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The ability of pulp sensibility tests to evaluate the pulp status in primary teeth

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Background. Accurate determination of the pulp status is the most important part of conservative pulp therapy.

Aim. The aim of this study was to assess the ability of thermal and electrical pulp tests to assess the pulp status in primary teeth.

Design. Seventy-eight primary molar teeth in 36 children were investigated. Fifty-six teeth had unknown pulp status in need of endodontic treatment, and 22 were intact teeth with no signs of pulp disease. Cold, hot and electrical pulp testing (EPT) were performed on each tooth. The gold standard was established by direct inspection of the pulp after an access cavity had been made. The sensitivity, specificity, positive and negative predictive values for each test and different sequential combinations of pulp testing were calculated. Sequential combination test analysis was used for data analysis.

Results. The highest accuracy was found for EPT, followed by heat and cold tests. No significant difference was found between the accuracy of EPT and the heat test (P-values > 0.05); however, the accuracy of EPT was significantly higher than that of the cold test (P-value < 0.05).

Conclusion. Based on this study, EPT can be used as a reliable test for diagnosing the pulp status in primary teeth.

Introduction

Accurate determination of the pulp status is the most important part of diagnosis in endodontics. A combination of the patient's history as well as pulp sensibility tests and radiographic images leads a dentist to diagnose the pulp status which then determines the treatment options[1].

Despite some technical shortcomings of pulp sensibility tests, these tests are widely employed to assess the pulp status in permanent teeth, and they are considered to be an important part of clinical endodontic procedures[2,3]. There is, however, little information to suggest that pulp testing of primary teeth is equally useful[4].

Recent recommendations on the benefits of indirect pulp treatment in primary teeth make the importance of pulp diagnosis in paediatric dentistry very critical[5]. Currently, there is a lack of evidence-based investigations about pulp tests in primary teeth even though it is essential for clinicians to know the status of the pulp before determining a treatment plan for their patients. In addition, determination of the pulp status as part of the post-traumatic injury assessment of primary teeth may affect the management of traumatized teeth[6].

A review of the literature from 1965 to October 2010 revealed only one investigation about the reliability of pulp sensibility testing in primary teeth. Asfour *et al.*[4] used primary maxillary canines for pulp testing with ethyl chloride and an electrical pulp tester (EPT). They suggested that pulp testing was valid in primary teeth but they did not report the sensitivity, specificity, positive and negative predictive values (NPV) of these tests. Therefore, the purpose of this investigation was to compare the sensitivity, specificity, positive and NPVs of different pulp sensibility tests in primary teeth by comparing the test results

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with the clinical findings noted after preparing an endodontic access cavity.

Material and methods

This study was approved by the Ethics Committee of Kerman University of Medical Sciences (KA/88–15). Informed consent for all subjects who participated in this study was obtained from their parents after the nature of the procedures and the possible discomforts and risks had been fully explained.

Inclusion and exclusion criteria

Children with medical conditions or behavioural problems were not included in the study. Patients with no systemic disorders and who had carious primary molar teeth in need of conservative pulp therapy were included in this investigation. Additional criteria for inclusion included the following: the teeth were in normal furcation, had normal periapical bone structure, no root resorption or less than one-third of the root with physiological resorption evident on a periapical radiograph.

Pulp sensibility tests

All patients were children aged between 6 and 8 years, and they were treated in the postgraduate clinic of the Pediatric Department of the Kerman Dental School in Iran from May 2009 to March 2010. Each child was instructed to raise his or her hand at the moment he or she felt a cold, tingling or uncomfortable sensation during the pulp testing. The cold test involved spraying EndoFrost (Roeko EndoFrost; Coltene Whaledent, Langenau, Germany) on a size 2 cotton pellet. The cotton pellet was held in the spray until a frosty appearance was observed on its surface, and then, it was applied to the middle third of the buccal surface of the primary molar that was being tested. The cotton pellet was left in contact with the teeth either for 10 s or until the child raised a hand to indicate that a sensation had been felt. Care was taken to avoid contacting the gingivae or the adjacent teeth. When conducting the heat test, a thin layer of lubricant was placed on the tooth surface, and then, a heated gutta-percha stick was applied to the surface of the tooth. To use the EPT, the teeth were isolated with cotton rolls and dried with cotton gauze. An Analytic Technology digital pulp tester (Sybron Endo, Vitality Scanner model 2006; Kerr Italia, Glendora, CA, USA) was used in accordance with the manufacturer's instructions. A drop of toothpaste (Darugar, Tehran, Iran) was used as the conducting medium. Teeth that responded to the EPT at a level lower than 80 were considered to have a normal pulp response.

On completion of each pulp test, an interval of 2 min was allowed so that pulp could return to its normal condition before being tested again. The order of employing pulp test was selected by randomized selection. All thermal tests and the EPT electrode were applied at the middle third of the crown.

The 'gold standard' for the pulp status was established by direct inspection of the presence or absence of bleeding in the teeth that required pulp treatment after an access cavity had been made. Teeth with partially necrotic pulps were considered to be necrotic. In all of the non-carious intact teeth, the pulp was judged to be clinically normal. Intact teeth with no caries were selected where panoramic radiographs were required for orthodontic reasons.

The sensitivity, specificity, positive and NPVs based on clinical visual examination of the access cavity for each test and different combinations of pulp testing were calculated (Table 1). The 95% confidence intervals for each indicator were calculated by exact binomial distribution in STATA v.10., STATA Corp., College Station, TX, USA.

Results

In this study, 78 primary first and second molar teeth in 36 children were investigated.

Table 1. Variables and corresponding calculation formula.

Tests	Formula
Sensitivity	$TP/(TP + FN) \times 100$
Specificity	$TN/(TN + FP) \times 100$
Positive predictive value	$TP/(TP + FP)$
Negative predictive value	$TN/(TN + FN)$
Accuracy	$(TP + TN)/(TP + FP + FN + TN)$

TN, true negative; TP, true positive; FP, false positive; FN, false negative.

Fifty-six teeth had an unknown pulp status but were in need of endodontic treatment, while 22 teeth were sound intact teeth. One of the patient's results for heat and EPT were excluded from the study because he did not cooperate while these tests were being performed on his teeth. Therefore, the number of tested teeth for cold was 56, whereas 55 teeth were evaluated for heat and EPT tests.

Amongst the 22 sound intact teeth, there were some negative responses to EPT, cold and heat tests – 4.54%, 22.72% and 27.27%, respectively, of this group.

In the carious teeth, the highest true negative condition was recorded for EPT followed by the heat and cold tests, respectively (Table 2). Sensitivity for EPT, cold and heat tests was 80% [confidence interval (CI) 95%: 51.9–95.7], 73.3% (CI 95%:44.9–92.2) and 86.7% (CI 95%: 59.5–98.3), respectively. Specificity for EPT, cold and heat test was 92.5% (CI 95%:79.6–98.4), 75% (CI 95%: 58.8–87.3) and 70.7% (CI 95%: 54.5–83.9), respectively (Table 3). The highest accuracy rate was calculated for EPT, followed by the heat and the cold tests (Table 3).

Table 4 shows three diagnostic test combinations. A total of 84.6% of the primary teeth responded positively to all three tests. Of these, 92.4% were noted to have bleeding pulps after access cavity preparation. There were 15.4% of the teeth that had no reaction to the pulp tests, and 83.3% of these were necrotic upon visual inspection of the exposed pulps.

No significant association was found between the accuracy of the EPT and the heat test (P-values > 0.05). The accuracy of the EPT was, however, significantly higher than that of the cold test (P-value < 0.05). There was no significance difference in the accuracy of the different diagnostic test combinations (P > 0.05).

Discussion

This study was carried out to evaluate the validity of common pulp diagnostic tests in primary teeth. Results showed that the

Table 2. Results of diagnostic sensibility tests and visual inspection following access cavity preparation.

	Cold test		Heat test		Electric pulp test	
Tests	**+**	**–**	**+**	**–**	**+**	**–**
Visual inspections						
Presence of bleeding (D–)	29 (TN)	12 (FP)	30 (TN)	10 (FP)	37 (TN)	3 (FP)
Absence of Bleeding (D+)	4 (FN)	11 (TP)	2 (FN)	13 (TP)	3 (FN)	12 (TP)

TN, true negative; TP, true positive; FP, false positive; FN, false negative; D–, no presence of disease; D+, presence of disease.

Table 3. Diagnostic sensibility test results following calculation of the variables.

Variables	Sensitivity (CI 95%)	Specificity (CI 95%)	PPV (CI 95%)	NPV (CI 95%)	Accuracy
Tests					
Cold	73.3% (44.9–92.2)	70.7% (54.5–83.9)	47.8% (26.8–69.4)	87.9% (71.8–96.6)	0.714
Electrical pulp testing	80% (51.9–95.7)	92.5% (79.6–98.4)	80% (51.9–95.7)	92.5% (79.6–98.4)	0.891
Heat	86.7% (59.5–98.3)	75% (58.8–87.3)	56.5% (34.5–76.8)	93.8% (79.2–99.2)	0.782

CI, confidence interval; PPV, positive predictive value; NPV, negative predictive value.

Table 4. Characteristics of the variables after calculating combinations of the sensibility tests.

Characteristics	Sensitivity (CI 95%)	Specificity (CI 95%)	PPV (CI 95%)	NPV (CI 95%)	Roc area (CI 95%)
Test combinations					
CCWE*	66.7% (38.4–88.2)	97.6% (87.1–99.9)	90.9% (58.7–99.8)	88.9% (75.9–96.3)	0.821 (0.695–0.974)
CCWZ†	66.7% (38.4–88.2)	82.9% (67.9–92.8)	58.8% (32.9–81.6)	87.2% (72.6–95.7)	0.748 (0.611–0.885)
CCE‡	73.3% (44.9–92.2)	97.6% (87.1–99.9)	91.7% (61.5–99.8)	90.9% (78.3–97.5)	0.854 (0.736–0.973)
CWE§	73.3% (44.9–92.2)	92.7% (80.1–98.5)	78.6% (49.2–95.3)	90.5% (77.4–97.3)	0.830 (0.707–0.953)

PPV, Positive predictive value; NPV, negative predictive value; *Combination of cold, warm tests and electrical pulp testing (EPT); †Combination of cold and warm tests; ‡Combination of cold test and EPT; §Combination of warm test and EPT; Confidence interval; Roc area = Sensitivity × Specificity/2.

specificity of EPT is higher than that of cold and heat tests for primary molar teeth. In the present study, all primary teeth were dried with gauze prior to EPT usage. Air blasts were not used because this could have evoked pain in teeth with hypersensitive dentine[7].

In the present study, no significant difference was found between the accuracy of EPT and that of the heat test (P-values > 0.05). The accuracy of the EPT was, however, significantly higher than that of the cold test (P-value < 0.05). In contrast, Asfour *et al.*[4] reported that the difference in response rate between EPT and cold test (ethyl chloride) in intact sound primary teeth was not statistically significant. The difference between the methods of evaluation may be the reason for disagreement between the results of these studies. Asfour *et al.*[4] used intact primary maxillary canine teeth with no or little sign of root resorption, and they employed a visual analogue scale for the evaluation of the responses of the participants. In the present study, carious primary teeth were used, and direct inspection of the pulp was employed as the gold standard of pulp diagnosis in primary teeth with carious lesions, while intact teeth served as controls. Most previous investigations have used similar methods for evaluating pulp sensibility to diagnostic tests[8–10].

Petersson *et al.*[8] evaluated the ability of thermal tests and EPT to identify the pulp sensibility status in permanent teeth. They calculated the sensitivity, specificity, positive and NPVs. They reported that the overall agreements between the diagnostic tests and the gold standard (direct pulp inspection) were 86%, 71% and 81% for the cold test, the heat test and EPT, respectively. In their study, the highest accuracy was found with the cold test followed by the EPT and heat test, respectively. In contrast, the present study showed that the highest accuracy was obtained with the EPT followed by the heat test and the cold test (Table 3).

Sensitivity of a diagnostic test is defined as the ability of the test to detect disease in a patient who actually has that disease, whereas the specificity of a test is defined as the ability to diagnose the absence of disease[2]. As a response to a pulp sensibility test represents a clinically normal pulp and the absence of necrosis, the absence of a response to the sensibility test is assumed to indicate the presence of disease.

In the present study, the sensitivity for the EPT, cold and heat tests was 80% (CI: 51.9–95%), 73.3% (CI: 44.9–92.2%) and 86.7% (CI: 59.9–98.3%), respectively. This means that 73.3% of the primary teeth with necrotic pulps were identified as being necrotic by the cold test, while 86.7% were identified by the heat test and 80% by the EPT (Table 3). In the present study, the specificity for the EPT, cold and heat tests was 92.5% (CI: 79.6–98.4%), 70.7% (CI: 54.5–83.9%) and 75% (CI: 58.8–87.3%), respectively. This means that 70.7% of primary teeth without a necrotic pulp were identified as being clinically normal by the cold test, while 75% were identified by the heat test and 92.5% by the EPT (Table 3). Taken together, it appears that the sensitivity of the heat test and the specificity of the EPT were the highest amongst the sensibility tests used in the present study.

The positive predictive value (PPV) represents a test result that shows the diseased condition of a tooth when it is truly diseased. In the current study, the PPV for the cold test, heat test and EPT was 0.478, 0.565 and 0.80, respectively. Thus, there was a probability of 47.8% that no response to the cold test represented a necrotic pulp, while there was a 56.5% probability with the heat test and 80% with the EPT (Table 3).

The NPV represents a test result that correctly shows the tooth to be free from disease[2]. In the present study, the NPV for the cold test, the heat test and the EPT was 0.879, 0.938 and 0.925 respectively. Thus, there was a probability of 87.9% that a response represented a clinically normal pulp when the cold test was used, with a probability of 93.8% with the heat test and 92.5% with the EPT (Table 3). The PPV is more dependent on specificity, whereas the NPV is more responsive to sensitivity[2]. Based on PPV and NPV in the present study, the EPT showed the most reliable results followed by the heat and cold tests.

In the current study, there was no significance difference in the accuracy of the various diagnostic tests combinations. This finding is in

contrast to the results reported by Weisleder *et al.*[9], who found that the use of the EPT in combination with one of the commonly used cold pulp tests (CO_2, Endo Ice) provided more accurate results for the evaluation of the pulp status compared with using only one of the tests. The difference between the types of teeth may be a reason for the conflicting results of the two studies. In the present study, primary teeth were evaluated whereas Weisleder *et al.*[9] tested permanent teeth.

The results of the current study regarding intact sound teeth and their responses to the pulp sensibility tests showed higher responses to EPT in comparison with the heat and cold tests.

In this study, the testing agents were applied on each tooth at intervals of 2 min. Previous investigations used the same interval when comparing various pulp sensibility tests[7,9,11,12].

A size 2 cotton pellet was used for the cold test because a previous investigation reported that this size of cotton pellet can produce lower temperatures than other carriers[13].

Evaluating the length of pulp bleeding time after access cavity preparation in primary teeth can be used to differentiate reversible pulpitis from irreversible pulp status. A drawback for the present study was not evaluating pulp bleeding time after access cavity preparation.

Conclusions

The EPT alone was useful for determining the pulp status in primary teeth. The accuracy of the EPT was higher than that of either of the thermal tests as well as that of the combinations of these three diagnostic tests.

What this paper adds

- This investigation showed reliability of sensibility tests to determine pulp status in primary teeth.

Why this paper is important to paediatric dentists

- Paediatric dentists should be aware of which diagnostic test(s) is (are) more reliable in determining pulp status in primary teeth.
- Information regarding pulp status may help dentists to provide a more reasonable treatment plan and to determine prognosis before starting treatment in carious primary teeth.

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