the conjunction of an electric pulp tester so that the results from one test will verify the findings of the other test. If a mature, non-traumatized tooth in the oral cavity does not respond either to EPT or cold, then the tooth may be considered non-vital. However, care should be taken along with proper procedure while testing multi-rooted teeth, as they may respond positively to a cold stimulus, even though only one of the roots consists of the vital pulp tissue. The cold test may be used to differentiate between reversible and irreversible pulpitis can be achieved[47].

ELECTRIC PULP TESTER

The electric pulp test is one of the tests used to determine pulp vitality. The electric pulp tester, when testing for pulpal vitality, uses nerve stimulation. The objective of this electric pulp tester is to stimulate a pulpal response to the tooth by subjecting it to go through an increasing degree of electric current [48]. A positive response is an indication of vitality and helps in determining the normality or abnormality of that pulp. No response to the electrical stimulus can be an indication of pulp necrosis [49].

TEST CAVITY PREPARATION

This test may be served as a last resort in testing for pulp vitality. It is only considered to be used when the results of all other tests have proved inconclusive [50]. Its value in dental clinical practice has been largely anecdotal as there is no evidence base to support its effectiveness. The test cavity is made by drilling through the enamel–dentine junction by following preventive measures to eradicate any dilemma. This is done in case of an unanesthetized tooth along with good isolation of the tooth. This may be achieved under a rubber dam with a small round diamond bur in a high-speed handpiece with adequate coolant. The patient is asked to respond

immediately if any painful sensation is being felt during the drilling procedure of the tooth. If the patient feels certain pain that persists once the bur contacts the sound dentin, then the procedure is terminated completely and the cavity is restored

LOCAL ANESTHETIC TEST

When dental symptoms are poorly localized or referred most of the time, then the prediction of an accurate diagnosis is extremely difficult. Sometimes, patients may not even be able to specify whether the symptoms are from the maxillary or mandibular arch. In such cases, and where pulp testing has proved inconclusive, an anesthetic test may be helpful. The technique involved in this local anesthetic test includes certain procedures that are being followed in a stepwise manner. In the beginning, there is a use of either infiltration or an intraligamentary injection along with which the most posterior tooth in the area suspected of causing the pain sensation is being anesthetized. If the pain persists and prolongs once after the tooth has been fully anesthetized, the tooth immediately mesial to it is then completely anesthetized, and so on routine goes by, until the pain completely disappears and subsides. If the source or origin of the pain sensation cannot be even localized to the upper (maxilla) or lower (mandible) jaw, an inferior alveolar nerve block injection is given; cessation of pain indicates the involvement of a mandibular tooth. This approach has an advantage over a test cavity, which may incur iatrogenic damage.

PULP VITALITY/ VASCULARITY TESTS-

PULSE OXIMETRY

It is considered to be a non-invasive oxygen saturation monitoring device widely used to record blood oxygen saturation level [51]. Pulse oximeter is a piece of standard equipment in operating rooms, including intensive care units, emergency rooms, etc. where sedation & analgesia are provided [52]. This device is currently under investigation in case of dental practice to detect pulpal blood circulation by its non-invasive design.

The principle of this is based on Beer's law which relates the absorption of light; by a solute to its concentration and optical properties at a given wavelength. In the red region, oxyhemoglobin absorbs less light than deoxyhemoglobin and vice versa in the case of the infra-red region[53]. The system has a probe which contains a diode that limits light in two different wavelengths.

1. Red Lights (660mm)

2. Infra-red light (850mm)

There is a silicon photodetector diode which is placed on the opposing surfaces of the tooth. This is connected to a microprocessor. The ideal placement of the probe is in the middle third of the crown.

Many dentists have approved pulse oximetry to be an effective manner of pulp testing. It is also very evident in the time of "impact injury" where the blood supply remains intact but the nerve supply is being damaged. Gingival circulations can also be used to detect the pulse based on this device [54].

Limitations include the background absorption associated with venous blood and tissue constituents. In addition to this there are chances for refraction and reflection of light that may add on to its disadvantage.

DUAL WAVELENGTH SPECTROPHOTOMETRY-

DWLS is a method that is independent of a pulsatile circulation. This method completely ensures the measure of oxygenation changes in cases of the capillary bed rather than in the supply vessels and hence does not depend on the pulsatile blood flow [55]. DWLS depends on the presence or absence of oxygenated blood at 760mm and 850mm. DWLS helps to differentiate reproductive readings between a pulp chamber of a vital and non-vital tooth.

In young children, where there are avulsed and replanted teeth with open apices, the blood supply is regained within the first 20 days after replantation but nerve supply lags. Repeated readings are taken in such cases up to 40 days to ensure an increase in blood oxygenated level that means the healing process has occurred; the pulp of such teeth has also started to recover [27] [56]. The instrument is comparatively small, portable, relatively inexpensive, and suitable for usage in clinical practice.

LASER DOPPLER FLOWMETRY

It is considered to be a noninvasive, electro-optical technique which allows the semiquantitative recording of the pulpal blood flow[57]. The technique is based on the Doppler principle whereby light from a laser diode is incident on the tissue which is scattered by moving the RBC's; thus the frequency broadened[58].

The frequency broadened light along with the laser light scattered from static tissue is photo detected and the resulting photocurrent processed to provide a proper blood flow measurement. It helps to locate the revascularization property accurately of a tooth.

THERMOGRAPHY/CROWN SURFACE TEMPERATURE

Thermography is a test that uses an infrared camera to detect blood flow in the pulpal body tissue. It is effective in recording heat patterns as wheels. It has become an important diagnostic tool because of the accurate measurement of regional temperature and differentiation of temperatures while doing the dental procedure[59].

It is a non-invasive, and highly accurate method of measuring the body's temperature. The teeth that need to be assessed must be isolated using rubber dams. The technique is complex and requires the subjects to be at rest for 1 hour period to test[60].

TRANSMITTED LIGHT PHOTO THERMOGRAPHY(TLP)

It is a non-invasive technique used to monitor pulpal blood flow and has been successfully applied in human studies. It has been suggested that TLP incurs less signal contamination from the periodontal blood flow than the other devices[61].

Conclusion

An accurate assessment of tooth vitality is of the utmost paramount importance in clinical practice. It is required to establish devices with better materials for easy handling. These devices are used in dental clinical practice on a large scale, thus it should be less expensive. Rapid advancements in the knowledge and applied technology related to the pulpal blood flow as well as pulp vasculature may lead the way to a more objective, accurate, and predictable means of pulp vitality assessment.

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Ethical Clearance

Not Required

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