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REVIEW

Electric pulp testing: a review

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Abstract

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Electric pulp testing (EPT) has been available for more than a century and used in dental practices worldwide. This article provides an overview of this diagnostic aid. The PubMed database from 1953 was used initially; the reference list for pulp testing featured 1071 articles, and for EPT identified 121 papers. A forward search was undertaken on these articles and using selected author names. Potentially relevant material was also sought in contemporary endodontic texts, while older textbooks on endodontics, operative dentistry and pain revealed historic information and primary research not found electronically. A short account of the innervation of the pulp is followed by an historic overview. Clinical considerations discussed include tooth isolation, glove wearing and tester electrode placement. Orthodontic treatment, pacemaker wearing and patient medications are considered. Research applications are also discussed. While EPT is valuable, no single pulp testing technique can reliably diagnose all pulp conditions. Careful collection of patient history regarding the problem tooth and prudent use of appropriate radiographs are also helpful. The shortcomings of electric tests, especially in the case of immature and concussed teeth, must be understood. The demeanour of the patient and the responses given by control teeth also require careful consideration.

Keywords: diagnosis, electric pulp testing, endodontics.

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Introduction

Diagnosis of the health of the pulp and pulp-related dental pain are problematic (Rowe & Pitt Ford 1990), and may lead to difficulties in planning treatment (Marshall 1979). Indeed, the dental profession is yet to establish a simple and reliable method to diagnose diseases of the dental pulp. The ideal pulp test method should provide a simple, objective, standardized, reproducible, nonpainful, noninjurious, accurate and inexpensive way of assessing the condition of the pulp tissue (Chambers 1982). In endodontics, pulp testing may involve thermal and electric pulp testing (EPT). These tests are also defined as sensibility tests, as they assess whether there is response to a stimulus. 'Pulp vitality' implies blood supply, which thermal and electric tests do not confirm. Further information when attempting to diagnose the condition of the pulp may come from appropriate radiographs, blood flow tests such as laser Doppler flowmetry if available, preparation of test cavities and anaesthetic tests. However, none of the current pulp testing methods meets all criteria.

Electric pulp testing is based on stimulation of sensory nerves, and requires and relies on subjective assessments and comments from the patient. These can lead to false-positive and false-negative results. Nevertheless, EPT remains an important aid, and when properly used, it is a safe clinical test that can provide useful information regarding health and disease (Seltzer *et al.* 1963a, Mumford 1967, Dummer *et al.* 1980).

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In the pulp chamber coronal nerve bundles diverge and branch out towards the pulpo-dentine border (Dahl & Mjör 1973, Gunji 1982). Nerve divergence continues until each bundle looses its integrity and smaller fibre groups travel towards the dentine. This route is relatively straight until the nerve fibres form a loop resulting in a mesh that is termed the plexus of Rashkow. The density of this nerve plexus is well developed in the peripheral pulp along the lateral wall of coronal and cervical dentine and along the occlusal wall of the pulp chamber. The nerve fibres emerge from their myelin sheaths and branch repeatedly to form the subodontoblastic plexus. Finally, the terminal axons exit from their Schwann cell investiture and pass between the odontoblasts as free nerve endings (Byers & Närhi 2002).

Two types of sensory fibres are present in the pulp, the myelinated (A fibres) and unmyelinated C fibres. The A fibres predominantly innervate the dentine and are grouped according to their diameter and conduction velocities into Aβ and Aδ fibres. The Aβ fibres may be more sensitive to stimulation than the Aδ fibres, but functionally these fibres are grouped together. Approximately 90% of A fibres are Aδ fibres. The C fibres innervate the body of the pulp. The Aδ fibres have lower electrical thresholds than the C fibres and respond to a number of stimuli which do not activate C fibres (Olgart 1974). Aδ fibres mediate acute, sharp pain and are excited by hydromechanical events in dentinal tubules such as drilling or air-drying (Byers 1984). Pulpal Aβ- and Aδ- fibres respond to drilling and dentine probing and probably belong to the same functional group (Närhi 1985, 1990). Aδ fibres may act as mechanoreceptors that trigger withdrawal reflexes so that potentially damaging forces may be avoided (Dong *et al.* 1985, Olgart *et al.* 1988, Byers & Närhi 1999). The C fibres mediate a dull, burning and poorly located pain and are activated only by stimuli reaching the pulp proper (Närhi 1985, Markowitz & Kim 1990). C fibres have a high threshold and can be activated by intense heating or cooling of the tooth crown. Once activated, the pain initiated by C fibres can radiate in the face and jaws. C fibre pain is associated with tissue injury and is modulated by inflammatory mediators, vascular changes in blood volume and flow, and increases in pressure (Närhi 1990).

As the intensity of the stimulus increases, more sensory nerves are activated and this results in a progressive increase in the sensory response. The response to a given stimulus will be greatest where neural density is the highest. Key factors in pulp testing are the thickness of the enamel and dentine and the number of nerve fibres in the underlying pulp. Lilja (1980) found that the highest concentration of neural elements was in the pulp horn region. A progressive decrease in the number of nerve fibres in the cervical and radicular areas was observed. Similar findings were reported by Byers & Dong (1983). Presumably the direction of the dentinal tubules is also important in establishing pulp test responses in various parts of the tooth crown. The dentinal tubules run an almost straight course from the incisal edge of anterior teeth to the pulp horn. Elsewhere in teeth the course of tubules is somewhat curved and resembles an ‘S’ shape. Because it is principally the fluid in the tubules that conducts electrical impulses from the pulp tester electrode to the pulp, the shorter the distance between the electrode and the pulp, the lower the resistance to the flow of current (Bender *et al.* 1989).

Efforts to determine the pain threshold values of normal teeth have been made using a square wave stimulus of 10 ms duration every 2 or 3 s (Bjorn 1946). Mumford (1963) used a monopolar stimulator and demonstrated that the narrowest range of oscilloscope reading of the square wave was 0.7–4.5 μA. Subsequently, he modified his procedure and used a 30-ms stimulus at 20 counts per second, applied to a larger contact area. The pain perception threshold range was then recorded as 2.2–20.5 μA, still too great to be of practical clinical value (Mumford 1965, 1967). A later study found no correlation between the threshold of teeth and the pathological state of their pulps (Matthews *et al.* 1974).

Based on single-nerve-fibre recording studies, the pulp nerve fibres responded to lower current intensities and a small number of pulpal afferents is needed to evoke neurone responses when electrical stimulation is applied (Närhi *et al.* 1979, 1982). This suggests that EPT might produce a false-positive response in teeth with pulpal necrosis. One study demonstrated an overlap of the thresholds of pulpal and periodontal nerves, thus periodontal nerves may be stimulated to a level that gives a false indication of tooth ‘sensibility’ (Närhi *et al.* 1979).

History

The use of electricity in dentistry is attributed to Magitot and described in his book *Treatise on Dental Caries* published in France in 1867 (cited in Prinz 1919). Magitot advocated the use of an induction current to localize carious teeth (Prinz 1919). Later, Marshall (1891) and Woodward in 1896 (cited in Prinz 1919) used electricity to demonstrate vital and nonvital pulps. Woodward found the following:

If a few cells of a cataphoretic apparatus are in action, and the positive electrode be applied to the dentine or metallic filling in a vital tooth, while the negative pole is at the cheek or wrist of the patient, a distinct sensation should be felt, while in the case of a dead pulp there will be no response; usually even a small filling will transmit a distinct shock in a vital tooth, which is absent in a devitalised tooth.

A mild interrupted current has also been used for the test'. However, Roentgen in 1895 was probably the first to introduce the use of electricity clinically for diagnosing diseases of the pulp (Grossman 1976).

In 1901, investigators in Europe attempted to standardize the instrument used for electrical stimulation of the dental pulp, and conducted experiments with reliable and informative results (cited in Kaletsky & Furedi 1935). In the same year, Futy (cited in Kaletsky & Furedi 1935) used a device where the primary current of an induction coil fed two electrodes. One was held in the patient's hand, and the other applied to the tooth with a platinum pin covered with water-saturated cotton. Up to 2 V were applied, controlled with a rheostat. Futy observed that:

1. Normal teeth reacted when moist
2. Devitalized teeth did not react, even to much greater amounts of current
3. Teeth with inflamed pulps had a much lower threshold of irritability, requiring less current for a response
4. Teeth with normal enamel responded best when tested near the neck of the tooth.

In 1907, Hafner made a similar observation regarding the effects of the electric current on vital and devitalized teeth using alternating and direct current (cited in Prinz 1919 and Kaletsky & Furedi 1935). An instrument with two electrodes was controlled with a rheostat supplying up to 5 V. In order to obtain the most accurate interpretation, he used another tooth as a control. This control tooth was presumed to be normal, and was anatomically similar to the tooth under test. A rubber dam was applied. Hafner found that the diseased tooth either did not respond to a large amount of current, or else responded violently to a comparatively small amount of current that had no effect on the control tooth. He interpreted these findings as suggesting that the pulp of the problem tooth was either dead or inflamed.

These earlier studies using different currents had similar conclusions:

1. Teeth with normal enamel and normal pulp tissue gave definite results, more or less painful, according to the individual, regardless of the instrument used
2. Teeth with inflamed pulp reacted to a much smaller amount of current than teeth with normal pulps
3. Devitalized teeth did not respond at all.

The usefulness of electric pulp tests became a topic of controversy for decades. Early studies attempted to correlate the clinical pulp status with the results of electric testing. Investigators thought that electrical testing could diagnose degrees of pulp inflammation (Capon 1925, Thoma 1929) as well as distinguish between vital and nonvital pulps (Kesel & Stephan 1934).

Reiss & Furedi (1933) electric pulp tested 130 teeth. After the tests they examined the pulp tissues directly after extirpating the pulps or sectioning the teeth following extraction. They found that of the teeth tested normally with the EPT, 63.5% had normal histology; of teeth responding positively with low current, 92% were pathological with 33% showing inflammation; of the teeth that responded to high current, 90% were pathological; and of the teeth that gave no response to the highest current, 100% were pathological with 58% being necrotic. Their study set the pattern for further investigations which tested the teeth and then examined the pulps directly by extraction and sectioning or by pulp extirpation (Kaletsky & Furedi 1936, Stephan 1937, Ziskin & Wald 1938, Kaletsky 1943, Ziskin & Zegarelli 1945).

Seltzer *et al.* (1963b) studied correlations among clinical signs, tests and symptoms to the pathological status of the pulp, hoping that more realistic diagnostic criteria could be developed. Results in relating electric pulp tests to histological findings in 129 teeth showed that 'the electric pulp test was of some value in suggesting the possibility of a inflammatory state, but it was far from definitive' (Seltzer *et al.* 1963b). These findings were supported by Lundy and Stanley (1969) who concluded that 'the electric pulp test is not a sufficiently discreet or refined instrument to detect changes in pulp conditions, but it may suggest changes in the pulp if a more severe inflammatory change occurs'. They also stated that 'no correlation existed between the electric pulp test values and a specific histopathologic state, but a negative reading does occur when the pulp is necrotic'.

In the 1970s EPT regained popularity when new designs of instrument were introduced. Several studies claiming advantages and disadvantages were published. There were two electric testing modes, bipolar and monopolar, which could be divided in to two subclasses, those with mains connection and those using batteries (Ehrmann 1977, Närhi *et al.* 1979). However, the most common types are battery operated.

Prior to the mid-1950s bipolar instruments were used, while almost all testers in use today are monopolar. Bipolar testing involves placing two electrodes on the tooth, one on the buccal surface and the other on the palatal/lingual surface, with current passing through the crown from one electrode to the other. Monopolar testing involves only one electrode applied to the tooth. The patient completes the electric circuit by holding the metallic handle of the EPT, or a lip clip is applied (Kolbinson & Teplitsky 1988, Guerra *et al.* 1993).

Monopolar and bipolar testers are based on the production of impulses of negative polarity. These are reported to reduce the voltages required to stimulate nerve response in the pulp, and reduce the possibility of stimulating the nerves in the periodontium (Bjorn 1946). Various designs of pulp testers have been described, some of them in great detail (Civjan *et al.* 1973, Hietanen & Rantanen 1973, 1976, Matthews & Searle 1974, Grayson 1977, Stark *et al.* 1977, Kleier *et al.* 1982, Kitamura *et al.* 1983, Cooley *et al.* 1984, Dummer & Tanner 1986, Dummer *et al.* 1986, Robinson 1987). Testers produce different electric impulses (Dummer *et al.* 1986). The output can be increased by turning a dial or is automatically increased with digital readout in more recent models (Dummer *et al.* 1986, Rowe & Pitt Ford 1990). Most practitioners consider a response or no response as being the important finding, rather than instrument setting required.

Clinical considerations

The electric pulp tester is technique sensitive and has limitations (Millard 1973, Cooley & Barkmeier 1977). The requirements of an EPT are adequate stimulus, an appropriate application method and careful interpretation of results. Tests require tooth isolation and conducting media. They may be frightening to patients, are sometimes painful and can elicit a response from the periodontium (Chambers 1982). They are not recommended for use on crowned teeth or in patients wearing orthodontic bands (Fulling & Andreasen 1976a). In these cases the response may be caused by conduction of the current to the gingival or periodontal tissues and adjacent teeth through contacting metallic restorations or orthodontic appliances (Rowe & Pitt Ford 1990, Myers 1998). Crowned teeth may be tested using a small electrode tip onto root structure and with the tooth isolated with plastic strips interproximally. Orthodontic arch wires should be removed to allow testing.

Tooth isolation during EPT is essential. As early as 1907 rubber dam was used to prevent gingival conduction (Hafner, cited in Prinz 1919). Electric current can also be transferred between adjacent teeth through contacting metallic restorations (Myers 1998). Drying the enamel, the placement of a plastic strip interproximally and use of rubber dam can prevent electrical impulses from spreading across the surface of the tooth and to adjacent teeth (Mumford 1956, Myers 1998). Spread of current to the periodontium may give a false-positive response (Närhi *et al.* 1979, Cooley *et al.* 1984, Myers 1998). The breakdown products of localized pulp necrosis may also conduct, passing current to adjacent pulp tissue in the same tooth (Dummer *et al.* 1980).

A conducting medium should be used to ensure that maximum current passes from the electrode to the tooth surface (Michaelson *et al.* 1975, Cooley & Robison 1980). A laboratory study by Martin *et al.* (1969) concluded that the interface medium made no appreciable difference to either the voltage or the electric current transmitted. However, a recent study demonstrated that different media may influence electric testing (Mickel *et al.* 2006).

Wearing gloves while performing electric tests has been controversial, with infection control directives of the American Dental Association (Jakush & Mitchell 1986) and the Centers for Disease Control calling for the routine use of gloves at all stages when treating patients. The electric circuit could be completed by the operator retracting the patient's lip or touching the patient's skin with another ungloved hand (Lado 1983); alternatively, the pulp tester may have a special ground electrode which hooks over the patient's lip (Ehrmann 1977). In 1977 it was reported that the EPT could be used effectively with the operator wearing latex gloves, but higher readings were obtained (King & King 1977). Using gloves was considered as a source of error, gloves preventing the functioning of one machine and giving a higher reading with another (Booth & Kidd 1988). Another study found that the use of gloves while performing pulp tests did not alter the readings (Anderson & Pantera 1988). Latex gloves act as a capacitance, altering the electrical output from the EPT (Treasure 1989). Current advice is that gloves can be worn, providing the patient completes the circuit by holding the metal handle of the EPT probe, or a lip clip is used (Kolbinson & Teplitsky 1988, Cailleteau & Ludington 1989, Guerra *et al.* 1993).

There are several considerations regarding optimal placement of the tester electrode. The response threshold is reached when an adequate number of nerve terminals are activated to attain a so-called summation effect (Närhi *et al.* 1979, Johnsen 1985). As the intensity of the stimulus increases, more sensory nerves are activated and this results in a progressive increase in the sensory response (Närhi *et al.* 1979). An area of high neural density should have a relatively fast and strong response and require the least electric current (Bender *et al.* 1989). Studies have reported the best position for the tester electrode on anterior and premolar teeth (Ziskin & Zegarelli 1945, Hannam *et al.* 1974, Fulling & Andreasen 1976b, Cooley & Robison 1980, Bender *et al.* 1989). Bender's group concluded that placing the electrode at the incisal edge of anterior teeth evoked a response with the least amount of electrical current (Bender *et al.* 1989). In human permanent molars the highest concentration of neural elements is in the pulp horns, with progressively fewer in the cervical and radicular regions of the pulp (Lilja 1980). Relatively few studies report EPT of molars (Cooley & Robison 1980, Dreven *et al.* 1987, Anderson & Pantera 1988, Certosimo & Archer 1996, Carnes *et al.* 1998, Branco *et al.* 2006, Goodman *et al.* 2006, Lai *et al.* 2006, Meechan *et al.* 2006, Modaresi *et al.* 2006). A new study has revealed that the optimum site for tester electrode placement on molars is the tip of the mesiobuccal cusp (Lin *et al.* 2007). Placing the patient in control, by using their fingers rather than voice responses to discontinue the EPT circuit, allows them to feel more at ease with the procedure. This results in more reproducible readings, and reduces the latent time between the onset of each participant's response and the point at which the test is discontinued (Cailleteau & Ludington 1989, Nam *et al.* 2005).

In 1974, a study was performed using a dog wearing a pacemaker, and the EPT switched the pacemaker to a fixed rate by causing interference (Woolley *et al.* 1974). The study is commonly cited as the rationale for not using an EPT in patients with pacemakers. However, at that time pacemakers were relatively unsophisticated. Three subsequent *in vitro* studies have reported no effects on pacemakers from EPTs (Adams *et al.* 1982, Luker 1982, Miller *et al.* 1998). More recently, an *in vivo* study simulated EPT use on 27 patients with implanted cardiac pacemakers or cardioverter/defibrillators. The report found that EPTs did not produce any interference effects (Wilson *et al.* 2006).

When the EPT is properly used it is a safe clinical test providing information on the condition of pulpal nerves. However, it does not always correlate with the condition of the pulp (Seltzer *et al.* 1963b, Mumford 1967, Dummer *et al.* 1980). Sometimes the clinician is unsure of the diagnosis, despite analysis of clinical findings (Marshall 1979). False positive and false negatives arise (Petersson *et al.* 1999). Previous studies have shown a high incidence of false-positive responses associated with EPT (Seltzer *et al.* 1963b, 1965, Dummer *et al.* 1980). Several explanations have been proposed:

1. The response may be caused by conduction of the current to the gingival or periodontal tissues (Rowe & Pitt Ford 1990).

2. A tooth causing a 'toothache' may still have inflamed pulp tissue present (Seltzer *et al.* 1965).

3. The breakdown products associated with localized pulp necrosis seem capable of conducting electrical current to adjacent infected and probably hypersensitive pulp tissue within the same tooth (Dummer *et al.* 1980).

4. The current may be conducted to adjacent teeth through contacting interproximal metallic restorations or orthodontic appliances (Rowe & Pitt Ford 1990, Myers 1998).

The EPT does not provide any information about the vascular supply to the pulp, which is the true determinant of pulp vitality. Studies indicate that there is a poor correlation between clinical information and the histopathological status of the pulp (Seltzer *et al.* 1963a, 1965). A negative EPT response indicated total necrosis in 72% of cases and localized necrosis in 25.7% of cases (Seltzer *et al.* 1963a). Therefore, in 97.7% of cases a negative response to the electric pulp test would indicate that root canal treatment should be carried out. Multi-rooted teeth may have a partially necrotic pulp and healthy pulp present in the root canal system, and these teeth are able to respond positively to testing (Peters *et al.* 1994). The EPT can also be helpful in diagnosing the state of a pulp in a tooth that has undergone pulp canal calcification. They are useful when these teeth do not respond to a thermal test, but respond to the EPT in the absence of a periapical radiolucency.

Traumatic injuries to teeth present problems with respect to vitality. Teeth that temporarily or permanently lose their sensory function will not respond to EPT and are described as 'concussed' (Kaletsky 1943, Bhaskar & Rappaport 1973, Pileggi *et al.* 1996, Waikakul *et al.* 2002). These teeth, however, may have intact vasculature. Bhaskar & Rappaport (1973) described 25 traumatized anterior teeth and EPT in all cases gave a negative response. After making endodontic access the researchers found the pulps were vital and concluded that EPT did not correlate with microscopic findings following traumatic injuries. They recommended that for traumatized teeth pulps should be considered vital until proved otherwise. Animal studies have investigated this aspect of EPT to determine the time period taken for injured teeth to return a baseline response (Pileggi *et al.* 1996).

The EPT is often unreliable in testing immature permanent teeth (Fulling & Andreasen 1976b, Klein 1978, Brandt *et al.* 1988) as full development of the plexus of Rashkow does not occur until 5 years after tooth eruption (Johnsen 1985). Several years elapse before the root apex closes, and the maturation of innervation is slow. Pulpal nerves fail to terminate among the odontoblasts and reach the predentine or dentine, as is found in fully developed teeth in occlusion (Fulling & Andreasen 1976b, Klein 1978). In immature permanent teeth testing with cold is a more effective method (Fuss *et al.* 1986).

Orthodontic tooth movement has been shown to produce changes in tissue respiration within the pulp as well as an inflammatory process within the periodontium (Hamersky *et al.* 1980). Testing for pulp sensibility during orthodontic treatment is also considered unreliable (Burnside *et al.* 1974, Hall & Freer 1998). However, these studies only demonstrated a decreased or total lack of response to EPT during force application. A recent study by Cave *et al.* (2002) indicated that orthodontic force increased the response threshold to EPT. The effect is almost instantaneous and may still be elevated up to 9 months later. Practitioners should interpret responses to EPT cautiously in orthodontic patients; thermal testing with carbon dioxide snow may be more reliable.

Sensibility tests are dependent on patient responses. Anxious or young patients may have a premature or false-positive response due to the expectation of feeling an unpleasant sensation (Cooley & Robison 1980). Drugs, including narcotics and alcohol, can also influence EPT responses (Degering 1962, Carnes *et al.* 1998). However, meperidine did not alter the EPT response, but a systemic dose of acetaminophen (paracetamol) had an impact on the response to EPT (Carnes *et al.* 1998, Kardelis *et al.* 2002). Modaresi *et al.* (2006) used EPT to measure the influence of a nonsteroidal anti-inflammatory drug (NSAID) on the effectiveness of local anaesthesia. They concluded that inflamed teeth had a lower threshold compared to normal teeth, and pre-administration of the NSAID improved the effectiveness of local anaesthesia for teeth with inflamed pulps.

The common techniques used in practice to assess the pulp status of teeth are EPT and thermal tests. Unfortunately, the interpretation of pulp test results is not a definitive procedure and all available data must be considered in reaching a diagnosis (Hyman & Cohen 1984). A positive response only confirms that Aδ fibres in the pulp chamber are responsive.

Thermal tests are also subjective. Some clinicians have suggested that using ice or other low temperature diagnostic materials like dichlorodifluoromethane may create hypothermic anaesthesia. Research shows that hypothermic anaesthesia is not achieved when dichlorodifluoromethane is used (Pantera *et al.* 1993). There is also no effect on the reliability of subsequent pulp testing with EPT once dichlorodifluoromethane has been applied. Petersson *et al.* (1999) described a 'gold standard' method. They pulp tested 59 teeth and compared the result by direct inspection of the pulp chamber contents. They concluded that the probability of a sensitive reaction for a vital pulp was 90% with cold, 83% with heat and 84% with an EPT, and in nonvital pulp it was 89% with cold, 48% with heat and 88% with the EPT. The accuracy was 86% for the cold test, 71% for heat and 81% for the EPT (Petersson *et al.* 1999). This indicates that cold and the EPT are reliable to a similar extent in the diagnosis of vital and nonvital pulps.

Research applications in analgesia

The first investigators to use EPT for evaluating the effectiveness of local anaesthetics were Bjorn (1947) followed by Harris (1956). The EPT has been used as an indicator of the effectiveness of local anaesthesia during operative procedures (Ågren & Danielsson 1981, Kaufman *et al.* 1984, Montagnese *et al.* 1984, Vreeland *et al.* 1989, Nist *et al.* 1992, Certosimo & Archer 1996, Costa *et al.* 2005, Fernandez *et al.* 2005, Mikesell *et al.* 2005, Modaresi *et al.* 2005, Branco *et al.* 2006, Goodman *et al.* 2006, Kanaa *et al.* 2006a,b, Lai *et al.* 2006, Meechan *et al.* 2006, Modaresi *et al.* 2006). Various methods are used to evaluate the depth of anaesthesia in clinical studies. One is soft tissue, lip and tongue-tip numbness. These signs are further complicated by interpretation of pain by the subject, which is highly variable and depends on their emotional and psychological status and past experiences (Certosimo & Archer 1996). The EPT offers a useful means for measurement of local anaesthesia. Studies have also suggested that EPT is an accurate means of evaluating local anaesthesia in teeth with noninflamed and inflamed pulps (Dreven *et al.* 1987, Modaresi *et al.* 2005).

Conclusion

While EPT is a valuable test in general and specialist endodontic practice, no single technique can reliably interpret and diagnose all pulpal conditions. Cold testing and EPT may accurately diagnose pulp vitality in over 80% of cases. Careful collection of patient history concerning the problem tooth and examination of appropriate radiographs are also essential. The shortcomings of EPT, especially in the case of immature and concussed teeth, must be understood. Careful consideration of the patient, tooth isolation and the responses given by control teeth are also necessary.

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