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Review Article

Dental Pulp Assessment - The First Step Towards an Accurate Diagnostic in Endodontics

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Abstract

Diagnosis is defined as the process of determining the nature of a disease or disorder [1]. In endodontics, assessing the condition of the dental pulp is both of cardinal importance for an accurate diagnosis and key for achieving a successful treatment. Pulp vitality testing implies using specific diagnostic tests, being an important part of a comprehensive endodontic examination. It decisively contributes to the decision concerning the choice of the endodontic treatment method to be further used.

Keywords: Diagnosis; Dental Pulp; Vitality Test

Canadian physician Sir William Osler, one of the "Big Four" founding professors of Johns Hopkins Hospital, and frequently been described as the father of modern medicine, was the first to bring medical students out of the lecture hall for bedside clinical training [2]. He is often quoted to have famously stated around the turn of the 20th century: "listen to your patient, he is telling you the diagnosis" [3].

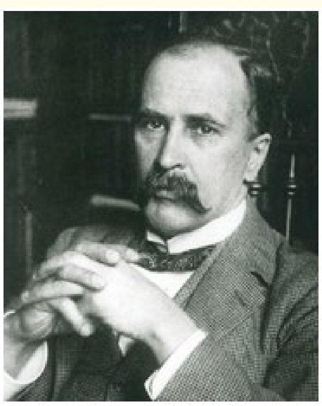

Figure 1: Sir William Osler (1849–1919).

In endodontics "listening to the patient" mostly means understanding the patient's complaints about pain. As dental pulp cannot be directly investigated, its assessment is conventionally based upon the level responses to thermal and electrical sensibility tests that stimulate the pulpal nerves [4] and thus relies on the level of pain experienced.

The innervation of the pulp-dentin complex is mainly carried out by A-type (both δ and β) and C-type fibers, classified according to diameter, myelination, and nerve impulse conduction speed. These fibers are activated by different stimuli and mediators, producing changes in pain characteristics. A-type fibers are especially responsible for taking over cold thermal stimuli and cause acute pain. C-type fibers are responsible for pain with a diffuse character, loosely localized.

The goal of conventional vitality tests is to classify the respective clinical situation in one of the following: vital tooth with functional pulp; vital tooth with the presence of a certain type of reversible or irreversible pulp inflammation; nonvital tooth.

Thermal testing is based upon one of the most broadly acknowledged theories meant to explain pulpal pain originating in cold or hot stimuli - the hydrodynamic theory. It states that thermal stimulation leads to dentinal fluid flow at temperature variations and movement of the odontoblast processes, which mechanically stimulates and triggers subsequent neuronal depolarization. The cold pulp test relies on outward hydrodynamic fluid flow to stimulate A-delta fibers in the pulp [5].

It is the most frequent pulp test applied by dental practitioners [6,7]. Refrigerant sprays (most performed), dipped Ethyl chloride in cotton pellet, ice, or sticks of frozen carbon dioxide (dry ice) are used for this purpose. The tooth involved needs to be dried and well isolated.

Figure 2: Refrigerant sprays used for cold pulp testing.

Figure 3: Odontotest™ (Air Liquide Healthcare) produces sticks of frozen carbon dioxide snow ("dry ice").

Heat testing is only recommended to be used when the main complaint includes heat sensitivity. Heat testing relies on hydrodynamic fluid flow in a pulpward direction, away from the stimulus, causing the same A-delta fiber stimulation - as the cold pulp test does [5].

The heat pulp test uses heated gutta-percha stick, rubber polishing cups or hot water. The negative pressure created by the cold test results in significantly more nerve impulses than the positive pressure created by the heat test. Compared to the cold test, the pulp stimulation, and thus the patient response, is much lower.

Figure 4: Heat pulp testing: heated gutta-percha stick and rubber cup friction.

Electric pulp testing (EPT) measures the responsiveness of the pulp to electrical stimulation. EPT produces a high-frequency electric current that creates ionic changes in the dentinal fluid, especially targeting the closest myelinated A-delta fibers in the dental pulp [4,5].

The pulp Positive response only indicates the viable neural transmission and the presence of vital nerve fibers but does not prove the health of the tissue or assess any potential damage of the vascular supply of the pulp.

In myelinated nerves, the electric pulp test works by causing an ionic change across the neural membrane by electrical stimuli, which influences the action potential via a fast-jumping action at the nodes of Ranvier [8].

Figure 5: Electric pulp testing.

To ensure an accurate diagnosis, it is important to conduct all tests on the suspected tooth, as well as the adjacent and contralateral teeth to obtain a comparative result [9].

As a result of the conventional pulp sensibility testing methods, pulp vitality is indirectly monitored by assessing the neural response and not considering the vascular circulation. As a result, some teeth that do not respond to these tests despite having intact vasculature do so because they temporarily or permanently lose their sensory function [10,11].

The response to these stimuli can indicate the type of pain, but not the pulp changes or the stage of a possible pulp inflammation, as the level and type of pain cannot be perfectly correlated with the pulp pathophysiology. On the other hand, a diagnosis cannot be exclusively based on pain of pulpal origin since there are also nonodontogenic sources of pain in the craniofacial region.

These tests can yield false-negative and -positive results, as in the case of immature teeth or teeth that have suffered recent trauma [12].

The main flaw concerning pulp sensibility tests is that these tests only rely on the subjective patient's response to pain in terms of threshold, intensity, and duration. Sensibility tests exhibit inherent limitations, as they do not measure true vitality, but sensibility, by determining whether the nerve supply can respond to a stimulus. The true indication of vitality is whether the vascular supply is intact [13].

An ideal pulp vitality testing method should be simple, objective, standardized, reproducible, accurate, inexpensive, painless, and noninvasive [14]. Conventional pulp testing is subjective, not standardized, not reproducible, often inaccurate, and obviously more or less painful.

The development directions regarding dental pulp testing methods include pulse oximetry, laser Doppler flowmetry, dual wavelength spectrophotometry, ultrasound Doppler flowmetry, transmitted-light plethysmography, electronic thermography, thermographic analysis of tooth vascularization using thermal stimulation, etc.

Pulp vitality testing methods such as pulse oximetry (PO), laser Doppler flowmetry (LDF), and ultrasound Doppler flowmetry (UDF) have been developed to overcome the limitations of pulp sensibility testing. These methods assess pulpal blood flow without relying on the patients' responses, thus providing a more accurate evaluation of pulp status.

Pulse oximetry (PO) is a non-invasive method that is based on the Beer-Lambert law, which states that "An unknown concentration of solute (hemoglobin) dissolved in a known solvent (blood) can be assessed by the light absorption of the solute" [15]. The system consists of a sensor with two diodes of different wavelengths that will be absorbed by deoxygenated and oxygenated hemoglobin - red light (600 nm) and infrared light (940 nm), respectively - and a photoreceptor connected to a microprocessor. This one captures the emissions and obtains the pulp oxygen saturation (SpO_2) and pulse data. Changes in the absorption of light by the photoreceptor happen as pulp blood flow pulsates. This in turn will determine the SpO_2 levels comparing the data obtained with the previously established curves of oxygenated and deoxygenated hemoglobin, thus detecting the pulpal oxygen saturation. Limitations that hinder pulse oximetry use in daily dental practice are mainly due to the absence of a specific pulse oximeter for dental use [16].

Figure 6: Pulse Oximeter Probe for Dental Use.

Laser Doppler flowmetry (LDF) appraises the numbers and velocity of erythrocytes in circulation in the pulp, being thus capable of assessing between a healthy and necrotic tooth [17]. A laser doppler flowmetry (LDF) test can assess pulp vitality considering changes in pulp blood flow [18]. The test object of this investigation is the local microcirculation system of the teeth [19]. It uses LDF equipment and LDF probes, of which each consist of one afferent and one efferent optic fiber, conducting the light to and from the tooth surface. It is an especially useful monitoring tool for detection of the changes in the PBF of the traumatized teeth [20,21]. LDF measurements allow a reliable and precise examination of the blood supply to the pulp of the affected teeth immediately after a traumatic event. In contrast, the current conventional pulp vitality tests require a longer period to avoid false-negative results [22].

Figure 7: Laser Doppler flow machine (Moor Instruments Ltd. Millwey Axminster Devon, UK).

Ultrasound Doppler flowmetry (UDF) is mainly useful when assessing dental pulp in cases of tooth dyschromia. This method doesn't use a laser to transmit light into the pulp blood vessels - the case of Laser Doppler flowmetry – or a red and infrared LED light beam - as for pulse oximetry - through the tooth structure. On the contrary, ultrasonics can detect blood flow regardless of coronal discoloration [23,24].

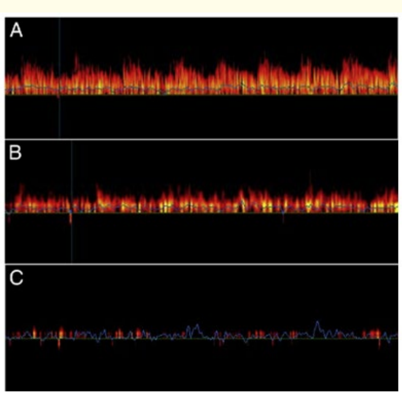

Figure 8: Waveforms from UDF: (A) a normal pulsatile waveform of pulpal blood flow, (B) an example of an ''unstable'' waveform, and (C) a waveform of a negative UDF result. (Ahn, 2018) [25].

Transmitted-light plethysmography (TLP) is another optical technique to detect circulatory changes occurring in the dental pulp. It was developed for pulp testing to improve pulse oximetry by adding light with a shorter wavelength, using a 525-nm LED [26].

The system works by detecting the pulsation intensity of light transmitted through a tooth and visualizing the pulpal blood flow synchronized with the heartbeat [27].

TLP uses a light source to illuminate the tissues and a photodetector to measure the changes in light intensity. Only specific wavelengths of light are absorbed by hemoglobin, and the remaining light passes through the tooth and is detected by a receptor [28].

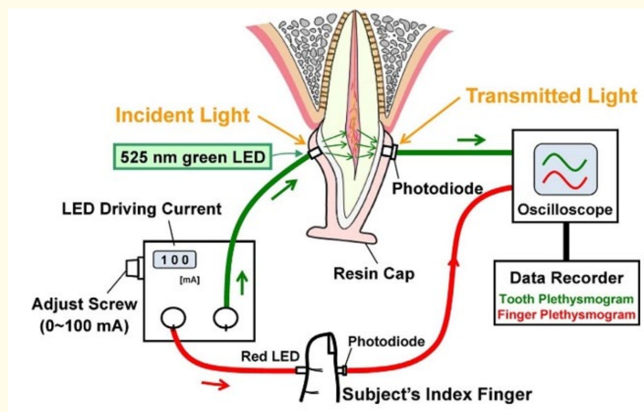

Figure 9: Schematic drawing of the TLP system (Knörzer, 2019).

Pulp tests based on the assessment of the existence of pulpal blood flow and the effects determined by it are considered to be objective and more reliable, but only some of these are closer to becoming common practice - pulse oximetry and laser Doppler flowmetry. Conventional tests, especially cold pulp testing and electric pulp testing, are still in use, due to accessibility and user experience. The foreseeable future evolution of dental pulp testing methods needs more high-quality studies for the development of practical and reliable tests to aid the clinical decision-making process.

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