

The assessment of pulpal vitality : a review

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ABSTRACT

One of the greatest diagnostic challenges in clinical practice is the accurate assessment of pulp status. This may be further complicated in pediatric dentistry where the practitioner is faced with a developing dentition, traumatized teeth, or young children who have a limited ability to recall a pain history for the tooth in question. Dental pulp testing is a useful and essential diagnostic aid in endodontics. Pulp sensibility tests include thermal and electrical tests, which extrapolate pulp health from sensory response. With all pulp tests, the results need to be carefully interpreted and closely scrutinized as false results can lead to misdiagnosis which can then lead to incorrect, inappropriate or unnecessary treatment.

Introduction

The vitality of pulp is a function of vascular supply of the pulp within a tooth, and pulpal circulation is the true determinant of pulp vitality. The assessment of pulpal status is a diagnostic challenge in clinical practice. An accurate diagnosis is important to achieve a good treatment outcome.

The conventional pulp testing methods used routinely include thermal stimulation (heat or cold), electrical or direct dentine stimulation. These tests fall short of the ideal pulp vitality testing as they indirectly monitor pulp vitality by measuring neural responses.[1] The types and relative number of sensory nerves varies in a normal tooth depending on the stage of root development. Johnsen et al found that the neural development was incomplete in immature teeth, greatly variable in young mature teeth and complete in older teeth.[2] The teeth with incomplete root development may have a higher threshold to electric pulp tester Fulling et al. The permanent teeth may not exhibit full alpha myelinated axon innervations until 4-5 years after eruption. These tests are considered difficult to carry out or are inconclusive when used in children with immature or traumatized teeth.[3] It has been suggested that conventional pulp diagnostic tests are not precise, as clinical symptoms do not co-relate well with actual pulpal status. Children tend to adapt their behavior and limit their ability to respond appropriately to these tests in order to avoid painful stimulus, that can lead to false results with conventional tests.[3]

Teeth that have temporarily or permanently lost their sensory function due to trauma, or following orthognathic surgery are found to be non-responsive to the conventional pulp testing method, although the vasculature may be intact.[1] Conventional methods have limitations in providing accurate diagnosis in such conditions. Thus a more precise test would be of great value to assess the pulpal blood supply rather than nerve function.

A new approach to determine the presence of vital pulp

tissue is made possible by optical technology. These include Dual wavelength spectrophotometry, Pulse oximetry, Laser Doppler flowmetry, Transmitted light-photoplethysmography. Most of these devices are very sensitive devices that detect pulp blood components or blood flow.[4] These tests are noninvasive, objective, painless and therefore promising tests for young children.

Pulse oximeter is based on placing arterial blood vessels between a light source and a detector. The light source diode emits both red light and infrared light, which is received by a photodetector diode. The ratio of the amplitudes of the infrared with red light is compared, and the oxygen levels are determined with known absorption curves. It is proven effective and is routinely used in medical applications. Pulse oximeter being an objective test, requires no subjective response from the patient and directly measures the blood oxygen saturation levels.

Pulp Testing Techniques and Effectiveness

Pulp Sensibility Testing

Thermal Tests The application of agents to the teeth to increase or decrease temperature and to stimulate pulp sensory responses through thermal conduction has been the most commonly used modality for pulp testing. While some of the techniques have been described as "crude" in many ways, their usefulness as diagnostic aids cannot be denied.[5,6]

Cold Tests : Ethyl chloride and ice have been popular in the past, but CO₂ snow and other refrigerants such as dichlorodifluoromethane (DDM) have been shown to be effective [7] and superior to ice and ethyl chloride.

(i) Ice : This is perhaps the simplest cold testing agent requiring practically zero cost to prepare and it can be made in a standard household freezer. A common way to make ice in useful

sizes and dimensions involves freezing water in empty local anesthetic cartridges. However the clinical handling, infection control issues, and the direct application of ice can be difficult and problematic.[5] Isolation with rubber dam may be of assistance to avoid thermal stimulation of multiple teeth.

(ii) Refrigerant spray : Due to its ease of storage, relatively cheap cost, and simple application technique, refrigerant spray is widely used in clinical settings.

(iii) Carbon dioxide snow (CO₂) : CO₂ snow, or dry ice, is prepared from a pressurized liquid CO₂ cylinder [8] using a commercially available apparatus known as the Odontotest. This involves the liquid CO₂ being forced through a small orifice such that when it comes under atmospheric pressure most of the liquid will be converted into dry ice. The CO₂ is collected in a hollow removable carrier, encased in a thin plexiglass tube. The dry ice is collected in a "pencil stick" form that can then be applied to one tooth at a time with the aid of the supplied plunger.

B. Heat Test Typical methods used include gutta-percha [9] or compound material heated to melting temperature and directly applied to the tooth being tested with lubricant in order to facilitate removal of the material. Heated ball-ended metallic instruments placed near the tooth (but without touching the tooth surface), battery-powered controlled heating instruments and hot water bathing with the tooth isolated by rubber dam are other alternative methods.

Electric Pulp Test Electric pulp testing (EPT) works on the principle that electrical stimuli cause an ionic change across the neural membrane, thereby inducing an action potential with a rapid hopping action at the nodes of Ranvier in myelinated nerves. The pathway for the electric current is thought to be from the probe tip of the test device to the tooth, along the lines of the enamel prisms and dentine tubules, and then through the pulp tissue.[6] The "circuit" is completed via the patient wearing a lip clip or by touching the probe handle with his/her hand; alternatively, the operator can have one "gloveless" hand that touches the patient's skin.[10,11] A "tingling" sensation will be felt by the patient once the increasing voltage reaches the pain threshold, but this threshold level varies between patients and teeth, and is affected by factors such as individual age, pain perception, tooth surface conduction, and resistance.[6]

The correct technique for using the electric pulp tester is also important for accurate response. In order to ensure that the appropriate current pathway is followed, correct placement of the EPT probe tip flat against the contact area, and having a conducting medium such as toothpaste between the probe tip and the tooth surface is essential.[12]

Jacobson found in an in vitro experiment involving incisors and premolars, that placing the probe tip labially within the incisal or occlusal two-thirds of the crown gave more consistent results.[13]

Test Cavity : The preparation of a test cavity has been suggested as a last resort in a tooth where no other means can ascertain the pulp status. Cutting into dentine using a high or low speed bur without local anesthetic may give some indication of whether the sensory element of the pulp is still functioning although it is unlikely that this procedure would provide any more information than thermal and electric pulp sensibility tests. Whilst the defect made in the tooth can be repaired with restorative dental

materials, this method is nonetheless considered invasive and irreversible. A consideration must be made for the apprehensive patient, as it is likely that he or she may react nervously and confound the response. Hence, test cavities are not generally recommended as a means of testing pulp sensibility.

Pulp Vitality Testing

Laser Doppler Flowmetry (LDF)- 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 last 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 showed negative response to traditional vitality testing during the first 6 months. However LDF indicated that revascularization had occurred much soon.

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 reading. 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 help to promote patient co-operation and acceptance.

Pulse Oximetry Compared to laser Doppler flowmeters, pulse oximeters are relatively inexpensive [14,15] and commonly used in general anesthetic procedures. The term oximetry is defined as the determination of the percentage of oxygen saturation of the circulating arterial blood.[16] Oxygenated haemoglobin and deoxygenated haemoglobin are different in colour and therefore absorb different amounts of red and infrared light. The pulse oximeter therefore utilizes probes emitting a red and an infrared light to transilluminate the target vascular area, which allows the photodetector to identify absorbance peaks due to pulsatile blood circulation, and thereby calculates the pulse rate and oxygen saturation level (SaO₂).

Limitations / Influencing Factors

Intrinsic limitations include excessive carbon dioxide in the blood stream interfering with deoxygenating values. Increased acidity and a metabolic rate arising from inflammation cause deoxygenation of hemoglobin and changes in the blood oxygen saturation.[17-19]

Extrinsic interferences may be caused by the probe

movement, overhead Xenon arc lamps (because of electromagnetic interference), and problems within the probe itself. These might include artifact signals within the electronics of the probe or interfacial geometry difficulties if the anatomic characteristics of the teeth prohibit adequate isolation of the beam-to-receptor path.[20,21] Because of this, the use of a gel for improving light transmission between the tooth and the system probe has been mentioned.[22] Also, this technique cannot be used for pulp testing in extensively restored teeth (i.e. with full coverage restorations).

The critical requirement for using the pulse oximeter in dentistry is that the sensors should conform to the size, shape, and anatomy of the tooth and that the LED and the photodetector should be parallel to each other so that all the light emitted by the LED sensor is received by the photodetector sensor. Also, the probe should be held firmly onto the tooth to ensure accurate measurements. If the sensor cannot adapt with the shape and size of the crown, reliable results may not be obtained. Clinicians must ensure that a safe level of knowledge for applying a pulse oximeter is maintained in order to ensure that test results are not compromised.[23]

Variations in Probe Design for Dental Usage

There are no probes specific for teeth in the market. This is a limitation of the general use of the pulse oximeter in dentistry. The probes used for finger or infant's foot readings cannot accommodate the tooth structure because of the beam distortion, so some researchers have successfully used modified finger probes or adapted the instrument to the teeth to show the system reliability in the diagnosis of pulp vitality.[24]

Noblett et al [25] used a rubber dam clamp as the base for the sensor design. Two slots were prepared in each wing parallel to the tooth surface. Electrical terminals were placed into the prepared slots. The slots-type terminal was selected to allow placement and removal of sensor elements and to maintain a stable position. The tape enclosing the emitter and detector was removed, allowing insertion of the elements into the slot connectors attached to the clamp.

Kahan et al [14] built and tested a reflectance tooth probe. Pulse-wave readings from the teeth were found to be synchronous with the finger probe but not consistently. They concluded that the accuracy of the commercial instrument was disappointing, and, in the form, it was not considered to have predictable diagnostic value. They also showed that it was easier to maintain continuous readings from mandibular incisors than from maxillary incisors.

Goho [3] explored the use of a modified ear probe to evaluate pulpal oxygen saturation. Vital teeth consistently showed oxygen saturation values that were lower than the values recorded on the patient's fingers. Non vital teeth recorded oxygen saturation values of 0%.

Along with decreasing costs and more experience with these systems, the use of pulse oximetry in routine clinical endodontic practice in the future is likely to increase. An effort to manufacture an adaptable sensor for the teeth would be helpful.

Summary

An accurate assessment of tooth vitality is of paramount importance in clinical practice. Currently, no vitality tests have been proven to be superior in all aspects compared to pulp sensibility tests. For an accurate pulpal diagnosis, one should not rely on a single test; rather it is recommended to assess pulp vitality with at least two reliable test. Rapid advances in knowledge and applied technology relating to pulpal blood flow may lead the way for a more objective, accurate and predictable means of pulp vitality assessment.

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