Determining predictability and accuracy of thermal and electrical dental pulp tests: An in vivo study

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Abstract

Introduction: Pulp sensitivity testing, even with its limitations and shortcomings, has been and still remains a very helpful aid in endodontic diagnosis. Pulp sensitivity tests extrapolate pulpal health from the sensory response. The aim of the present study was to identify the sensitivity, specificity, positive and negative predictive values (NPVs) of thermal and electrical tests of pulp sensitivity.

Materials and Methods: Pulp tests studied were two cold and heat tests respectively and electrical test. A total of 330 teeth were tested: 198 teeth with vital pulp and 132 teeth with necrotic pulps (disease prevalence of 40%). The ideal standard was established by observing bleeding within the pulp chamber.

Results: Sensitivity values of the diagnostic tests were 0.89 and 0.94 for cold test, 0.84 and 0.87 for the heat tests, and 0.75 for electrical pulp test and the specificity values of the diagnostic tests were 0.91 and 0.93 for the cold tests, 0.86 and 0.84 for the heat tests, and 0.90 for electrical pulp test. The NPVs were 0.91 and 0.96 for the cold tests, 0.89 and 0.91 for the heat tests, and 0.84 for electrical pulp test. The positive predictive values were 0.89 and 0.90 for the cold tests, 0.80 and 0.79 for the heat tests and 0.88 for electrical pulp test. The highest accuracy (0.9393) was observed with cold test (icy spray).

Conclusions: The cold test done with icy spray was the most accurate method for sensitivity testing.

Keywords: Electrical pulp test; predictive value; sensitivity value; specificity value; thermal pulp test

INTRODUCTION

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 application of agents to the teeth to increase or decrease temperature and to stimulate pulp sensory responses through thermal and electrical conduction has been the most commonly used modality for pulp testing.[2,3] In cases where a pulp is suspected to be the source of pain with the patient complaining of pain onset and aggravation by specific thermal triggers, pulp testing agents are useful in identifying the offending tooth.[4,5]

Teeth were investigated according to whether they were true/false negatives (TN, FN where “negative” was defined as the absence of disease) or true/false positives (TP, FP where “positive” was defined as the presence of disease). Sensitivity and specificity describe the results of a procedure in a dichotomous way.[6] The sensitivity of pulp test can be defined as its ability to identify teeth with no pulp or with diseased pulp (sensitivity = TP/[TP + FN]).[7] The specificity of a pulp test is its ability to identify pulps without disease (specificity = TN/[TN + FP]).[7] The positive predictive value (PPV) is defined as the probability that a “positive” result truly represents a tooth with a diseased pulp or with no pulp (PPV = TP/[TP + FP]) and the negative predictive value (NPV) is defined as the probability that a “negative” result truly represents a disease free pulp (NPV = TN/[TN + FN]). Under the same definition, the overall rate of agreement of the test results to the actual
pulp health can be expressed as accuracy (accuracy = [TP + TN]/[TP + TN + FP + FN]).[7]

Therefore, the aim of this study was to identify the sensitivity, specificity, positive and NPVs and accuracy of thermal and electrical pulp tests. The null hypothesis was that there is no difference between sensitivity, specificity, PPVs, and NPVs of thermal (cold and heat) and electrical tests to determine pulp sensitivity.

MATERIALS AND METHODS

This cross-sectional study with institutional ethical clearance registration number as TDC/IRB-EC/40/2013 was performed from June 2013 to June 2014. According to the ethical principles of the Declaration of Helsinki, informed and written consent were obtained from the patients before the clinical tests. A total of 330 subjects without a previous clinical diagnosis of pulp status were examined. The inclusion criteria were as follows: Systemically, healthy patients between 17 and 50 years of either sex who did not have medication for 3 months before the study began. Grossly carious teeth indicated for extraction because of poor prognosis were selected for the study. The exclusion criteria were teeth with full surface crowns, large restorations, recent trauma, regressed pulpal chambers, or calcified root canals and orthodontic treatment.

The endodontic diagnostic tests were performed by a single researcher who was blinded to clinical signs and symptoms, dental histories, and radiographic findings. Each participant was instructed to raise his/her hand at the moment that he/she felt a sensation during testing.

Cold pulpal testing (icy spray)
A clinical researcher sprayed a No. 2 cotton pellet with a refrigerant spray (Butane) (Icy Spay; Detax GmbH and Co. KG, Germany), which was then placed onto the crown of the tooth (at the middle third of the buccal surface) for 18 s or until the participant raised a hand to indicate that he/she felt a cold sensation.[8] A digital infrared thermometer was used to ensure that the temperature used was the same for all the patients (80°C).

Hot pulpal testing (hot ball burnisher)
A red hot burnisher was placed onto crown (at the middle third of the buccal surface) for 60 s. Or till the participant raises his/her hand to indicate that he/she felt a hot sensation. Digital infrared thermometer was used to confirm the temperature used of burnisher (i.e., 60°C).

Ideal standard
The presence (vital pulp) or absence (necrotic pulp) of bleeding from pulp after root canal access opening was used as the reference standard. When vital tissue was observed in the apices but necrotic tissue was observed in the chamber, the condition was partial necrosis of pulp. Since the treatment is the same, the conditions were combined into one group (i.e. necrotic group). Twenty-five endodontically treated teeth were used as negative controls.

Teeth with vital pulp
The results of the tests in teeth with vital pulp were reported (in seconds) as follows: (1) The number of seconds from the application of the stimulus until the participant raised a hand was defined as the first time (FT) evaluation for cold and heat tests, and (2) the number of seconds from removing the stimulus until the absence of the sensation felt during testing was defined as the second time (ST) evaluation. All the subjects of the study were slatd for endodontic treatment followed by extraction because of vital teeth had irreversible pulpitis, and the nonvital teeth had necrotic pulps having a poor prognosis.

Statistical analysis
The TP, FP, TN, and FN responses were identified. Based on these parameters, the sensitivity, specificity, PPV, NPV, accuracy and prevalence were calculated for each test. Correlations (Spearman rho) were calculated between the times of the responses (FT and ST) of the patients (in vital teeth) and the tests. The results were analyzed with Stata statistical software (version 11; StataCorp, College Station, TX, USA).

RESULTS

Three hundred thirty subjects were evaluated. One hundred thirty-two pulps were classified as necrotic (no bleeding), and 198 pulps were classified as vital (bleeding from pulp).
The cold test by icy spray identified most teeth with necrotic pulps as necrotic i.e TPs (125 of 132), and the remaining teeth had sensitive responses suggestive of FNs (7 of 132).

The electrical test identified least teeth with necrotic pulps as nonsensitive i.e TPs (100 of 132) and most teeth as sensitive i.e FNs (32 of 132) as shown in Table 1.

All 198 teeth that had clinically vital pulp (TNs) showed sensitive responses with all of the tests (cold, hot, and electrical). The sensitivity, specificity, positive, and NPVs and accuracy are shown in Table 2.

The highest values were observed when comparing the ideal standard with the cold test done by icy spray\(^*\) i.e., 94% of the teeth with necrotic pulp were identified as necrotic, whereas 93% of the teeth with vital pulp were identified as vital. There was a probability of 90% that no sensitive reactions represented necrotic pulp, and 96% of vital pulps had reactions observed with the cold test. The accuracy was 91% for cold test by ice stick and 94% for cold test by icy spray.

The results of the tests (in seconds) in teeth with vital pulp are shown in Table 3. The fastest FT response was observed with the cold test done by icy spray\(^*\) (3.3 ± 2.8), and the fastest ST was observed with heat test done by ball burnisher\(^*\) (5.8 ± 4.3).

**DISCUSSION**

When predictive positive and negative values are estimated, the prevalence of the disease must be considered because the predictive values (PPV and NPV) vary according to the prevalence of the disease\(^{1,6}\) and to compare predictive values from different studies, it is necessary to have the same prevalence.

**Comparison of predictive values**

The predictive values in this study were based on a prevalence of 40%. Weisleder et al. 2009 also reported predictive values, used a disease prevalence of 30% for their calculations and reported PPV of 0.93 and 0.83, whereas NPV of 0.74 and 0.87 for the cold test and electric pulp test (EPT) respectively.\(^{18}\) In a study done by Villa-Chávez et al. 2013, the NPV was 0.90 for the cold test, 0.89 for the heat test, and 0.83 for the electrical test, and the PPV was 1.0 for all three tests with the prevalence of 45%.\(^{16}\) In our study, PPVs were 0.89 and 0.90 for the cold test using ice stick and icy spray, respectively, 0.80 and 0.79 for the heat test using hot gutta-percha and hot burnisher, and 0.88 for electrical pulp test whereas The NPVs were 0.91 and 0.96 for the cold test using ice stick and icy spray respectively, 0.89 and 0.91 for the heat test using hot gutta-percha and hot burnisher, and 0.84 for electrical pulp test.

### Table 1: True positive and false negative value for necrotic teeth

| Testing methods               | True positive (n=132) | False negative (n=132) |
|------------------------------|------------------------|------------------------|
| Ice sticks                   | 118                    | 14                     |
| Icy spray                    | 125*                   | 7                      |
| Hot gutta-percha             | 112                    | 20                     |
| Hot burnisher                | 115                    | 17                     |
| Electrical pulp test         | 100*                   | 32                     |

*Highest true positive value, *Lowest true positive value

### Table 2: Sensitivity, specificity, positive predictive value, negative predictive value and accuracy

| Comparison between test        | Sensitivity | Specificity | PPV  | NPV   |
|-------------------------------|-------------|-------------|------|-------|
| Ideal test versus ice sticks  | 0.89        | 0.91        | 0.89 | 0.91  |
| Ideal test versus icy spray   | 0.94*       | 0.93        | 0.93 | 0.96  |
| Ideal test versus hot gutta-percha | 0.84   | 0.86        | 0.80 | 0.89  |
| Ideal test versus hot burnisher| 0.87       | 0.84        | 0.79 | 0.91  |
| Ideal test versus electrical pulp test | 0.75 | 0.90        | 0.88 | 0.84  |

*Highest sensitivity value. PPV: Positive predictive value, NPV: Negative predictive value

### Table 3: Results of the tests in teeth with vital pulp

| Time (s) | Mean±SD | Electrical pulp test |
|----------|---------|----------------------|
| Cold test by icy spray | 3.3±2.8* | Cold test by ice stick |
| Hottest by gutta-percha | 4.8±2.1 | Hottest by burnisher |
| Hottest by icy spray | 5.8±4.3* | - |

*Fastest FT, *Fastest ST. FT: First time, SD: Standard deviation, ST: Second time

### False-positives and negatives

In the present study, we observed ninety FNs responses in teeth with necrotic pulp; the cold test by ice stick identified 28% (n = 14) whereas icy spray identified 14% (n = 7), and the hot pulp testing identified as 40% (n = 20) and 34% (n = 17) by gutta-percha and ball burnisher respectively. The electrical pulp testing identified 64% (n = 32 responses). Different explanations have been proposed for FN results. For example, these responses might be caused by conduction of the current to the adjacent gingival or periodontal tissues. Canal moisture from putrescent pulp (also called moist gangrene) or the presence of inflamed pulp tissue in partially necrotic, infected pulp may be a factor. Furthermore, the breakdown products associated with localized necrosis conduct electrical current to adjacent inflamed pulp tissue. A calcified tooth structure might also be capable of conducting electrical current to tissue apical to an area of pulp necrosis. Furthermore, a multi-rooted tooth might have inflamed pulp tissue in one canal, whereas the pulp chamber and other canals might be necrotic and infected. Finally, pulp sensitivity tests rely on the patient’s response; therefore, a false response might occur in anxious or young patients.

### Accuracy

The most accurate test was the cold test done using icy spray (0.9393) and ice stick (0.9060), followed by heat test done using gutta-percha, hot ball burnisher (0.8575) and electric pulp testing (0.8484).
In this study, the stimulus was placed on the middle third of the buccal surface however it has been reported that thermal test and EPT are considered to be more accurate at cervical region because of thinnest enamel surface.[10]

The following strategies were used to prevent bias: (1) Thermal and electrical tests were compared with an ideal standard; (2) the comparisons of all tests were conducted by a single researcher; (3) the location and duration of the stimulus were the same in all of the tests; (4) an infrared sensor was used to monitor the temperature in the thermal test and to ensure the temperature during application of the test; (5) the presence and absence of disease were defined; and (6) in the present study, the researcher allowed at least 5 min to elapse after each pulp test. It has been reported in an in vitro study that at least 2 min are required for pulpal border of the dentin to return to its normal temperature after the application of thermal stimuli.[7,11]

CONCLUSIONS

Diagnosis is often as much an art as it is a science. Clinician’s must combine the results of their clinical examination, radiographic findings, reported dental history, and clinical experience to arrive at an accurate diagnosis. The results showed that the probability that a sensitive reaction represented a vital pulp was highest with cold test by icy spray followed by ice sticks, hot ball burnisher and hot gutta-percha and least with electric pulp testing.

Correct application of pulp test in the appropriate clinical situation is important as not all pulp testing agents are suitable for all clinical situations. Furthermore, a combination of pulp vitality tests will provide more accurate results for the evaluation of pulpal vitality.

With the advancement in diagnostic science and tools, pulp sensitivity testing will always remain as a gold standard.

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Conflicts of interest
There are no conflicts of interest.

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