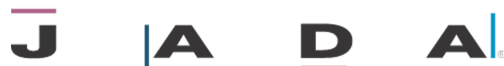


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J Am Dent Assoc 2009;140;1013-1017

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The validity of pulp testing

A clinical study

Rebeca Weisleder, DDS; Shizuko Yamauchi, DDS, MS; Daniel J. Caplan, DDS, PhD; Martin Trope, DMD; Fabricio B. Teixeira, DDS, MS, PhD

The most important part of a treatment plan is diagnosis, and in endodontics the accurate determination of pulpal vitality or nonvitality is essential. The pulpal tissue cannot be directly inspected before endodontic treatment commences because the pulp is enclosed within a calcified barrier. Therefore, indirect methods must be used to determine pulpal vitality. The most commonly used tests are thermal and electrical tests that stimulate the pulp by means of either dentin liquid movement as temperature changes or an electrical current conducted through the tooth, providing electrical stimulation of the pulpal nerves.¹

According to Seltzer and colleagues,² pulpal inflammation may develop after the application of irritants to the teeth. If the irritant is mild, this inflammation may resolve; when the action of the irritant continues for a long time, the response may become chronic. Eventually, pulp repair or necrosis may occur. The inflammation also may be partial or total, depending on the amount of tissue involved.

ABSTRACT



Objective. In this article, the authors report on an in vivo study in which they assessed the validity of two commonly used cold pulp tests (carbon dioxide [CO₂] and 1,1,1,2-tetrafluoroethane) and an electrical pulp tester (EPT) in determining pulp vitality by using direct inspection of the pulp as the reference standard.

Methods. One hundred fifty patients undergoing endodontic therapy at the University of North Carolina School of Dentistry (Chapel Hill) undergraduate clinic participated in this study. Before routine endodontic treatment, the authors classified participants by means of EPT, CO₂ and tetrafluoroethane as having either vital or necrotic pulps. Students recorded true pulpal status (vital/necrotic) by observing blood within the pulp chamber after an access cavity was made. The authors calculated the sensitivity, specificity and positive and negative predictive values of each test and the test combinations to describe their validity and clinical usefulness.

Results. Ninety-seven percent of teeth responding positively to all three tests contained vital pulps, whereas 90 percent of the teeth that failed to respond to any of the tests contained necrotic pulps. Ten percent of the teeth not responding to any of the tests contained vital pulps. For all other combinations of test results, 54 percent of teeth contained vital pulps, and 46 percent contained necrotic pulps.

Conclusions. These findings support the use of either of the cold tests and the EPT for diagnosis of pulpal status.

Clinical Implications. Cold test and EPT used in conjunction resulted in a more accurate method for diagnostic testing.

Key Words. Endodontic therapy; diagnostic tests; dental pulp test. *JADA 2009;140(8):1013-1017.*

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Although the perfect diagnostic test results always would be positive in the presence of disease and always would be negative when no disease is present, results of previous studies have shown a high proportion of false-positive and false-negative responses associated with electrical and thermal pulp tests.³

Many thermal testing agents have been studied and found to be effective for diagnosis. Fuss and colleagues⁴ determined that an electrical pulp tester (EPT), carbon dioxide (CO₂) and dichlorodifluoromethane (DDM) were efficient for this purpose. Dummer and colleagues⁵ stated the importance of the correct diagnosis for rendering the correct treatment. Correct diagnosis translates to having the correct tooth identified so that the clinician can offer the best treatment and, therefore, address the patient's chief complaint.¹

The validity of a diagnostic test is best described by its sensitivity and specificity, whereas its clinical usefulness in a given population is best described by its positive and negative predictive values⁶:

- Sensitivity is the proportion of cases identified correctly by means of the diagnostic test. For example, if EPT had a sensitivity of 80 percent, it would mean that 80 percent of vital teeth responded to EPT.

- Specificity is the proportion of noncases identified correctly by means of the diagnostic test. For example, if EPT had a specificity of 70 percent, it would mean that 70 percent of necrotic teeth did not respond to EPT.

- Positive predictive value is the proportion of positive test results that are cases. For example, if EPT had a positive predictive value of 90 percent, it would mean that 90 percent of teeth that responded to EPT were vital, so the remaining 10 percent would be false-positive results (that is, they would be teeth that responded to EPT despite being necrotic).

- Negative predictive value is the proportion of negative test results that are noncases. For example, if EPT had a negative predictive value of 60 percent, it would mean that 60 percent of teeth that did not respond to EPT were necrotic, so the remaining 40 percent would be false-negative results (that is, they would be teeth that did not respond to EPT despite being vital).

Few studies related to validity of pulpal vitality test devices are found in the literature.

Fuss and colleagues⁴ studied the accuracy of EPT, CO₂ snow, DDM, ethyl chloride and ice.

They reported the specificities of the tests and mentioned sensitivity but did not calculate predictive values.⁴ Peters and colleagues³ reported only the sensitivity of various testing agents. They found that teeth not responding to cold or EPT had a high probability of being necrotic or pulpally diseased. Petersson and colleagues¹ evaluated the ability of hot (heated gutta-percha), cold (ethyl chloride) and electrical tests to register pulpal vitality; they then calculated the sensitivity, the specificity and the negative and positive predictive values by using direct inspection of the pulpal tissue as a reference standard. Their results indicated an 89 percent probability that a nonsensitive reaction with the cold test represented a necrotic pulp, versus 48 percent with the heat test and 88 percent with the electrical test. Conversely, the probability that a sensitive reaction represented a vital pulp was 90 percent with the cold test, 83 percent with the heat test and 84 percent with the electrical test.

We conducted an *in vivo* study to assess the validity of two commonly used cold pulp tests (CO₂ and 1,1,1,2-tetrafluoroethane) and an EPT in determining pulpal vitality, and we used direct inspection of the pulp as the reference standard.

MATERIALS AND METHODS

Before we began the study, the protocol was approved by the institutional review board at the University of North Carolina at Chapel Hill. We selected 150 patients undergoing endodontic treatment in the undergraduate clinic at the University of North Carolina School of Dentistry. Inclusion criteria were age of 18 to 76 years and an American Society of Anesthesiologists medical status of I or II (status I patients are considered to be healthy; status II patients have mild to moderate systemic disease or are healthy [status I] but demonstrate a more extreme anxiety about and fear of dental care).^{6,7} Exclusion criteria were teeth with full-surface crowns, large restorations, recent trauma, regressed pulpal chambers or calcified root canals. We also excluded from the study patients experiencing moderate or severe pain.

After participants signed the consent forms and agreed to undergo endodontic therapy, they

ABBREVIATION KEY. CO₂: Carbon dioxide.

DDM: Dichlorodifluoromethane. **EPT:** Electrical pulp tester. **NPV:** Negative predictive value. **PPV:** Positive predictive value. **SN:** Sensitivity. **SP:** Specificity.

underwent diagnostic tests administered by a member (R.W. or S.Y.) of the Department of Endodontics who was blinded to the patients' chief complaints, recent dental history and radiographic findings. Each participant was instructed to raise his or her hand the moment he or she felt a cold or tingling sensation during the testing.

First, the researcher sprayed a no. 2 cotton pellet with a refrigerant (1,1,1,2-tetrafluoroethane) (Hygenic Endo-Ice Green [Endo-Ice], Coltène Whaledent, Cuyahoga Falls, Ohio) and placed it on the crown of the tooth for approximately 15 seconds or until the participant raised a hand to indicate that he or she felt a cold sensation (a protocol similar to one used in other studies^{3,4,8-10}). Second, the researcher, using Odonotest plastic cylinders (Miltex, York, Pa.), prepared CO₂ sticks and applied them to the crowns for either 15 seconds or until participants raised their hands. Third, the researcher isolated the teeth by using cotton rolls, dried them and then used an EPT (Analytic Technology Pulp Tester, Analytic Technology, Redmond, Wash.) to apply an electrical impulse to the tooth. Teeth responding at a level lower than 80 were considered vital.³ The researcher allowed at least two minutes to elapse after each pulp test because investigators conducting *in vitro* studies have reported that after application of thermal stimuli, the pulpal border of the dentin returns to its normal temperature within this period.^{3,4}

After conclusion of the tests, the students administering treatment anesthetized the teeth by using 2 percent lidocaine with 1:100,000 epinephrine administered as either inferior alveolar nerve block or local infiltration. The students isolated the teeth by using a rubber dam and accessed the chamber, then recorded whether or not the pulp was hemorrhagic. If the students observed vital tissue in the apexes of teeth with necrotic tissue in the chamber, they considered the teeth partially necrosed (and thus necrotic) in the analysis. We used 10 endodontically treated teeth as negative controls.

Each participant contributed one tooth to the analysis. We calculated the sensitivity, specificity and positive and negative predictive values of each test and compared each possible variation of results for the tests in combination to describe each test's validity and clinical usefulness; clinical pulpal status (that is, presence or absence of hemorrhage at access of the pulpal chamber) was

the reference standard evaluation.¹ We conducted all analyses by using statistical software (SAS 9.0, SAS, Cary, N.C.).

RESULTS

The figure describes the validity and clinical usefulness of the three diagnostic tests as used individually in this sample. Sensitivity for the Endo-Ice test, the CO₂ test and EPT were 76 percent, 76 percent and 92 percent, respectively (for example, 92 percent of vital teeth responded to EPT). Specificities for the three tests, respectively, were 92 percent, 89 percent and 75 percent (for example, 75 percent of necrotic teeth did not respond to EPT). Positive predictive values for the three tests, respectively, were 93 percent, 90 percent and 83 percent (for example, 83 percent of teeth that responded to EPT were vital). Negative predictive values for the three tests, respectively, were 74 percent, 73 percent and 87 percent (for example, 87 percent of teeth that did not respond to EPT were necrotic).

The table shows that two diagnostic test combinations composed 75 percent of the eight possible test combinations. A total of 42 percent of teeth responded positively to all three tests; of these teeth, 97 percent were vital. A total of 33 percent of teeth responded negatively to all three tests, and of these teeth, 90 percent were necrotic. Of the remaining teeth (25 percent), 54 percent were vital and 46 percent were necrotic.

DISCUSSION

We designed this clinical study to assess the validity of three commonly used pulpal vitality tests. Our findings suggest that, when used to evaluate pulpal vitality before accessing a tooth, EPT in combination with CO₂ or Endo-Ice spray provides more accurate results than does any of the tests alone. However, EPT helps determine pulpal vitality or necrosis rather than the histologic condition of the pulp, but even necrotic pulp occasionally evinces painful responses. Furthermore, no clinical sign or symptom designates the histopathologic status of the pulp with certainty.

Our findings suggest that both CO₂ and EPT or Endo-Ice and EPT testing should be used to obtain more accurate results for evaluation of pulpal vitality. For example, only 83 percent of teeth responding positively to EPT alone were vital, compared with 97 percent when both EPT and the cold tests were used. In our study, there was no significant difference in the accuracy of

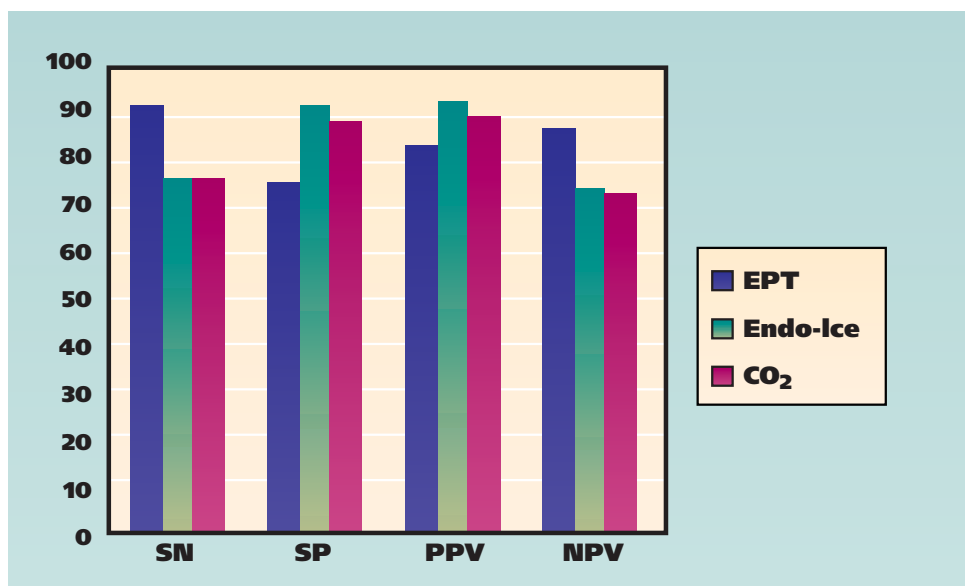


Figure. Characteristics of individual diagnostic tests (N = 150). EPT: Electrical pulp tester. Endo-Ice: Hygenic Endo-Ice Green, Coltène Whaledent, Cuyahoga Falls, Ohio. CO₂: Carbon dioxide. SN: Sensitivity (the percentage of all vital teeth that tested positive on the diagnostic test). SP: Specificity (the percentage of all necrotic teeth that tested negative on the diagnostic test). PPV: Positive predictive value (the percentage of all teeth testing positive on the diagnostic test that were vital). NPV: Negative predictive value (the percentage of all teeth testing negative on the diagnostic test that were necrotic).

TABLE

Combined predictive ability of diagnostic tests (N = 150).			
TESTING METHOD	NO. (%) OF TEETH	PULP STATUS (%)	
		Vital	Necrotic
EPT,* Endo-Ice,† CO₂‡			
Positive	63 (42)	97	3
Negative	50 (33)	10	90
Other Combinations§	37 (25)	54	46

* EPT: Electrical pulp tester.
 † Endo-Ice: Hygenic Endo-Ice Green, Coltène Whaledent, Cuyahoga Falls, Ohio.
 ‡ CO₂: Carbon dioxide.
 § The authors calculated the sensitivity, specificity and positive and negative predictive values of each test and compared each possible variation of results for the tests combined to describe each test's validity and clinical usefulness. Clinical pulpal status (that is, presence or absence of hemorrhage at access of the pulpal chamber) was the reference standard evaluation.

either Endo-Ice or CO₂ for diagnostic testing. Sensitivity and specificity describe the accuracy of the diagnostic tests when the true status of the teeth is known (that is, they aid in assessing the validity of the diagnostic test). Positive predictive value and negative predictive value describe the accuracy of the diagnostic test when the true status of the teeth is unknown (as would be the situation clinically). For example, 93

percent of the teeth testing positive with Endo-Ice truly were vital, whereas only 83 percent of the teeth testing positive to EPT truly were vital. Our clinical findings were in agreement with those of Fuss and colleagues,⁴ who showed that DDM, CO₂ and EPT tests were equally valid when used to test the pulpal vitality in adult patients.

Our study improves on previously published studies because our sample size of 150 patients is larger than that of other studies; in addition, the pulpal diagnostic tests used in this study are used commonly in clinical practice. For example, in our study, we used Endo-Ice and CO₂ to test the response to cold. Ethyl chloride and ice have been reported to be less reliable by Jones⁹ and by Rickoff and colleagues.¹¹ Augsburger and Peters¹² and Peters and colleagues³ concluded that CO₂ snow produced a statistically greater intrapulpal temperature decrease than did either ice or skin refrigerant. Georgopoulou and Kerani¹³ showed that there is no significant difference in the reliability of any of the methods used.

Petersson and colleagues¹ evaluated the ability of heat (heated gutta-percha), cold (ethyl chloride) and EPT to register pulpal vitality and then calculated the sensitivity, the specificity and the negative and positive predictive values by using direct inspection of the pulpal tissue as a reference standard. Their results indicated an 89 percent probability that a nonsensitive reaction with the cold test represented a necrotic pulp, versus 48 percent with the

heat test and 88 percent with electrical tests. Conversely, the probability that a sensitive reaction represented a vital pulp was 90 percent with the cold test, 83 percent with the heat test and 84 percent with the electrical test. These results agree with our clinical findings because we used pulpally diseased teeth in the evaluation of the pulp-testing agents and, therefore, considered the conditions to resemble the clinical situation in which vitality testing is a necessary diagnostic tool. In 10 percent of teeth that tested negative on all three tests, pulps were not necrotic; thus, even though vitality tests are accurate tests of pulpal status, we still need more precise methods.

CONCLUSION

The results of this study suggest that the use of EPT in combination with one of the commonly used cold pulp tests will provide more accurate results for the evaluation of pulpal vitality than will using one of these methods alone. ■

Disclosure. None of the authors reported any disclosures.

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