Clinical

PRACTICE

Dental Pulp Neurophysiology: Part 2. Current Diagnostic Tests to Assess Pulp Vitality

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ABSTRACT

In this second part of our 2-part review, we discuss recent research about pulp tests that determine the vitality of the tooth and clinically accepted pulp testers. A pain response to hot, cold or an electric pulp tester indicates the vitality of only a tooth's pulpal sensory supply; the response does not give any idea about the state of the pulp. Although the sensitivity of these tests is high, when false-positive and false-negative results occur, they may affect the treatment of the tooth. A tooth falsely diagnosed as nonvital with an electric pulp tester may undergo an unnecessary root canal, whereas one falsely diagnosed as vital may be left untreated, causing the necrotic tissue to destroy the supporting tissues (resorption). The vascular supply is more important to the determination of the health of the pulp than the sensory supply. Pulp death is caused by cessation of blood flow and may result in a necrotic pulp, even though the pulpal sensory supply may still be viable. The pulp can be healed only if the circulating blood flow is healthy. Although still under investigation, diagnostic devices that examine pulpal blood flow, such as the pulse oximeter and laser Doppler flowmetry, show promising results for the assessment of pulp vitality.

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In part 1 of this 2-part review, we discussed the importance of understanding the neurophysiology of the dental pulp.[1] In part 2, we examine the relation between the pulpal neural distribution and several pulp tests that determine the neural response rather than the state of the vascular supply which determines the vitality of any tissue. We also examine recent innovative tests that determine vascularity. We do not discuss the different techniques that help clinicians reach a definitive diagnosis, such as digital radiography and radiovisiography, because these are beyond the scope of this review. Neither do we discuss the cavity test as a mechanical way to test whether the coronal tooth pulp is necrotic because this test relies mainly on a negative response (i.e., no response) to the electric pulp test, together with information obtained from a periapical radiograph. In this second part of our 2-part review, we discuss recent research about pulp tests that determine the vitality of the tooth and clinically accepted pulp testers.

Diagnostic Tests Related to the Neurophysiology of the Dental Pulp

Electric Pulp Tester

The electric pulp tester is widely used to differentiate between lesions of endodontic origin and those not seen on radiographs.[2]

Figure 1: Electric pulp tester.

This device (**Fig. 1**) is designed to deliver an electric current to stimulate the closest myelinated A-delta fibres; the device does not usually stimulate the unmyelinated C fibres because of their higher threshold.[3] The electric pulp tester indicates the neural transmission and presence of vital nerve fibres, but does not measure the health or integrity of the pulp. Recently traumatized teeth that may temporarily lose their sensory function have no response to the device, even though their vascularity is intact (false-negative),[4,5] whereas teeth that are partly necrotic may give a response, even though they lack a blood supply (false-positive).[6]

An interface medium is necessary to conduct electrical impulses to the tooth[7]; this medium should be non-liquid-based because a liquid-based medium may give false-positive results if contact with the gingival tissues[8,9] or saliva[10] occurs. In a recent study, Mickel and others[8] found that K-Y lubricating gel and Crest baking soda and peroxide whitening tartar provided maximum conduction of electrical current to the cathode. The authors concluded that a good conduction medium is important in cases in which a false-negative result is predicted, such as in pulp-canal obliteration and recently traumatized teeth.

Also, the location of the electrode on the buccal surface was tested in several studies.[7,11] Bender and others[11] found that the best placement of the electrode is the incisal third of anterior teeth where the least amount of electric current provoked a response. Others placed the electrode on the occlusal third of the buccal surface,[12] centred between the gingival margin and the occlusal edge of the buccal surface[13–15] or on the gingival third of the buccal surface.[7,16,17] A recent study[18] specifically designed to determine the best site for the placement of the electrode on the molar tooth surface found no significant difference between maxillary and mandibular molars in male and female subjects. Placement of the electrode on the mesiobuccal cusp tip elicited the lowest response. Placing the electrode more apically and to the centre of the supporting cusps showed an increase in the threshold response level. These results were related to the presence of pulp horns, where there is a high concentration of neural elements.[19,20]

On the basis of our clinical experience, it is our opinion that the best placement of the electrode is at the gingival third of the buccal surface of the natural tooth structure and that an electrocardiogram gel should be used as the interface medium.

Thermal Tests (Application of Cold and Heat)

The application of heated water (hot water bath) or softened, heated gutta-percha to the tooth is commonly used to deliver heat to the pulp. These methods may produce sufficient heat to stimulate the C fibres and produce pain that lingers, is prolonged and is usually delayed about 2 to 4 seconds. It is important to use heat cautiously to avoid any damage to the pulp tissue.[21,22]

Several methods are used to apply cold to the teeth, such as ice sticks (0°C), CO_2 sticks (–78°C), ethyl chloride (–5°C) and dichlorodifluoromethane ([DDM] –50°C).[23] Fuss and others,[24] who assessed the reliability of thermal tests and electrical tests for adults and young patients, found that CO_2 and DDM are more effective than ice and ethyl chloride. CO_2 produces a greater decrease in pulp temperature than DDM[25] and a quick response from the pulp. This greater decrease in temperature has no detrimental effect on the pulp tissue.[24,26–29] In another study[30] to determine the effect of different carriers on transferring the cold application to the tooth, the authors reported that a large cotton pellet is preferable to a small one, to cotton rolls or to a wooden-handle cotton tip. They also reported that sprayed DDM produced a more efficient, colder effect than the dipping technique. The manufacturer reformulated the DDM into 1,1,1,2-tetrafluoroethane that has a low liquid temperature and, presumably, is more environmentally safe. Jones and others[31] found that this refrigerant spray was more likely to produce a response than the CO_2 dry ice. The spray also cooled the tooth in significantly less time, regardless of whether the tooth was restored or covered, or neither.

Importance of Assessing the Blood Supply as an Indication for Pulp Vitality

As Cohen and Burns[10] reported, response to current clinical tests indicates only that sensory fibres are vital. However, 10%–16% of the results of these tests are false.[6] The nervous system, which is highly resistant to inflammation, may remain reactive, even though all surrounding tissues have degenerated; therefore testing the sensory supply may give a positive response when the pulp is damaged (i.e., a false-positive result).[32] This test may also leave the patient with an unpleasant sensation.[33] A false-negative result (i.e., no response) may be obtained in cases of calcific metamorphosis,[34] recently traumatized teeth[35,36] and incomplete root formation.[34]

The vitality of the pulp is determined according to the health of the vascular supply, not of the sensory fibres.[4,34,37,38] The pulp receives its blood supply through thin-walled arterioles entering through the apical and accessory foramina. These arterioles run longitudinally through the centre of the pulp, branching out to its periphery where they form a capillary network in the subodontoblastic area. These capillaries do not enter the dentin; they drain into the venules that run alongside the arterioles and pass out through the same apical foramen.[39,40]

Different methods may be used to assess the blood flow in the pulp: for example, isotope clearance,[41] local hydrogen-gas desaturation[42] and labelled microspheres.[43] Because of the limitations on the use of isotopes with humans, these methods remain experimental (in vitro). A study[44] to determine whether a change in tooth temperature can trigger pulpal blood flow concluded that this method of assessing blood flow in the pulp was not clinically reliable.

Experimental Diagnostic Methods to Assess the Blood Supply

Although they have a few drawbacks, the techniques described in this section have the most potential for clinical application in the future.

Dual-wavelength Spectrophotometry

Dual-wavelength spectrophotometry (DWS), which is done with a noninvasive portable instrument, can be used to test pulpal blood flow. Oximetry by spectrophotometer determines the level of oxygen saturation in the pulpal blood supply with a dual-wavelength light source (760 and 850 nm).[45,46] This instrument may be useful for determining pulp necrosis and the inflammatory status of the pulp.[45]

Nissan and others[46] did an in vitro study to determine the feasibility of using DWS to identify teeth with pulp chambers that are either empty, filled with fixed pulp tissue or filled with oxygenated blood. Their findings indicated that continuous-wave spectrophotometry may be a useful method for testing pulp.

Pulse Oximetry

Since the study of Nissan and others,[46] further research has focused on pulse oximetry, which is based on DWS. Pulse oximetry is widely used in medical practice to measure levels of oxygen saturation during the administration of intravenous anesthesia,[47] and is routinely used in emergency rooms and in situations in which sedation and analgesia are used.[48] Pulse oximetry is noninvasive and atraumatic, characteristics that make it valuable to dentistry. This technology is based on a modification of Beer's law: namely, the absorption of light by a solute is related to its concentration at a given wavelength.[49] Pulse oximetry also uses the characteristics of hemoglobin in the red and infrared range: oxyhemoglobin absorbs more light in the infrared range than deoxyhemoglobin, and vice versa in the red range. Schmitt and others[50] found that pulse oximetry effectively determined the oxygen saturation in a tooth model in vitro. Noblett and others[33] who used a rubber dam clamp as a base for the sensor design in an in vitro pulpal-circulation model found that this design accurately determined oxygen saturation in blood circulating through the pulp chamber of a tooth model. Kahan and others[51] examined a modified tooth probe and found no consistency between its results and those of a finger probe. Gopi Krishna and others[52] produced consistent readings when they compared a customized dental sensor with the finger sensor. They recommended that sensors should suit the anatomy of the tooth and that the light-emitting sensor and the plot receptor should be parallel to each other. They also recommended that the probe firmly grip the tooth surface for accurate measurement. Gopikrishna and others[53] compared a custom-made pulse-oximeter dental probe with thermal and electrical tests for the assessment of pulp vitality. They found that the sensitivity of the pulse oximeter is 100%; the cold test, 81%; and the electrical pulp tester, 71%. (Sensitivity indicates the ability of a test to report disease in patients who have the disease.[6]) This same group carried out a study[54] comparing the ability of the new pulse-oximeter method with that of the electrical and thermal tests to measure pulp vitality in recently traumatized teeth, whose condition can be complicated by a delay in diagnosis. They used a modified pulse oximeter that had a multisize oxygen sensor of small dimensions suitable for placement on human teeth and a sensor holder that maintained the stability of the teeth and the sensor. They reported constant vitality readings throughout the study from 0 to 6 months with the pulse oximeter, and variable readings with the electrical and thermal tests (responses varied from none on day 0 to beginning to respond on day 28 to almost total response for the 3-month period).

Laser Doppler Flowmetry

Laser Doppler flowmetry (LDF) is an accurate, noninvasive, reproducible, reliable method[55–58] of assessing blood flow in microvascular systems with a diode that projects an infrared light beam through the crown and pulp chamber. This light beam is scattered through moving red cells and static tissues.[59] Its frequency shifts when the beam passes through moving red blood cells, but remains constant when the beam passes through static tissue.[59,60] The LDF technique takes about an hour to produce recordings, making it impractical for dental practices unless its time frame can be shortened to a few minutes.

In dentistry, LDF was used to assess pulpal blood flow as an indication of the vitality of traumatized teeth.[56,61–63] LDF was also used to assess gingival blood flow in flaps after ridge augmentation[64] and during Le Fort I osteotomy,[65] and to assess blood flow in intact teeth in animals[66] and in man.[55] Gazelius and others[55] used LDF to study pulpal blood flow with He-Ne light, a general purpose for LDF, rather than one optimized for measuring pulpal blood flow. Pettersson and Öberg[59] designed an LDF instrument for measuring blood flow in human pulp and used it to assess the viability of pulp in intact and traumatized teeth. They used an infrared laser diode with a longer wavelength that gave better penetration than the He-Ne wavelength. Sasano and others[67,68] designed and developed a transmitted laser-light flow meter that used high-powered laser light to monitor the pulpal blood flow of teeth rather than the conventional light flow-meter apparatus. Konno and others[69] used the same apparatus to evaluate changes in pulpal blood flow in dogs' molar intrusion, using a skeletal anchorage system.

LDF is reported to be technique-sensitive[61]: its readings are affected by the movement of the patient, a nonfixed probe or a mobile tooth.[70,71] The technique yields false-positive results when used for endodontically treated teeth[72] and when the gingival blood flow is measured.[70,71] Moreover, intracoronal and extracoronal scattering of the laser beam calls for special precautions such as covering the gingiva and the crown of the tooth.[73,74]

Conclusions

Information about the physiology of pulpal pain and the sensory fibres causing this pain, together with information gathered from the patient, and the use of appropriate devices to test pulp sensitivity and vitality are very critical to reaching an accurate diagnosis on which to base an appropriate treatment plan. Multiple devices that test pulp viability are available on the market, but they test the viability of nerve fibres as a measure of pulp vitality, resulting sometimes in false-positive or false-negative results. These can lead to unnecessary endodontic procedures if these tests are not substantiated with results of other diagnostic measures. Pulpal blood flow, which is at least as important as testing the neural supply of the pulp, must also be examined. Although still being studied, methods to test blood flow look very promising and should soon be in use in the dental clinic. ❖

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