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Understanding Electric Pulp Testing

Lado EA[1]*, Caudle R[2], Bowers T[3] and Fundora M[4]

[1]Oral and maxillofacial surgery department, University of Florida College of Dentistry, USA

[2]Oral and maxillofacial surgery in the neuroscience division, University of Florida College of Dentistry, USA

[3]Department of Oral & Maxillofacial Surgery, University of Florida, USA

[4]Dental student at the University of Florida, College of Dentistry (UFCD), USA

***Corresponding author:** Dr. Lado, Associate professor in the oral and maxillofacial surgery department at the University of Florida College of Dentistry (UFCD), USA, Email: elado@dental.ufl.edu

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Abstract

Many dentists find use of the Electric Pulp Tester (EPT - a diagnostic tool historically used to determine the vitality of dental pulps) perplexing if not useless. One reason for its' decreased popularity may be a failure to fully appreciate how it works as well as its' limits in determining the health of pulp tissues. This manuscript explores the means by which the test is accomplished and discusses interpretation of its findings.

Keywords: Necrobiosis; Electric Pulp Tester; Necrosis; Electrolyte

Abbreviations: EPT: Electric Pulp Tester

Introduction

When diagnosing the cause of a toothache, it is often necessary to establish the overall health of the dental pulp. Historically the electric pulp tester (EPT) has been used to establish vitality and referred to as a pulp "vitality" tester or "Vitalometer®." It requires sending an electric charge through the pulp canal of a tooth by applying an electrode to the surface enamel and completing the circuit via a ground. The assumption is that if the patient reports feeling an electric current prior to reaching the maximum output of the EPT, the pulp tissue are deemed to be vital. However, it does not establish the health of the pulp, it merely affirms the completion of a circuit and a judgment as to the health of the pulp must be based on assimilation of other test results and all pertinent history. There are attempts to correlate higher readings (when compared with a "control tooth") to a diseased pulp. Unfortunately, proper evaluation of the health of the dental pulp requires: correlating the history of pain, clinical signs and symptoms including onset and character of pain as well as diagnostic test results. Tests include: radiographic interpretations, thermal and electric pulp tests (EPT) as well as a functional evaluation, especially masticatory pain. Integrating this information enables the dentist to assess the health of the dental pulp and evaluate its' potential to heal [1].

The dentist may find his diagnosis skewed, especially if the electric pulp test and thermal results are preferentially considered at the expense of other signs

and symptoms including the history, character and onset of pain. Just because a pulp tests within normal limits to thermal and the EPT at a given point in time, it does not ensure that it is healthy and capable of repair. This is especially true when the source of pain is from a dying pulp (partial pulp necrosis or necrobiosis. Necrobiosis has been found to contribute to false positive and negative test results due to atypical neural responses to stimulation [2]. It can also be argued that reactions to challenges to the pulp vary with the physical conditions within the circuit that can interfere with the transmission of the electric charge. Thus, erroneous diagnosis may result from improperly conducted pulp tests and a failure to consider all pertinent information leading to misinterpreted results. An example of a specious result is the failure of a tooth to respond to a thermal test. One may be inclined to assume the pulp is non-vital but it could be a "false negative" response. The EPT presents an opportunity to confirm the result.

No sensation at the maximum output of the EPT tends to affirm a necrotic pulp, while a positive reading indicates that the thermal test might be the result of a false negative response. Note neither of these tests, even when combined, confirm a diagnosis. It is possible to have false negative or false positive readings with both tests, especially when the surface enamel is undermined with decay or the coronal portion of the pulp tissue is necrotic but viable pulp tissue remains in the lower portion of the canal. A challenging diagnosis may necessitate additional testing as well as an assessment of the history of the onset and character of pain. In an effort to discourage the notion that an EPT is a vitality test it has recently been termed a "sensibility" test [3]. This change is equally confusing in that it still assigns the health status of the pulp to ordinal readings generated by the EPT, evidenced by the stratagem that calls for comparing readings to those of a "control tooth."

Jespersen J, et al. [4] suggested that a negative EPT reading (no sensation reported at maximum output of the tester) is an excellent predictor of necrosis, whereas a positive reading is a relatively poor predictor of vitality. It has also been suggested that the EPT may result in fewer false-negative responses when compared with cold testing in older patients because sclerotic dentin may insulate the pulp tissue from the thermal challenge by impeding the flow of dentinal fluid within the tubules (Brannstroms' hydrodynamic theory of dental pain). These suggestions may be valid under specific circumstances. At best, however, the EPT should be considered an adjunct to thermal testing and history in determining the health of the pulp especially when there is no response to the stimulus. Attempts to claim one test method is more accurate than the other is spurious since the specific physical condition of each tooth dictates the outcome of the test. Rational for the use of an EPT will be discussed but keep in mind that it alone does not convey the health of the pulp.

Discussion

The purpose of this treatise is to provide insight into the workings of the EPT and interpretation of test results. It focuses on physical conditions that affect EPT readings. Failure to consider these conditions that can lead to misinterpretation and has, without doubt, contributed to the EPT's decline in acceptance. As you progress through this discussion it will become apparent that an arbitrary selection of a contralateral tooth is not a valid control. The best that can be expected by testing a contralateral tooth is to determine the pulp tester is working and that the sensation felt by the patient is similar to and in-fact a reaction to the electric stimulation.*

Numerous studies have attempted to correlate EPT readings to the health of the dental pulp. In a landmark study by Seltzer, Bender and Ziontz of twenty-five teeth with histologically confirmed partial pulp necrosis, 32% (eight teeth) of the readings were above that of the control tooth; 28% (seven teeth) were about the same and 12% (three teeth) responded lower than the control tooth. Seven teeth (28 %) did not respond at all. Since there was no correlation with the histologic diagnoses they concluded that the viability of the pulp to heal could not be determined by comparing the EPT readings to that of a control tooth [5]. They also noted that control teeth "often gave abnormal readings" thus bringing into question the value of comparing EPT readings with a control tooth. They speculated the abnormal reading from the control teeth were attributable to undiagnosed pulp pathosis. Unfortunately, these pulps were not evaluated histologically to corroborate their speculation since they did not present with any other symptoms. The following discussion should bring to light possible causes for the erratic reading.

Even though studies have not demonstrated a convincing correlation of EPT readings to the health of the pulp tissue, the published literature often suggests higher readings infer that the pulp may be in the process of dying (necrosis). This inference encourages testing a contralateral tooth and comparing readings. Bearing in

*Pressure exerted by the EPT tip when placed on the tooth with symptomatic apical periodontitis may be sufficient to cause pain arising from the PDL. Conceivably, the patient may interpret the discomfort as stimulation from the EPT.

mind Seltzer's findings, this comparison should be considered suspect if not unwarranted.* The literature suggests that the EPT is accurate only about 80% of the time with the rest resulting in false positive or false negative findings [6,7]. It is important to note that numerous conditions (not related to the overall health of the pulp) affect the EPT readings. Speculative reasons for erroneous readings (besides operator error) have ranged from incomplete formation of the nerve plexus of Raschkow in developing teeth, to the inability of a child to provide reliable information [8-10]. I find these speculations suspect and that the variations in readings are more likely a result of resistance (R) within the circuit specific to each tested tooth.

Several types of pulp testers are available to the dentist including analog and digital devices. Manual rheostats control the amplitude of the stimulus from the analog pulp tester, while the digital pulp tester automatically increases the amplitude incrementally so long as the circuit remains complete. Both have advantages and disadvantages including costs and ease of operation. Neither of the readings derived from a manually rotated dial on an analog pulp tester or LED readout on a digital pulp tester are a measure of the actual voltage or current applied to the tooth. Each simply represents an ordinal scale reflecting the intensity of the momentary electric charge being delivered. Dental pulp tissue is predominantly enervated with 2 afferent nerve fibers (a-delta and C fibers) each characterized by transmission of a specific character of pain, (a-delta transmits a sharp pain while C fibers transmit an aching pain). The literature claims the a-delta fibers respond at lower voltage than the C fibers but there is no evidence that the patient feels a difference in the character (sharp Vs aching) of the electrical stimulation. Presumably, the a-delta fibers respond at a lower challenge than the C fibers but there is no correlation established with inflamed tissues. There does not appear to be a difference in the sensation based on the specific sensory nerves that are stimulated, so the role of the particular sensory nerve may be minimal other than to provide a pathway for electric conduction.

At this time, a review of basic electricity is in order. Recall Ohm's Law "E = I x R" where E is the electromotive force (volts), I is the current (amperage), and R is the resistance (ohms). For the sake of argument, in a closed circuit, where amperage remains relatively constant, voltage must increase as resistance increases. An additional and salient consideration offered in this article is the concept of "current density". Current density is the concentration of electricity flowing through a restricted area such as the tooth apex. According to "Pouillet's law", Resistance is inversely proportional to the cross-sectional area. Applying this concept to a tooth we see that voltage must increase to over-come the resistance as the size of the apex decreases. Let's explore this concept in terms of fluids, i.e. force equals unit volume/area. Since the physics of fluid flowing through a pipe is analogous to the flow of electricity, the following analogy is offered.

Picture the force generated by five gallons of water per minute coming out of a culvert. One could imagine a small animal drinking at the exit quite comfortably. Now imagine the same five gallons per minute flowing out of an oral hygiene irrigating device. That much water forced through the small opening of the device would be sufficient to tear the gingiva apart. Thus; restricting the diameter of the opening while maintaining the same volume of water, necessitates increasing the force at the point of exit. i.e. current density. This principle applies to the flow of electricity through a tooth. As current flows through the pulp tissues and out the apical foramen, a large apex presents a low Current Density, allowing current to flow with little force (volts) the way water flows through a culvert. On the other hand, a restricted apex presents a high Current Density, thus the force (volts) required to advance through the apex must increase. (The higher the voltage or force, the more painful the perception.) However, if the opening is sufficiently large to allow the flow prior to reaching the sensory threshold, pain will not be perceived. This concept of current density readily explains why deciduous teeth and newly erupted teeth with open apices do not reliably respond to the electric pulp tester. It also explains why posterior teeth with multiple apices respond at higher readings. The current density in posterior teeth is reduced because the multiple apices present a larger overall opening. The resistance (R) attributable to the area of the apex is not the only restriction to the flow of current through a tooth. Resistance may be affected by the conductivity and amount of toothpaste (conduction paste) placed on the enamel. The greater amount of the surface coated reduces the resistance [11]. But it does not end there. A wide variation in readings may be attributed to the resistivity of enamel and dentin. Mumford has reported the resistivity of enamel to range from 2.67×10^6 to 6.9×10^6 ohms/cm^2 and dentin from 11×10^3 to 52×10^3ohms/cm^2 [12]. The specific electrolyte used to assure transmission through the enamel also effects resistance. One manufacture of an EPT specifically advises avoiding the use of popular desensitizing toothpaste since it does

*If the control tooth is tested first, the "shock" may be enough to sensitize the patient and become guarded against a second shock on the suspect tooth.

not facilitate conduction.* Other conductive media have been evaluated and presented a wide range of conductance [13].

The following is a list of factors that affect the resistance within the circuit and thus the EPT reading:

i. Thickness of enamel
ii. Desiccation of enamel (excessive air drying)
iii. Thickness of dentin, presence of secondary or tertiary dentin
iv. Caries/restorations impeding the flow of current to the pulp chamber
v. Incomplete isolation of the tooth (Short circuit with adjacent teeth)
a. Calculus bridging to adjacent teeth or periodontium
b. Remaining moisture at the contacts
c. Inadvertent contact with the gingiva or mucosa
d. Restorative materials contacting at proximal surfaces or gingiva. (Mylar strips may be used to isolate the tooth from adjacent teeth).
vi. Dryness of patients' hand if used to complete the circuit on the metal wand. This is often seen in construction workers with dry calloused hands.
vii. Presence of a vertical fracture blocking the current flow through dentin to the pulp
viii. Large open apex (current density) as seen in newly erupted or deciduous teeth.
ix. A void within the pulp chamber created by necrosis (Necrobiosis)
x. Failure to operate the pulp tester according to the instruction manual.
xi. Defective or inoperable pulp tester. (Week battery).
xii. Loss of the insulative shield on the pulp tester tip. Contact of the side of the tip with oral soft tissues wills short circuit the flow of current.

An additional problem may involve provoking pain from an inflamed PDL. Pressure from the electrode tip applied to the tooth may be sufficient to cause pain that the patient may interpret as a positive test. A solution to this would be to maintain a completed circuit by withdrawing the tip from the surface of the tooth but maintain a strand of electrolyte through which the charge may traverse. Given the number of factors that affect EPT readings, one can appreciate its' waning popularity. It has been determined that a correlation exists between voltage and digital readings; however, individual recordings are not reproducible over time on the same subject of clinical relevance is the notion that comparing digital readings for teeth with suspected diseased pulps to teeth with "normal" pulps may be of minimal value since many factors other than the status of the pulp effect the resistance and thus affect the reading obtained [14]. However, when used to establish "continuity" and not vitality, the resultant findings are less complicated.

How It Works

Recall electricity travels along the path of least resistance. Examining the function of the Digital pulp tester, we find that the electric charge travels through the entire tooth surface due to the conductive nature of dentin. Upon reaching the root surface, the charge flows from dentin to PDL to somatic tissues through the arm, fingers and grounds out on the wand where the circuit is completed. Upon completion of this circuit that the digital unit incrementally increases the voltage until it overcomes the resistance created by the apical foramen and reaches the sensory threshold. Upon sensation of the weak shock, the patient releases the wand, the circuit is broken and electric flow ceases. A maximum voltage is preset within the unit to avoid delivering an uncomfortable shock to the patient. If the maximum voltage is reached and the patient does not report feeling it, the presumption is that the circuit through the apex is incomplete and most likely due to a void within the pulp chamber created by the necrosis of pulp tissue. However, another possibility is that the apex is wide open as seen in newly erupted teeth and deciduous teeth allows for the electric charge to pass through without reaching the threshold for perceiving a shock.

Rational for conducting an electric pulp test

Periodically a tooth may present radiographic evidence of an apical rarefaction or opacity and a question arises as to the status of the pulp. This is often seen associated with teeth that have been traumatized/discolored/undergone a silent death following restoration or pulp cap. However; it can also be a radiographic anomaly, or even an anatomical finding such as the mental foramen. Since thermal (cold) tests have been known to yield false negative and positive results, the EPT serves as an additional confirmatory test. In fact, anytime a questionable cold test outcome is suspected, it should be followed with an EPT if practical. Keep in mind that many of the factors that could result in a questionable cold test result could also affect the EPT result. It is common for a recently traumatized tooth to yield an erratic electric pulp test. Any traumatized tooth, not involving the pulp, should be reevaluated @ 72 hours and again at 2 and 6 weeks. If the pulp has not healed within 6 weeks, the pulp has likely necrosed and continuity through the pulp chamber is lost. The EPT should go to its' maximum output without the patient feeling the stimulation. If the tooth is to be

*Instruction pamphlet for digital EPT provided by SybronEndo, 1332 South Lone Hill Ave, Glendora, CA 91740

retained, endodontic treatment would be indicated. A reading short of the maximum output would indicate continuity but not necessarily a vital pulp. For instance, a pulp chamber filled with pus could provide a pathway for the current to flow. The health of the pulp must be determined by history of unprovoked pain and other appropriate diagnostic tests. Keep in mind that a fracture in dentin could provoke a sharp pain but would not be spontaneous if it has a chance of healing. A fracture could also impede the flow of the electric charge through the dentin to the pulp chamber and result in a false negative reading.

When is an Electric Pulp Test appropriate: An EPT should be conducted

On any tooth that fails to respond to thermal if a viable pulp is suspected to rule-out a false negative thermal test. If you suspect the patient has identified the wrong tooth based on symptoms. On any tooth with an apical rarefaction when an obvious cause is not evident such as; anatomical entities like the mental foramen or systemic conditions that cause radiolucency's in bone such as kidney disease/malignant and non-malignant tumors/cysts/osseous dysplasia/and a host of other conditions.

The following may be:

Causes of False Negative tests

a. Electric charge fails to pass through the apex and generate sufficient electric charge to cause pain. (Short circuits) shorts through gingiva or mucosal lining of the mouth.
b. Excess reparative dentin or restoration blocking the charge from reaching the pulp tissue. (Failure of the tester to generate sufficient voltage to overcome the resistance.)
c. Caries under the surface enamel blocking the flow of electricity.
d. Newly erupted or deciduous teeth with open apexes.
e. Defective or inoperative tester (Low battery).
f. Necrobiosis (Coronal portion of the pulp has necrosed leaving a void in the pulp chamber, while the remaining pulp further down the canal is still vital).
g. Use of an inappropriate electrolyte.

Causes of False Positive tests

a. Failure to adequately dry the tooth surface with resultant stimulation of gingiva or contacting adjacent restorations.
b. Stimulation of an inflamed PDL by pressing the EPT tip against the tooth.
c. Apprehension of the patient, especially if a "control tooth" is tested first and shocks the patient.

Conclusion

From the information presented, it should be apparent that contrary to conventional belief, the pulp tester is not a determinant of pulp health. It merely confirms continuity of the circuit. The health of the pulp must be determined by integrating the history of the chief complaint and timely tests keeping in mind that the disease process is a continuum and symptoms may change from one moment to the next.

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