THE EFFICACY OF THERMAL AND ELECTRICAL TESTS TO REGISTER PULP VITALITY

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Abstract

The present study was conducted to evaluate the ability of thermal (green endo ice and endo ice F) and electrical tests to register pulp vitality.

One hundred and thirty seven teeth with unknown pulp status was used in this study, ninety seven teeth were with vital pulp. Sensitivity, specificity, negative and positive predictive values were calculated.

The sensitivity of Green endo ice was 0.99, whereas for endo ice F it was 0.69 and 0.96 for electrical pulp tester. The predictive value for sensitive reaction representing a vital pulp was 99% with green endo ice, and only 70 % for endo ice F and 88% for electrical pulp testing.

Green endo ice presents the lowest intra pulpal temperature with 99% sensitivity.

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Introduction

The endodontic diagnosis is made on the basis of patient history, clinical observation, radiological examination and diagnostic tests. The primary problem in pulp diagnosis appears to be identifying the symptomatic tooth when the pulp is in an irreversible state with the disease restricted to the pulp canal system[1,2]. Ideally, any method used to assess the state of the dental pulp should be non invasive, painless, reliable, reproducible, standardized, easily performed and inexpensive. A major and essential part in the diagnosis of pulpal disease is the use of pulp sensibility tests. The most popular clinical tests are thermal and electric tests. However, a major limitation of these tests is that they indirectly monitor pulp vitality by measuring pulp nerve responses not the vascular system, which is the reliable means of evaluating pulp vitality status[3-5].

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No single element of the diagnostic process should be relied upon to make even what appear to be an uncomplicated diagnosis. Hence, two independent diagnostic test results that correlate should be used to indicate the disease process. Thermal and electrical pulp tester usually indicates whether there is a neural response from the pulp without indicating the state of health of the pulp. Some authors have reported inconsistencies between pulp symptoms and responses when compared with the histological findings[6,7]. Thermal tests activate hydrodynamic movement of fluid within dentinal tubules, which excite A-ð fibers[8]. The non-myelinated C-fibers are not activated by these tests unless they produce injury to the pulp[9].

Thus the pain sensation the patient experiences requires some vital pulp tissue, including odontoblasts for the function of hydrodynamic mechanism[10].

Electric pulp tester delivers a current sufficient to overcome the resistance of enamel and dentin and stimulate the A- ð fibers. The C-fibers do not respond to the conventional EPTs because significantly more current is needed to stimulate those[11]. A positive response to the EPT is the result of ionic shift in dentinal tubules causing local depolarization and subsequent

generation of action potential from intact nerve[12] The concept of sensitivity, specificity, positive and negative predictive values have been developed to characterize test accuracy and to describe the benefit of test usage[13].

As the calculations are based on comparison of the test results and the true disease status, identification of this true status become an important part of the evaluation of pulp status[14,15]. The accuracy rate of any diagnostic test is usually determined by the availability of gold standard[16].

Unfortunately, when diagnosing pulp status, a standard is not available to determine the accuracy of other tests as there is no consistently reported relationship between clinical symptoms and histopathological findings[2] and patient experiencing identical clinical symptoms may exhibit different histological status[16]. 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.

Materials and methods

Out of a total 171 consented individual recruited in this study, 137 patients (84 male and 53 female) had teeth with unknown pulp status were tested in endodontic clinic at Ajman Dental School /UAE, the other 34 individual (16 male & 18 female) were with sound teeth. The age range of the tested subjects was between 20 to 70 years.

The teeth subjected to the thermal and electrical pulp testing include incisors, canine, premolars and molars of either Maxilla or mandible. Pulp testing was performed by two trained investigators. Two types of cold tests were used as thermal test, the Endo Ice F and the Green Endo Ice (Coltene/Whaledent. Inc; Cuyahoga OH44223/USA).

The Endo ice F which is composed of mixture of propane and butan gas and the Green Endo ice which is composed of 1,1,1,2 tetrafluroethane fragrance were used by soaking a cotton pellet and immediately placed on intact labial or buccal middle third surfaces of tested teeth. For EPT(Parkell Co D626D-GC) was used and prior to applying the device to the tooth, the probe was checked on the skin of the hand to determine that current is completely passing through the probe[17] .

The main electrode (cathode) was coated with suitable conducting media (pumice) which is placed on tested teeth on the middle third if buccal surfaces and the anode were placed on patient hand to complete the circuit. This method has the advantage of giving more control to the patient as he/she can lift the hand as soon as a sensation is felt and this will immediately interrupt the current and was found to be more satisfactory[5]. All teeth were tested with the three testing methods and the tests were performed after drying the tooth with air and isolating it with cotton rolls. The gold standard (the facet of the pulp status) was detected by 137 teeth in need of endodontic treatment. After pulp testing procedure, the 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.

Specificity, sensitivity and positive and negative predictive values have been obtained to characterize test accuracy and to describe the benefits of test usage. (table1). To evaluate the thermal pulp tester the temperature of different refrigerant spray (green endo ice and endo ice F) that was used. A recently extracted maxillary central incisor was used to register the temperature changes by using an infra red laser thermometer (Master Cool Co.USA) placed inside the pulp chamber.

		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 of pulp tests.

To register the temperature changes, maxillary central incisor was resected and a 3 mm diameter cotton pellet was puffed with 5 puffs of the refrigerant spray and applied on the labial surface of the resected crown for 3 seconds. Meanwhile, infra red laser thermometer was placed inside the pulp chamber for 10 seconds and the lowest temperature obtained was recorded.

To minimize experimental errors, 10 incisors were used and the testing procedure was repeated again after placing the thermometer laser at ambient condition to return to the start mode, then the lowest pulp temperature was registered after cold application.

Results

About 70% of the tested teeth were from individuals in the second and third decade of age as shown in table (2). On opening the pulp chamber in 137 tested teeth that were in need for endodontic treatment, it was observed that 74 pulps were necrotic (no bleeding; pulp tissue destruction) and 81 pulps were vital (bleeding from pulp). In addition to that 16 teeth with caries not reaching the pulp (inflamed non exposed pulp), and 34 intact teeth were considered vital.

Age group (years)	Males	Females	Total
20-30	32	27	59
31-40	36	26	62
41-50	18	16	34
51-60	9	4	13
61-70	3	0	3
total	98	73	171

Table 2. Age and gender distribution of the studied sample.

These observations were considered as gold standards for comparison with different tests. The cold endo ice F test identified 71 out of 74 necrotic pulps as necrotic, while 3 teeth with necrotic pulps gave positive reaction. Out of 97 teeth with vital pulp need endodontic treatment; this test identifies 73 teeth, while 24 vital pulps did not respond to cold. Thirty two sound teeth were used as control teeth, 28 of them gave positive reaction and only 6 teeth did not respond. For Green endo ice test, Out of 74 tested pulps with necrosis, 68 were identified correctly, whereas only 6 teeth gave false positive results. For teeth with vital pulp need endodontic treatment, 96 teeth gave positive results and only one tooth gave negative result. For control teeth, all teeth gave positive results with green endo ice. For electrical pulp testing, 72 out of 74 teeth with necrotic pulp were correctly diagnosed and only 2 teeth gave false positive results. However, 87 teeth with vital pulp in need for endodontic treatment gave positive vitality and only 10 gave negative test to electrical stimulation.

All control teeth (with vital pulp) were EPT positive (table 3). Based on these findings, the sensitivity, specificity, positive and negative predictive values were calculated for each testing method. Sensitivity denotes the ability of a test to detect disease in patients who actually have the disease, for example green endo ice had a sensitivity of 0.99 which means it has a 99% chance of returning positive results when teeth with pulp disease are tested.

Pulp status	Sensitive results	Non-sensitive results
Endo ice F		
Necrotic	71 TN	3 FP
Vital	73 TP	24 FN
Control	28 TP	6 FN
Green endo ice		
Necrotic	68 TN	6 FP
Vital	96 TP	1 FN
Control	34 TP	0 FN
EPT		
Necrotic	72 TN	2 FP
Vital	87 TP	10 FN
Control	34 TP	0 FN

Table 3. Distribution of thermal and electrical pulp test results.

EPT had sensitivity of 0.69 and the endo ice F had sensitivity of 0.90. Specificity is the ability of a test to detect the absence of disease; hence specificity of green endo ice with specificity 0.92 has a 92% chance of returning negative result when performed on teeth without disease. EPT had specificity of 0.97 and the endo ice F has specificity of 0.97.The positive predictive value (PPV) which is the probability that a positive test result actually represents a disease-positive tooth and it was 0.94 for green

endo ice, 0.98 for EPT and 0.96 for endo ice F.

The negative predictive value (NPV) which is the probability that a tooth with negative test results is actually free from disease. It was 0.99 for green endo ice, 0.8 for EPT and 0.88 for endo ice. Any measurement system is designated valid if it is both accurate and precise.

A measurement system can be accurate but not precise, precise but not accurate, neither, or both. The accuracy rate for green endo ice was 96% and with precision of about 94%, while the accuracy rate for EPT was 93% with precision of 0.98 and the test with least accuracy was endo ice F which has 84% accuracy and 96% precision (table 4).

Test	Sensitivity	specificity	PPV	NPV	Accuracy	Precision
Endo ice F	0.69	0.96	0.96	0.70	84%	96%
Green endo ice	0.99	0.92	0.94	0.99	96%	94%
EPT	0.90	0.97	0.98	0.88	93%	98%

Table 4. Sensitivity, specificity, PPV, NPV, accuracy and precision of pulp tests.

This indicates that green endo ice is more accurate than other tests with high precision. To know the exact temperature of the pulp after cold application, and after fixing the room temperature on 24°C, we measure the thickness of each crown involved in this test.

The temperature of the cotton pellet after refrigerant spray application was also measured together with the tooth temperature before and after cold test application. (table 5).

Crown thickness	Tooth temp before cold application	Cotton pellet temp after endo ice F application	Tooth temp after endo ice application	Cotton pellet after green endo ice application	Tooth temp after green endo ice application
5	23.9	13.1	19.1	5.1	8.9
5.5	24.1	13.3	20.2	5.5	9.9
6	23.3	13	20.4	5	10.1
5	24.1	13	17.3	5.1	8.7
5	24.4	13.1	17.8	5.5	9.9
6	23.5	13.1	19.4	5.5	11.3
6.3	23.9	13	19.4	5.1	10.3
5	23	13.3	18.7	4.9	8.8
5.5	23.7	13.3	18.1	5	9.6
6	24.1	13	21.2	5.1	11.5
5.53±0.51	23.8±0.42	13.12±0.13	19.6±1.22	5.18±0.23	9.9±0.96

Table 5. Temperature changes on teeth tested with 2 cold pulp tests.

The temperature that reach the pulp after green endo ice application was (8.9-11.5°C) with mean temperature of 9.9°C and pulp temperature after endo ice F application was (18.1-21.2°C) with mean temperature of 19.1°C. Pearson correlation equation was applied among all variables, a statistically significant direct relation was seen between crown thickness and pulp temperature after application of green endo ice and endo ice F (r= 0.795 & 0.673 respectively).

Discussion

It is generally accepted that clinical tests are used to make the practical determination of pulp status. The use of multiple tests is one approach to decreasing uncertainty, since these tests may be performed very quickly and inexpensively. A perfect diagnostic test would always be positive in the presence of disease and negative in the absence of disease.

The precession on a test refers to the tendency of repeated measurements on the same sample to yield the same results. The concepts of sensitivity, specificity and positive and negative predictive values have been developed to characterize test accuracy and to compute the benefits of test usage. Since the calculations are based on a comparison of the test results and “true” disease status, identification of this “true” disease status becomes an important part of the evaluations. The so called “gold standards” usually refer to a definitive diagnosis of the pulp status after access cavity (bleeding or not).

Many studies on pulp vitality (sensibility) testing have dealt with a precession of the test; however, the extent to which a test correctly classifies conditions “accuracy” has been incompletely studied[18].

The present investigation was designed to study the accuracy of three commonly used vitality testing agents through calculating their sensitivity, specificity and predictive values.

The gold standard chosen for the tested teeth was based on direct inspection of the pulp tissue after opening the pulp chamber. The pulp was considered necrotic if the pulp chamber contained decomposed, non-bleeding tissue. Fuss & Colleagues[19] studied the accuracy of EPT, CO_2 snow, DDM, ethyl chloride and ice. They reported the specificities of the tests and mentioned sensitivity but did not calculate predictive values. Sensitivity and specificity describe the accuracy of the diagnostic tests when the true status of the teeth is known.

The present findings suggest that the highest sensitivity was for green endo ice which was 0.99 followed by endo ice F (0.90) and the least sensitivity was for EPT (0.69); whereas the highest specificity was for both EPT and endo ice F (0.97). This indicates that green endo ice has highest sensitivity and lowest specificity. However, our actual interest is in evaluating test response of patients with unknown disease status. This is measured by predictive values.

Positive and negative predictive value describes the accuracy of the diagnostic test when the true status of the teeth is unknown. In the evaluation of the predictive values of different vitality tests, it is important to consider the prevalence of the disease that the test is supposed to disclose, since the predictive values changes with the prevalence of the disease. The prevalence in this study was calculated from the following equation: ***[Unknown pulp status - Necrotic teeth / Unknown pulp status X 100]*** and it was about 43%.

Petersson et al[15] evaluated the ability of heat (heated gutta percha), cold (ethyl chloride) and EPT to register pulp status. The predictive values obtained in their study were based on 39% disease prevalence. They found that the negative predictive value (NPV) of green endo ice was 0.99 which was similar to that found in the present investigation; NPV for the EPT was also near to that obtained in Petersson et al (0.88 vs.0.84). Upon recalculation of this value using the same disease prevalence as Petersson et al, our NPV would be 0.95. Thus the results indicated a probability of at least 95% of teeth that did not respond to sensibility tests were necrotic. The least NPV obtained was for endo ice F which was 0.70 only.

Positive predictive value is the proportion of positive test results that are case. The positive predictive value (PPV) we obtained for cold tests were 94% for green endo ice and 96% for endo ice F. This means that 94-96% % of teeth respond to cold tests were vital, and the remaining 4-6% would be false positive results.

Upon recalculation based on 39% disease prevalence which is obtained in Petersson et al study [15] the values would be reduced to 89% for green endo ice and 92% for endo ice F which was close to that obtained by Petersson et al (89%).

For EPT the PPV obtained in the present study was 0.98 which becomes 0.94 after recalculation with disease prevalence of 39% used by Petersson et al. which is higher than that of Petersson et al (0.88). This means that 94% of teeth that responded to EPT were vital, and the remaining 6% would be false-positive result.

In an attempt to know the pulpal temperature of teeth immediately after cold application an infra red laser thermometer was used for a sample of 10 incisors with a crown thickness of about 5.5mm.

It was found that the pulp temperature was reduced by 41.6 % after green endo ice application and only 8.2 % after endo ice F application and there is direct relationship between crown thickness and the pulp temperature after cold application.

Thermal stimulation provides a greater response when more extreme temperature changes occur, causing more rapid and stronger fluid movement within the dentinal tubules, stimulating receptors, and exciting A-ð fibers[20,21]. However gradual temperature changes do not produce a rapid response but will eventually produce a response by C fibers[20,22] .

It has been well documented that cold uses as recommended will not cause pulpal or hard tissue damage at this temperatures[23.]

Some studies have shown that cold tests cause pulp degeneration if tissue freezing occurs[24,25].

However freezing has been shown to result only when a cold probe maintained a temperature lower than -10°C for 5-20 minutes.

The response to cold test requires more live tissue in the coronal aspect of the tooth than does a response to an EPT.

Shabahang[26] found that as thermal tests are not 100% accurate, an EPT is especially beneficial for confirming a questionable diagnosis. However, cold test should be used in conjunction with the EPT, so the results from one test can verify the findings of the other test.

Conclusions

Based on the results obtained from this study, it can be concluded that among the refrigerant sprays tested the green endo ice present the lowest temperature when measured immediately after application on teeth with 99% sensitivity.

Declaration of Interest

The authors report no conflict of interest and the article is not funded or supported by any research grant.

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