ABSTRACT

Pulp vitality test is crucial in monitoring the state of health of dental pulp, especially after traumatic injuries. The traditional pulp testing methods such as thermal and electric pulp testing methods depend on the innervation and often yield false positive and negative response. The newer pulp testing devices, some of which are still under development stage, detect the blood supply of the pulp, through light absorption and reflection, are considered to be more accurate and non-invasive. The article attempts to discuss issues related to pulp vitality testing in clinical endodontic practice and describes the principle on which these newer pulp testing devices are based and its mode of working.

Key words: Pulp vitality, Pulse oximetry, Laser Doppler flowmetry, Pulpal circulation, Revascularization, Light transmission.

Introduction

The assessment of pulp vitality is a crucial diagnostic procedure in the practice of dentistry. Current routine methods rely on stimulation of Ad nerve fibers and give no direct indication of blood flow within the pulp. These include thermal stimulation, electrical or direct dentine stimulation. These testing methods have the potential to produce an unpleasant and occasionally painful sensation and inaccurate results (false positive or negative can be obtained in many instances). In addition, each is a subjective test that depends on the patient's perceived response to a stimulus as well as the dentist's interpretation of that response. Recent studies have shown that blood circulation and not innervation is the most accurate determinant in assessing pulp vitality as it provides an objective differentiation between necrotic and vital pulp tissue. This article highlights tests relying on the passage of light through the tooth to detect pulp vitality with greater objectivity. They rely either on the detection of changes in the light absorption as it passed through the tooth, as in photoplethysmography, pulse oximetry and dual wavelength spectrophotometry or the shift in light frequency as it is reflected back from a tooth, as in laser Doppler flowmetry. This paper attempts to review the newer pulp vitality testing methods.

Pulse Oximetry

The pulse oximeter is a non-invasive oxygen saturation monitoring device widely used in medical practice for recording blood oxygen saturation levels during the administration of intravenous anesthesia. It contributes to the increased safety of general anesthesia. Pulse oximeter is a standard equipment in operating rooms and is routinely being used in other acute care settings,
including intensive care units, emergency rooms and endoscopy suites where sedation and analgesia are provided\textsuperscript{8}. Its wide acceptance in the medical field results from its ease of application and its capability of providing vital information about the patient's status.

This device is currently under investigation in dental practice to detect pulpal blood circulation by virtue of its non-invasive and atraumatic nature. Specific objectives were to develop a design for a dental sensor (a modified finger probe) that can be successfully applied and adapted to the tooth and well suited to detect pulsatile absorbance.

The principle of this technology is based on a modification of Beer's law, which relates the absorption of light, by a solute to its concentration and optical properties at a given light wavelength\textsuperscript{9}. It also depends on the absorbance characteristics of haemoglobin in the red and infra-red range. In the red region, oxyhaemoglobin absorbs less light than deoxyhaemoglobin and vice versa in the infra-red region. Hence one wavelength was sensitive to changes in oxygenation and the second was insensitive to compensate for changes in tissue thickness, haemoglobin content and light intensity.

The system consists of a probe containing a diode that emits light in two wavelengths:

I. Red light of approximately 660 nm  
II. Infra-red light of approximately 850 nm

A silicon photo detector diode is placed on the opposing surfaces of the tooth, which is connected to a microprocessor.

The probe is placed on the labial surface of the tooth crown and the sensor on the palatal surface. Ideal placement of the probe is in the middle third of the crown. If placed in the gingival third, disturbances from gingival circulation or any gingival trauma or bleeding will interfere with the readings. Incisally, less of pulp tissue is present for adequate detection of the pulse.

A number of clinical studies have proved that the pulse oximetry is an effective and objective method of evaluating dental pulp vitality. Though the surrounding insulation of the enamel and dentine are hindrances to the detection of a pulse in the pulp, it has proved to be a successful method in 70% of the clinical trials and further work is still in progress. It is also useful in cases of impact injury where the blood supply remains intact but the nerve supply is damaged\textsuperscript{12}. Also current results indicate that pulpal circulation can be detected by the pulse oximeter independent of gingival circulation. Signal filtration is now employed to make it easier to reproduce pulp pulse readings. Smaller and cheaper commercial oximeters are now available for routine clinical use in an average dental office.

Despite its advantages, limitations include background absorption associated with venous blood and tissue constituents, which should be differentiated. In addition to the absorption, refraction and reflection also occur as in Penumbra effect, which is seen in patients with strong tissue pulsations, where some of the light reaches the photo detector diode without passing through the tissue bed\textsuperscript{13}. The oxygen saturation values from the teeth routinely register lower than the readings from the patient's finger. This may be due to the limitations of using a probe designed for other body parts, not specifically for the anatomy of a tooth\textsuperscript{14}.

**Dual Wavelength Spectrophotometry**

Dual wavelength spectrophotometry (DWLS) is a method independent of a pulsatile circulation. The presence of arterioles rather than arteries in the pulp and its rigid encapsulation by surrounding dentine and enamel make it difficult to detect a pulse in the pulp space. This method measures
oxygenation changes in the capillary bed rather than in the supply vessels and hence does not depend on a pulsatile blood flow. Pulse oximetry is a method based on DWLS.

DWLS detects the presence or absence of oxygenated blood at 760 nm and 850nm. The blood volume or concentration channel (760 nm plus 850 nm) is arranged to respond linearly to the increase in light absorption. The oxygenation channel (760 nm minus 850 nm) senses the oxygenated blood because of the greater absorption at 850 nm as compared to 760 nm. In vivo and in vitro studies were conducted to differentiate between pulp chambers that were empty, filled with oxygenated blood or fixed pulp tissue. DWLS was able to differentiate with reproducible readings between a pulp chamber of a vital and non-vital tooth in vivo.

In young children, in cases of avulsed and replanted teeth with open apices, the blood supply is regained within the first 20 days after replantation but nerve supply lags behind. Repeated spectrophotometric readings taken at the start of the replantation and continuing upto 40 days later revealed an increase in blood oxygenation levels indicating a healing process and that the pulp of the avulsed tooth was recovering. Hence endodontic treatment need not be undertaken.

Even though the instrument was not specifically designed for dental use, it was easy to use and can be developed as a pulp tester. A major advantage is that it uses visible light that is filtered and guided to the tooth by fibreoptics. Thus unlike Laser light, added eye protection is unnecessary for the patient and the operator.

Still in vivo tests of this hypothesis are in progress. Influence of the gingival circulation cannot be ruled out and data on how large a mass of pulp tissue is needed for accurate readings must be determined. The test is non-invasive and yields objective results. The instrument is small, portable, relatively inexpensive and should be suitable for use in a private dental office.

**Laser doppler flowmetry**

Laser Doppler Flowmetry (LDF) is a non-invasive, electro optical technique, which allows the semi-quantitative recording of pulpal blood flow. The Laser Doppler technique measures blood flow in the very small blood vessels of the microvasculature.

The technique depends on the Doppler principle whereby light from a laser diode incident on the tissue is scattered by moving RBC's and as a consequence, the frequency broadened.

The frequency broadened light, together with laser light scattered from static tissue is photo detected and the resulting photocurrent processed to provide a blood flow measurement. The Doppler shifted laser light, back-scattered out of the tooth is detected by a photocell on the tooth surface. The output is proportionate to the number and velocity of the blood cells.

Over the past decade LDF technology has been used experimentally to monitor blood flow in the pulps of both, the animals and the humans. LDF has been shown to be valuable in monitoring revascularization of immature incisors following severe dental trauma. During follow-up examination the traumatized tooth was unresponsive to traditional vitality testing during the first 6 months. However LDF indicated that revascularization had occurred much sooner.

The primary issues in pulp-vitality testing as follows:

- A non-vital post-traumatized incisor has a better long-term prognosis if root canal therapy is completed before the necrotic pulp gets infected.
- The best outcome for the post-traumatized
immature incisor is for it to revascularize and continue normal root development, including increased root wall thickness, which is not possible to assess with conventional electrical and thermal testing20.

- Watching and hoping for revascularization using sensitivity testing may lead to infection in the post-trauma observation period.

Studies were carried out to compare LDF with conventional pulp tests, EPT (electric pulp testing) and thermal tests, in children with certain dental injuries. At the initial assessment at presentation, all tests had poor sensitivity and specificity; however at 3, 6, and 12 months, LDF was significantly better than the other tests21. There was no difference between tests at the later time periods, 18 months and 2 years. It was concluded that LDF identified more vital and non-vital teeth correctly at earlier time periods following injury than conventional tests.

The limitations of this method include a too expensive device for use in a dental office. The sensor should be maintained motionless and in constant contact with the tooth for accurate readings. Also the laser beam must interact with the moving cells within the pulpal vasculature. However, it is useful in young children whose responses are unreliable and its non-invasive nature helps to promote patient co-operation and acceptance.

**Other Testing Modalities**

The concept of diagnosing tooth vitality by temperature measurement can provide valuable information on the integrity of the underlying pulp. Howell et al used liquid cholesteric crystals and found that non-vital teeth have lower temperature than vital teeth22.

Fanibund in 1985 concluded from a laboratory study that it is possible to differentiate by means of crown surface temperature, distinct differences in vital and nonvital teeth. He used a Thermistor unit consisting of 2 matched thermistors connected back to back, one measuring the surface temperature of the crown (measuring thermistor) while the other acting as a reference thermistor23. The tooth to be tested was dried with gauze and the thermistor unit was positioned so that the measuring thermistor contacted the center of the buccal surface of the crown. The reference thermistor was suspended in air, close to it, but not touching either the measuring thermistor or the enamel surface.

An equilibrium was next achieved between the temperatures of the thermistors, the crown surface and the immediate environment by holding the measuring unit in the described position until a steady state was established for at least 20 seconds22. Stimulation of the crown surface was carried out by means of a rubber-polishing cup fitted to a dental contra-angle handpiece. The recordings were continued for a period of time following the stimulation period. It was found that a difference was obtained between the critical period for vital and non-vital teeth and the difference corresponded with a specific temperature change.

The feasibility of temperature measurement as a diagnostic procedure in human teeth was again demonstrated in 1986 by Fanibunda in another clinical study, using the time-temperature relationship method. Graphs were constructed from temperature readings of teeth at 15 seconds intervals. At the end of the cooling period, vital teeth illustrated a rise in temperature and following this a steady state was reached. Non-vital teeth, at the end of the cooling period did not show any rise in temperature before it reached a steady state. The temperature remained at a steady level or decreased further. Information in respect of tooth vitality can be gained from the time-temperature relationship method.
Recently, computerised infrared thermographic imaging (TI)\textsuperscript{24,25} for human teeth is under investigation to assess pulp vitality.

Further research is being undertaken with the sole aim of increasing the detectable difference between vital and non-vital teeth, so that a method of temperature measurement may be evolved which is of diagnostic significance under routine clinical conditions.

**Conclusion**

The unreliability of testing tooth pulp nerve response is well documented. When nervous sensations are inhibited or abolished in the tooth, for example following trauma, tooth transplantation procedures or during a general anaesthetic, conventional tests are of little value. However, a method based on the vascular response of the pulpi need not be restricted under such conditions. Recording the pulpal blood flow would be an objective assessment of the status of the pulpal blood circulation, a true indicator of pulp vitality. Optical devices that exploit the various absorbance properties of different substances within the dental pulp are being studied to determine pulsation and blood volume. They offer the advantages of being objective, non-invasive and atraumatic testing modalities, which result in greater patient acceptance and cooperation. Currently, the significance and reliability of these methods are being studied. It is hoped that newer technology will enable a more thorough study of the pulpal vasculature and define its role in pulp vitality testing.

**References**


