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Efficacy of Different Thermal Tests on Accessing the Vitality through Pulp Sensibility Tests: An In-Vivo Study

Allwyn Vincent T [1*] , Paluvary Sharath Kumar [2],Jayashankara CM[3], Mujahid ahmed[4], Anand gowda[5],Prithvi Raj T[6]

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ABSTRACT
Introduction: Despite its limits and drawbacks, pulp sensitivity testing has been and continues to be a highly useful aid in endodontic diagnosis. Pulp sensitivity tests use sensory responses to predict pulpal health. The purpose of this study was to determine the sensitivity, specificity, positive and negative predictive values (NPVs) of thermal and electrical pulp sensitivity tests.
Materials and Methods: Pulp tests studied were two cold and heat tests respectively and electrical test. A total of 165 teeth were tested: 99 teeth with vital pulp and 66 teeth with necrotic pulps (disease prevalence of 40%). The gold standard was established by observing bleeding within the pulp chamber.
Results: Sensitivity values of the diagnostic tests for cold test showed maximum values compared to heat tests followed by electrical pulp test in this present study and the specificity values of the diagnostic tests were 0.90 and 0.92 for the cold tests, compared to heat testsand electrical pulp test. Even the NPV and PPV for the cold tests are 0.90,0.95 and 0.88,0.89 respectively. NPV and PPV value for the heat test are 0.88,0.90 and 0.79,0.79 respectively.The highest accuracy (93%) 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

I. INTRODUCTION

Dental pulp vitality testing is an important and necessary diagnostic aid in endodontics since diagnosis is an important part of treatment planning. [1]. The gold standard for assessing the vitality condition of pulp is histological section examination. However, because the pulp is surrounded by a calcified barrier, this cannot be done before beginning endodontic therapy [2].

When the pain presentation is inconsistent and atypical, with the possibility of referred or nonodontogenic pain, pulp testing, as a confirmation or exclusion method, can aid in accurate diagnosis. Intra-pulp pressure changes have a considerable impact on sensory nerves of various dimensions, with pressure rises preferentially blocking larger diameter A-delta fibres and activating smaller diameter C-fibers. Because C-fibers are more resistant to hypoxia, they may continue to function even when the pulp degenerates as a result of the underlying disease. Pulp necrosis is likely to have progressed when there is no response to stimulation. It should also be noted that the subjective nature of pain, individual diversity in pain threshold, and pain modulation mechanisms make obtaining a precise history of clinical symptoms challenging [1,3].Because the pulp tissue cannot be physically viewed, indirect methods such as pulp sensibility tests must be used to identify the state of pulpal health by examining the condition of the nerve response within the tooth pulp but not the vascular system, which is stated s more reliable means of evaluating pulp vitality status.

The most common pulp sensibility tests are thermal and electrical tests that stimulate the pulpal nerves either by varying the flow of dentinal fluid, which causes movement of the odontoblast processes and thus mechanical stimulation of the pulpal nerves, or by conducting an electrical current through the tooth, which causes electrical stimulation of the pulpal nerves. [4,5]

No one component of the diagnostic process should be depended on to make even the most straightforward diagnosis. As a result, the illness process should be indicated by two independent diagnostic test results that correlate. Thermal tests stimulate hydrodynamic fluid movement within dentinal tubules, which excites A- fibers.[6] These tests do not activate nonmyelinated C-fibers unless they cause pulp injury.[7] Thus, the patient's pain feeling necessitates certain important pulp tissue, including odontoblasts, for the function of the hydrodynamic mechanism.[8] The electric pulp tester generates enough current to overcome the resistance of enamel and dentin and excite the A- fibres. Cfibers do not respond to ordinary EPTs because

they require substantially higher current to stimulate.[9]

A positive response to the EPT is caused by an ionic shift in the dentinal tubules, which causes local depolarization and the formation of an action potential from an intact nerve.[10] To characterise test accuracy and to illustrate the advantage of test usage, the concepts of sensitivity, specificity, positive and negative predictive values have been developed.[11] Because the calculations are based on a comparison of the test findings and the genuine disease status, determining this true condition has become a significant aspect of the pulp status evaluation.[12,13] The availability of gold standardsusually determines the accuracy rate of any diagnostic test.[14]

The aim of the present study was to evaluate the ability of thermal and electrical test to register pulp vitality and to determine the performance of each test through calculation of the sensitivity, the specificity and the predictive values by comparing the test results with the gold standard.

II. MATERIALS AND METHODOLOGY

Informed and written consent were obtained from the patients before the clinical tests. A total of 165 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 (1,1,1,2-tetrafluoro - ethane) (endo ice green 6 oz h05032 by bndhygeniccoltene/whaledentinc. by endo ice, 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 of the patients (−50°C).

Cold pulpal testing (ice sticks)

Ice sticks (7 mm) were prepared by filling 2 ml. Anestheticcarpules with water and placing them in the refrigerator which was later wrapped in a wet gauze and applied onto crown (at the middle third of the buccal surface) of teeth.

Hot pulpal testing (hot gutta-percha)

A heated gutta-percha rod was 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 warm sensation. A digital infrared thermometer to ensure that the temperature used was the same for all the patients (80°C).

Hot pulpal testing (hot ball burnisher)

A red hot ball 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).

Electric pulp testing

Electric pulp tester (Denjoy, Foshan CAN Dental Equipments Co., Ltd., China) is used to apply an electrical impulse to the crown of the tooth (at the middle third of the buccal surface). Tooth with a response of level lower than 70 will be considered vital.

gold standard method

The gold standard (the facet of the pulp status) was detected by 137 teeth in need of endodontic treatment. After pulp testing procedure, access opening was used as the reference standardthe pulp chambers were opened and the pulp status registered as either vital or necrotic by direct visual inspection (bleeding or no bleeding). Partial necrosis was considered necrotic (non-vital) pulp. The number of true positive (TP), false positive (FP), true negative (TN) and false negative (FN) test results was calculated for each method.

Statistical analysis

Specificity, sensitivity and positive and negative predictive values have been obtained to characterize test accuracy and to describe the benefits of test usage. (table1)

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		Condition as determined by gold standard		
		Clinically normal pulp	Necrotic or pulpless tooth	
Test outcome	Positive	True positive(TP)	False positive (FP)	⇨ Positive predictive value [TP/(TP+FP)]
	Negative	False negative (FN)	True negative (TN)	⇨ Negative predictive value [TN/(TN+FN)]
		⇩ Sensitivity [TP/(TP+FN)]	⇩ Specificity	Accuracy [(TP+TN)/(TP +TN+FP+FN)]

Table -1. Definition of sensitivity specificity positive and negative predictive value, and accuracy

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).

III. RESULTS

One hundred sixty five subjects were evaluated. Sixty six were classified as necrotic (no bleeding), and ninety nine 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 (62 of 66), and the remaining teeth had sensitive responses suggestive of FNs (4 of 66).

The electrical test identified least teeth with necrotic pulps as nonsensitivei.e TPs (50 of 66) and most teeth as sensitive i.e FNs (16 of 66) as shown in (table-2).

Table 2: True positive and false negative value for necrotic teeth.

Testing methods	True positive(n=66)	False negative(n=66)
Ice sticks	59	7
Ice spray	62	4
Hot gutta-percha	56	10
Hot burnisher	57	9
Electrical pulp test	50	16

All 99 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].{Table 2}

Test	Sensitivity	Specificity	PPV	NPV	Accuracy
Ice sticks	0.89	0.91	0.88	0.90	90%
Ice spray	0.93	0.92	0.89	0.95	93%
Hot gutta-percha	0.84	0.86	0.79	0.88	87%
Hot burnisher	0.86	0.84	0.79	0.90	85%
Electrical pulp test	0.75	0.90	0.87	0.82	84%

The highest values were observed when comparing the ideal standard with the cold test done by ice spray* i.e., 93% of the teeth with necrotic pulp were identified as necrotic, whereas 92% of the teeth with vital pulp were identified as vital. There was a probability of 89% that no sensitive reactions represented necrotic pulp, and 95% of vital pulps had reactions observed with the

cold test. The accuracy was 90% for cold test by ice stick and 93% for cold test by icy spray.

IV. DISCUSSION

It is widely acknowledged that clinical tests are utilised to determine the pulp state practically. The utilisation of numerous experiments, which can be carried out rapidly and affordably, is one method for reducing uncertainty. A perfect diagnostic test would always result in a positive result when a disease is present and a negative result when a disease is absent. The tendency for repeated measurements on the same sample to provide the same findings is known as precession in a test. To describe test accuracy and calculate the advantages of test usage, the concepts of sensitivity, specificity, and positive and negative predictive values have been devised.

Because the calculations are based on a comparison of test findings and "true" disease status, determining this "true" disease status is an important aspect of the evaluations. The term "gold standards" typically refers to a definitive diagnostic of the pulp state following access cavity (bleeding or not). Many studies on pulp vitality (sensibility) testing have dealt with the test's precession; nevertheless, the amount to which a test properly identifies situations "accuracy" has been understudied.[15] The purpose of this study was to determine the accuracy of five regularly used vitality testing agents i.e. pulp sensibility by determining their sensitivity, specificity, and predictive values and accuracy.

The gold standard for the tested teeth was determined by direct examination of the pulp tissue after opening the pulp chamber. If the pulp chamber included degraded, non-bleeding tissue, the pulp was considered necrotic.

Fuss and colleagues[16] investigated the precision of EPT, CO2 snow, DDM, ethyl chloride, and ice. They presented the test specificities and sensitivities but did not calculate predictive values. When the true status of the teeth is known, sensitivity and specificity characterise the accuracy of the diagnostic tests.

Comparison of predictive values

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.[17] 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%.[18] In our study, PPVs were 0.88 and 0.89 for the cold test using ice stick and icy spray, respectively, 0.79 and 0.79 for the heat test using hot gutta-percha and hot burnisher, and 0.87 for electrical pulp test whereas The NPVs were 0.90 and 0.95 for the cold test using ice stick and icy spray respectively, 0.88 and 0.90 for the heat test using hot gutta-percha and hot burnisher, and 0.82 for electrical pulp test.

False-positives and negatives

False negative results could be induced by current conduction to nearby gingival or periodontal tissues. Moisture in the canal from putrescent pulp (also known as moist gangrene) or the presence of inflamed pulp tissue in partially necrotic, infected pulp may be a problem. Furthermore, the breakdown products of localised necrosis transfer electrical current to nearby inflammatory pulp tissue. A calcified tooth structure could also transfer electrical current to tissue apical to a pulp necrosis location. A multi-rooted tooth may also have inflammatory pulp tissue in one canal while the pulp chamber and other canals are necrotic and diseased. Finally, because pulp sensitivity tests rely on the patient's response, a false response may occur in worried or stressed/ anxious patients.

When temperature variations are more dramatic, thermal stimulation causes more fast and stronger fluid flow within the dentinal tubules, activating receptors and rousing A-□ fibers.[19,20]20,21. Gradual temperature changes, on the other hand, do not create a fast reaction but will eventually produce a response by C fibers.[19,21]20,22. Cold uses as suggested have not been shown to produce pulpal or hard tissue damage at these temperatures.[22] Cold testing have been demonstrated in certain studies to produce pulp degeneration if tissue freezing occurs.[23,24] However, freezing has only been demonstrated when a cold probe maintains a temperature of less than -10°C for 5-20 minutes.The response to a cold test requires more live tissue in the coronal aspect of the tooth than a response to an EPT. Shabahang.[25] discovered that, because thermal tests are not 100% accurate, an EPT is especially useful for confirming a questionable diagnosis; however, the cold test should be used in conjunction with the EPT so that the results of one test can verify the findings of the other.

Accuracy

The most accurate test was the cold test done using icy spray (93%) and ice stick (90%), followed by heat test done using gutta-

percha(87%), hot ball burnisher (85%) and electric pulp testing (84%).

In the present 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.[19]

V. CONCLUSION

Diagnosis is frequently an art as much as a science. To arrive at an accurate diagnosis, clinicians must integrate the results of their clinical examination, radiographic findings, recorded dental history, and clinical experience. The results showed that the cold test by icy spray had the highest likelihood of representing a vital pulp, followed by ice sticks, hot ball burnisher, and hot gutta-percha, and the least with electric pulp testing. Furthermore, combining pulp vitality tests will yield more precise findings for determining pulpal vitality. Pulp sensitivity testing will always be the gold standard, despite advances in diagnostic knowledge and technologies.

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