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Review

Differences Between Laser Doppler Flowmetry and Pulse Oximetry in Endodontics

Mohsen Daghustani [1*], Shahad Alfarraj[2], Raghad Alenzi[3], Faisal Aldrees[4], Mohammed Almershed[5], Noorh Alajmi[6], Samaher Alfawzan[7], Heba Albrahim[8], Abdulelah Alshahrani[9], Rawya Ghamdi[10], Ahmed Alsubhi[11]

[1] *North Jeddah Specialist Dental Center, King Abdullah Medical Complex, Jeddah, Saudi Arabia*
[2] *General Dentist, Ministry of Health, Tabuk, Saudi Arabia*
[3] *General Dentist, Alwoud Medical Central, Skaka, Saudi Arabia*
[4] *General Dentist, Prince Sultan Armed Forces Hospital, Riyadh, Saudi Arabia*
[5] *Dental Department, Ministry of Health, Buraydah, Saudi Arabia*
[6] *College of Dentistry, Mustaqbal University, Buraydah, Saudi Arabia*
[7] *General Dentist, Abu Shajarah Primary Healthcare Center, Medina, Saudi Arabia*
[8] *Dental Department, Avicenna Dental Centers Co. ltd., Qatif, Saudi Arabia*
[9] *General Dentist, Modern Medical Complex, Riyadh, Saudi Arabia*
[10] *Dental Department, Ghassan N. Pharaon Hospital, Jeddah, Saudi Arabia*
[11] *General Dentist, Nizar Ghulam Medical Complex, Medina, Saudi Arabia*
Corresponding Mohsen Daghustani, *North Jeddah Specialist Dental Center, King Abdullah Medical Complex, Jeddah, Saudi Arabia,* email: ma-daghestani@moh.gov.sa

Correspondence should be addressed to **Mohsen Daghustani**, North Jeddah Specialized Dental Center, King Abdullah Medical Complex, Jeddah, Saudi Arabia. Email: ma-daghestani@moh.gov.sa

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Abstract

An essential diagnostic step in the practice of dentistry is the evaluation of pulp vitality. In particular after traumatic accidents, the results of a pulp vitality test are critical for tracking the health of tooth pulp. The innervation is a factor in the classic pulp testing techniques like thermal and electrical, which frequently produce misleading positive and negative results. Pulp vitality suggests that there is a blood flow in the tissues. The most recent pulp testing tools, some of which are still in the research and development stage, locate the pulp's blood supply and are thought to be more precise and non-invasive. Pulse oximetry and laser Doppler flowmetry have recently been used in assessments of pulpal circulation. The fundamental tenet of pulse oximetry is that arterial blood alone exhibits pulsatile absorbance between the light source and the photo detector. Laser doppler flowmetry is a semi-quantitative recording of pulpal blood flow made possible by the non-invasive, painless electro optical technology. Even in the microvasculature's incredibly tiny blood arteries, blood flow can be measured. Pulse oximetry is helpful in impact injury situations where the blood supply is unharmed, but the nerve supply has been compromised. Widespread clinical use of smaller and less expensive commercial oximeters is now possible in a typical dental office. The disadvantages include the lack of differentiation in background absorption related to venous blood and tissue elements. LDF is helpful for early childhood where responses are unreliable, and because it is non-intrusive, it encourages patient tolerance and cooperation. However, for usage in a dental practice, it is regarded as being too costly of a technology. Additionally, blood pigments in a stained dental crown may obstruct the transmission of laser light. Both techniques provide an objective evaluation of the state of the pulpal blood circulation.

Keywords: *pulse oximetry, laser Doppler flowmetry, endodontic diagnosis, pulp vitality, trauma*

Introduction

It has been established that conventional pulpal diagnostic tools are unreliable for determining the pulpal condition of teeth after traumatic injury, particularly for teeth with immature root development and open apex. These testing procedures all include a lot of subjectivity, rely on the patient's participation and comprehension of the scenario, and can be particularly challenging in situations involving young children. It is significant to note that the typical pulp viability tests only reveal whether or not the pulp contains nerve receptors, not whether or not the pulp has a blood supply. An essential diagnostic step in the practice of dentistry is the evaluation of pulp vitality (1). In particular after traumatic accidents, the results of a pulp vitality test are critical for tracking the health of tooth pulp. The innervation is a factor in the classic pulp testing techniques like thermal and electrical, which frequently produce misleading positive and negative results. Each test is also subjective and is based on how the patient feels they responded to a stimulus as well as how the dentist saw it (2). The most recent pulp testing tools, some of which are still in the research and development stage, locate the pulp's blood supply and are thought to be more precise and noninvasive. Laser Doppler flowmetry and pulse oximetry have recently been used in assessments of pulpal circulation (3, 4). Although both approaches are still in their early stages and are not yet suited for widespread clinical use, it is hoped that they will soon be incorporated into dentists' diagnostic toolkits.

Methodology

This study is based on a comprehensive literature search conducted on October 26, 2022, in the Medline and Cochrane databases, utilizing the medical topic headings (MeSH) and a combination of all available related terms, according to the database. To prevent missing any possible research, a manual search for publications was conducted through Google Scholar, using the reference lists of the previously listed papers as a starting point. We looked for valuable information in papers that discussed the information about differences between laser Doppler flowmetry and pulse oximetry in endodontics. There were no restrictions on date, language, participant age, or type of publication.

Discussion

The fundamental tenet of pulse oximetry is that arterial blood alone exhibits pulsatile absorbance between the light source and the photo detector (5, 6). A modified ear pulse oximeter probe was used on a tooth in previous research (7), which found a link between pulp and systemic oxygen saturation measurements. They advised using it as a reliable pulp vitality test. A viable pulp with a healthy vasculature may identify nonvital if just the nerve fibers are injured since pulp vitality is only a measure of vasculature health. This circumstance frequently occurs in teeth that have recently experienced trauma (8). However, compared to vascular tissue, pulp fibers are more resistant to necrosis (9). Thus, if only the pulp vasculature is injured, heat and electric testing could produce a false-positive result.

When there has been damage, teeth frequently do not react to traditional pulp testing techniques right away. Trauma-related damage, inflammation, compression, or stress on the nerve fibers in the apical area is what causes this momentary loss of sensitivity (10). Before a normal pulpal response can be elicited, one to eight weeks often pass. Nevertheless, longer observation times might be necessary (10). Initial neuronal degeneration in situations of trauma is characterized by intramyelin edema, axonal swelling, and incomplete loss of myelin sheaths (11). The clinical observations of 25 injured anterior teeth that failed to respond to standard vitality tests were reported in one study (4). All of the vital pulps were visible when the pulp chambers were opened. They came to the conclusion that standard vitality tests are actually sensitivity tests with uncertain predictive value for pulp tissue vitality. They advised delaying endodontic treatment in injured teeth and treating the afflicted pulp tissue as important unless apical radiolucencies or sinus tracts appeared. By confirming the existence of a healthy blood flow, the vitality of the pulp may be examined more accurately, allowing the healing capacity to be assessed early. A delayed diagnosis can also result in serious problems including inflammatory root resorption (12). Therefore, it's critical to assess the pulp's condition in these situations in order to establish whether root canal therapy is required. The concept is centered on a variation of Beer Lambert's law, which connects a solute's concentration and optical characteristics to how much light it can absorb at a specific wavelength. Additionally, it is influenced by hemoglobin's red and infrared absorbance properties (13, 14). Oxyhemoglobin absorbs less light in the red than deoxyhemoglobin, while the opposite is true in the infrared (6, 15). The sensor is positioned on the palatal

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aspect, and the probe is positioned on the labial aspect of the dental crown. The central third of the crown is the ideal location for the probe. If the device is positioned in the gingival third, disruptions from gingival circulation, gingival trauma, or gingival bleeding will affect the results, whereas less pulpal tissue is available incisally for effective pulse detection. The pulse oximeter has many benefits. It is a reliable and impartial way to measure tooth pulp vitality. It is helpful in impact injury situations where the blood supply is unharmed, but the nerve supply has been compromised. Gingival circulation is not necessary to determine pulpal circulation. Pulpal pulse readings can be repeated. Last but not least, widespread clinical use of smaller and less expensive commercial oximeters is now possible in a typical dental office. The disadvantages include the lack of differentiation in background absorption related to venous blood and tissue elements. Additionally, probes must be tailored to the structure of a tooth because measurements for oxygen saturation from the patient's finger generally record higher values than those from the teeth (16, 17).

Pulp vitality suggests that there is blood flow in the tissues. Therefore, a test may only be referred to as a vitality test if it really measures or evaluates pulp blood flow (15, 18). Laser doppler flowmetry (LDF) is a semi-quantitative recording of pulpal blood flow is made possible by the non-invasive, painless electro optical technology (19-23). Even in the microvasculature's incredibly tiny blood arteries, blood flow can be measured (24). The earliest laser Doppler approach was employed to calculate the red blood cell velocity in capillaries (25). LDF was created to measure blood flow in microvascular systems, such as those in the skin, gut mesentery, retina, and renal cortex (26). Since then, it has been routinely used to monitor blood flow, particularly in soft tissues (27, 28). This novel method made use of a helium-neon (He-Ne) laser beam that, when scattered by moving red blood cells, suffered a frequency shift in accordance with the Doppler principle. This caused a small portion of the light that was backscattered from the lighted area to shift frequency. A signal that was a function of the red cell flux was created when this light was detected and analyzed. With the use of this data, blood flow was calculated and expressed as a percentage of full-scale deflection at a specific gain. In both animals and humans, this technique was used to evaluate blood flow in healthy teeth (29). The usefulness of LDF approaches for pulp vitality assessment is shared by other species as well since they represent vascular instead of nervous responsiveness (30). Sasano et al. believed that the use of this method for measuring the viability of human pulp was constrained due to some of the inherent issues that it had (31, 32). Since the lasers used for LDF are typically about 1 or 2 mW in power, there have been no reports of pulp injury caused by this technique. The use of an excimer laser system emitting at 308 nm for residual tissue detection within the canals was the other method of using lasers for endodontic diagnostics (33, 34).

The method is based on the Doppler effect, whereby moving RBCs scatter light from a laser diode impacting on tissue, causing the frequency to be widened. A blood flow assessment is made possible by photodetection of the frequency widened light and laser light that has been scattered, as well as by photocurrent processing of the resulting photocurrent. LDF is an optical measurement technique that makes it possible to count and quantify the speed of the particles carried by a fluid flow. The particles (1–20 μm) need to be both large enough to scatter adequate light to detect signals and fine enough to follow the flow exactly (35, 36). The initial method made use of a laser made of helium-neon (He-Ne) that emits light at a wavelength of 632.8 nm. 780 nm and 780-820 nm are other semi-conductor laser wavelengths that have been employed (33). A fiber optic probe positioned against the tooth surface transmits laser light to the tooth pulp. Crossing the target area are two equal-intensity beams that were divided from a single beam. Red blood cells that are in motion cause their scattered light beams to be frequency-shifted, whereas static tissue causes the opposite to occur. The signal is created when the unshifted light is sent back by an afferent fiber in the same probe to photodetectors in the flowmeter (37, 38). The product of the concentration and mean velocity of red blood cells can be used to simplify the LDF output signal or Flux (39). The optical characteristics of a tooth alter when the pulp becomes necrotic, and this might cause changes in the LDF signal that are not related to variations in blood flow, it should be underlined (40). In reality, the Doppler-shifted backscattered light measurement of the tooth serves as an indication of PBF since red blood cells comprise the great bulk of moving particles within the system. In order to assess dynamic changes in blood flow, LDF monitors the movement of blood cells inside a minute volume of tissue (about 1 mm^3) (41).

When determining the pulpal vitality, the use of LDF is advised because it might be challenging to diagnose a

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tooth with a necrotic pulp, especially if referred pain is present. A proper test and its accurate interpretation are crucial in these circumstances (42). It can also be used for child pulp testing. Due to their subjectivity and reliance on the patient's response, sensitivity tests are unreliable in children. The measurement of pulpal blood flow (PBF) in deciduous incisors can be done using the LDF technique (43). The application of vitality tests, such as LDF, can aid in the differential diagnosis of these radiographic views since periapical radiolucencies may have nonendodontic sources (44). It tracks aging related PBF changes. It has been demonstrated using this technology that aging reduces the hemodynamics in the human pulp (45). Additionally, it is utilized to track how exercise affects PBF. According to research, PBF changes during activity, changing on average 38% from resting levels. It can also be used to measure PBF following orthognathic surgical therapy, monitor responses to local and systemic pharmaceutical agents (including local anesthetic solutions), monitor responses to electrical or thermal pulpal stimulation, and monitor reactions to orthodontic operations. Measuring PBF is helpful after trauma as traumatized teeth could have their nerve fibers compromised and produce a negative response to pulpal tests even though their blood circulation and thus their true vitality is present. Individuals who go through a segmental maxillary osteotomy have shown a marked decline in pulpal sensibility in teeth in the osteotomy region. LDF is a precise and impartial method for determining the health of the pulp in these teeth. LDF measurements correctly determine the pulp condition in vital versus nonvital teeth, and it is used to track the revascularization of replanted teeth (24). Advantages include accuracy, reliability, reproducibility, painless procedure and utility in case of luxated teeth. It is helpful for early childhood where responses are unreliable, and because it is non-intrusive, it encourages patient tolerance and cooperation (15). Further, it does have certain restrictions. For usage in a dental practice, it is regarded as being too costly of a technology. For reliable readings, the sensor must also be kept stationary and in close proximity to the tooth. Additionally, the pulpal vasculature's moving cells must interact with the laser beam. It is commonly accepted that LDF assessments for human teeth should be conducted four weeks after the original trauma and repeated at regular intervals until 3 months (37). As a result, it cannot be used right away after injury. Additionally, blood pigments in a stained dental crown may obstruct the transmission of laser light. It is important to take precautions to prevent the excitation of supporting tissues from producing misleading positive outcomes (38).

In order to assess the pulp vitality state of newly injured permanent teeth, Gopi Krishna et al. evaluated the effectiveness of a specially designed dental pulse oximeter probe with electric pulp testing and thermal testing. During a 6-month period, readings for pulp vitality were taken on recently injured maxillary incisors using a specially constructed pulse oximeter dental probe, electrical pulp tester, and thermal testing (16). The percentage of recently traumatized teeth that responded positively to thermal/electrical pulp tests rose from zero teeth responding on day 0 to 29.4% on day 28, 82.35% on day 2 and 94.11% on day three. Yet, from day 0 to 6 months into the research, all patients' pulse oximeter results were consistently positive for vitality (16).

Odor et al. looked at the distribution of laser light propagation through animal enamel and the pattern of light transmission through different species' teeth. They found that, although light from a laser Doppler probe seemed to contact the dental pulp in all species, it could have also been capable of reaching the periodontium in mammals with relatively small teeth, meaning that the reflected signal might not have been totally of pulpal cause (46).

Conclusion

It is generally known that evaluating the tooth pulp nerve response is unreliable. Conventional testing is of little use when neural feelings are suppressed or eliminated in the tooth, for instance after trauma, during tooth transplantation procedures, or while under general anesthesia. A technique based on the pulp's vascular response, however, need not be constrained in such circumstances. A genuine sign of pulp vitality would be to measure the pulpal blood flow, which would provide an objective evaluation of the state of the pulpal blood circulation. To assess pulse and blood volume, optical systems that take use of the varying absorbance qualities of various materials within the dental pulp are being researched. They have the benefits of being unbiased, non-invasive, and stressful testing techniques, increasing patient compliance and acceptability. The importance and dependability of these strategies are currently being researched. It is envisaged that advancements in technology will make it possible to investigate the pulpal vasculature in greater detail and clarify its function in pulp vitality testing.

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Data that support the findings of this study are embedded within the manuscript.

Author contribution

All authors contributed to conceptualizing, data drafting, collection and final writing of the manuscript.

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