

THE EFFECT OF DIFFERENT CONDUCTIVE SUBSTANCES ON THE RESPONSE OF ELECTRIC PULP TEST

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ABSTRACT

INTRODUCTION: Effect of conductive material used in electrical pulp test and gender on the response of test is important in making the correct diagnosis.

OBJECTIVES: The aim of the study was to compare the influence of different water-based and gel-based materials as conductive materials and gender on the response of electric pulp test (EPT).

MATERIAL AND METHODS: In order to examine the effect of different conductive materials and gender on the response of pulp test, 40 healthy upper incisor teeth from volunteers were selected. Normal toothpaste, toothpaste with chemical content, fluoride gel, ultrasound gel, and chlorhexidine gel were applied on each tooth separately as a conductive material.

RESULTS: Compared with respect to pulpal sensory thresholds, fluoride gel was found significantly to be lower than normal toothpaste, toothpaste with reduced chemical content, and chlorhexidine gel ($p < 0.001$, $p < 0.001$, and $p = 0.001$). There was no statistically significant difference between ultrasound and fluoride gels. Normal toothpaste showed a significantly lower threshold than toothpaste with reduced chemical content ($p = 0.005$), but significantly higher compared to ultrasound gel ($p = 0.001$). No significant difference was found between normal toothpaste and chlorhexidine gel. Threshold value of toothpaste with reduced chemical content was found to be significantly higher when compared with chlorhexidine and ultrasound gels ($p < 0.001$). There was no statistically significant difference between chlorhexidine and ultrasound gels ($p = 0.013$).

CONCLUSIONS: It was observed that water-based gel groups produce a better conductivity than toothpastes, and gender has no significant effect on the threshold value of electric pulp test. Interface materials, which provide good current transmission will allow the most reliable EPT and possibly reduce false negative response.

KEY WORDS: electrical pulp test, pulp threshold value, conductive material.

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INTRODUCTION

As a result of early diagnosis of diseases, clinicians apply conservative treatment methods. Therefore, possible complications and additional costs that could arise as a result of late diagnosis and/or inability to treat the disease are prevented [1]. An accurate assessment

of the condition of dental pulp allows successful diagnosis of dental diseases. A detailed history, clinical and radiographic evaluation, and special diagnostic tests are used for this purpose [2]. Therefore, various pulp tests are used as well as clinical examination methods and radiographic assessments to determine dental pulp condition during diagnosis and treatment planning [3].

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In the evaluation of pulp health, sensitivity tests showing pulp blood circulation, such as thermal tests and electric pulp test (EPT), are frequently used. In addition, there are vitality tests, including laser doppler flowmetry and pulse oximetry, which provide information about the vitality of the pulp.

An ideal pulp test should be painless, harmless, objective, simple, reproducible, inexpensive, and standardized in nature [4]. However today, there is no such a pulp test that meets all these criteria [5].

Pulp sensitivity tests are examinations evaluating the neurophysiological status of pulp, which are accepted as uncertain by the majority of clinicians, since they are based on subjective responses of a patient and dentists' observations [6, 7]. Furthermore, there are limitations of pulp sensitivity tests, such as they are not detecting pulpal blood flow. Laser Doppler flowmetry and pulse oximetry tests have been developed in order to eliminate the current deficiencies in pulp sensitivity tests. These are pulp vitality tests, which detect pulp blood flow by eliminating the subjective response received from the patient. Therefore, they are considered to provide more accurate and objective results on pulp health condition [7, 8]. However, these methods have some technical challenges, including movement of patient's head [9], non-pulpal voice [10, 11], signal detection limits [12], and the need for custom made probes [13].

EPT is a technically sensitive method, but with some limitations [14, 15]. Getting a correct answer from an EPT depends on providing enough stimuli, correct application method, and correct interpretation of the result obtained. First of all, a single tooth insulation and a conductive environment are required. Conductivity ensures that the maximum current flows from the electrode to the surface of tooth. Therefore, a conductive interface medium must be used [16-18]. These mediums can include a toothpaste, prophylaxis paste, colloidal graphite in alcohol, saline, inert oil, water, and electrode gel. The test can be uncomfortable and sometimes painful for patients [4]. In addition, false positive answers can be obtained from periodontal tissues. If there are crowns or orthodontic bands in the relevant teeth, the test cannot be applied [19]. In such a situation, metal-containing materials on the tooth cause the current to be transferred to the surrounding periodontal tissues, producing an erroneous response [20, 21]. Therefore, any factor that can significantly affect the response of EPT should be known by clinicians and must be considered in practical application.

Nevertheless, EPT is a clinical test that can provide reliable information about pulp health if applied correctly and carefully [22-24]. Sometimes, despite clinical findings analysis, a clinician cannot be sure of the diagnosis [25]. False positive and false negative answers can occur [26]. There are studies in the literature revealing the frequency of false positive responses due to EPT [24, 27].

It was observed that 72% of cases presented with total necrosis and 25.7% had localized necrosis with a negative response from EPT [28]. This situation indicates that root canal treatment is required in 97.7% of cases with negative response from EPT. In contrast, the positive response from EPT indicates that the nerve fibers in the pulp chamber are still sensitive. Especially in multi-rooted teeth, both necrotic pulp and vital pulp can be found together, and a positive response can be obtained from EPT [29].

OBJECTIVES

The main goal of this study was to compare the effect of conductors used on the response by investigating the pulpal sensory thresholds obtained using different conductors with EPT. An additional aim was to compare whether there is a relationship between gender and pulpal sensory level.

MATERIAL AND METHODS

Our study was initiated after being approved by the Tokat Gaziosmanpaşa University Clinical Research Ethics Committee, number 83116987-186, and the principles of the Declaration of Helsinki were followed. Informed consent was obtained from each participant.

There were two groups of conductor materials used in the study: water-based gels (fluoride gel, ultrasound gel, and chlorhexidine gel) and toothpastes (Colgate Total and Tebodont). Materials that can be found in clinics and alternative materials, which can be used as conductors were considered to be used in the study. Because of easy availability, low cost, and hypoallergenic properties, ultrasound gel was included in the study as an alternative.

Inclusion criteria were healthy maxillary central teeth without decay, no restoration, no trauma, no orthodontic treatment, and no periodontal disease. In addition, volunteer patients between 18 and 25 years of age, with no systemic diseases and pregnancy, who did not use analgesic and anti-inflammatory drugs in the last two weeks, who did not use cortisone for the last 6 months, with no bruxism complaints and no pacemaker were included in the study.

VITALITY TEST PREPARATION

The tested teeth were first cleaned with pumice and compressed air and water. Then, the teeth were isolated from saliva with cotton rolls and rubber dam, and dried with air (Figure 1). Parkell Digitest vitalometer device (300 Executive Dr. Edgewood, NY 11717, USA) was used in our study as specified in the user manual [30].

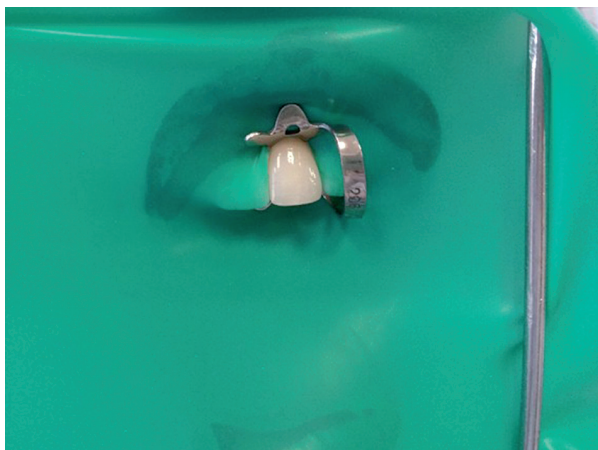


FIGURE 1. Isolation of teeth with rubber-dam

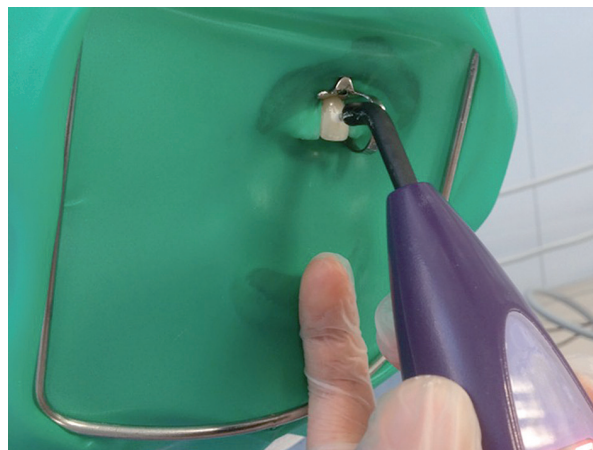


FIGURE 2. Performing measurements with digital vitalometer

The conductor groups used in the study were as follows: group 1: normal toothpaste (Colgate Total; Colgate-Palmolive Company, New York, USA); group 2: ultrasound gel (ultrasound gel Aqua, Aqua Medical, Istanbul, Turkey); group 3: chlorhexidine gel (Chlorhexidine Gluconate Gel Best, Best Dental, Turkey); group 4: toothpaste with reduced chemical content (Tebodont, Wild Pharma, Muttentz, Switzerland); group 5: fluoride gel (APF thixotropic gel; Dharma Research Inc., Miami, USA).

All groups were randomly applied to the same patient at a single visit. Electrical stimuli were used by placing the probe in the same area in the center of the middle third of labial surface of the tooth crown, selecting the materials in a random order, and waiting at least 1 minute between measurements with different materials (Figure 2). Tests were repeated twice, with each material to increase the reliability of the study. Interstimulus intervals of 1 minute were permitted between each test for the participants to settle down.

The tip of electrode was covered with a thin conductive layer, so that electricity could be transmitted by contacting the surface of enamel. Care was taken that a layer did not exceed 0.5 mm in thickness. In addition, the position of electrode on the tooth was kept as constant as possible during the experiment. After each test, the residual material on the tooth was wiped with 70% alcohol gauze. Then, the tooth surface was washed with water and dried with clean gauze and air spray.

The participants were instructed on how to define the first sensation, often described as “tingling”, “tremor”, and “electric shock”, or even the slightest sensitivity. While taking measurements, the patients were told to inform the practitioner by raising their hands when they felt any sense, and the numerical value on the EPT device was recorded. After the first measurement for each material, a second measurement was made by waiting at least 1 minute, and the average value of the two measurements was taken. Then, the measurements were re-

corded, and a comparison was made between different conductors. The same EPT device, lip clip, and probe were used to ensure standardization in measurements.

Numerical variables were expressed as mean \pm standard deviation (minimum-maximum), and categorical variables were presented as numbers and percentages for statistical analysis. One-sample Kolmogorov-Smirnov test was used to determine normal distribution of values. Mann-Whitney *U* test was used to compare numerical data of independent groups that did not show normal distribution. Friedman test was applied to compare numerical data of dependent groups that were not normally distributed. Bonferroni-corrected Wilcoxon test was used to evaluate dependent groups in pairs. Significance level was accepted as $p < 0.05$. However, as there were 5 groups in Bonferroni-corrected Wilcoxon test, the significance level was finally accepted as $p < 0.01$ (0.05/5).

RESULTS

The average age of the 40 patients (20 female, 50%, and 20 male, 50%) included in the study was calculated as 21.8 ± 1.2 .

The thresholds of pulpal sensory evaluated by EPT were calculated as 5.7 ± 2.0 with fluoride gel, 6.8 ± 2.7 with Colgate Total, 7.8 ± 3.3 with Tebodont, 6.5 ± 2.4 with chlorhexidine gel, and 5.8 ± 2.2 with ultrasound gel (Table 1).

Multiple comparisons were performed between average sensory levels obtained by using different conductive materials. As a result, fluoride gel caused a response at the lowest threshold values.

There was a statistically significant difference between the groups ($p < 0.001$) in terms of pulpal sensory thresholds. Fluoride gel had a significantly lower threshold value compared with Colgate Total, Tebodont, and chlorhexidine gel ($p < 0.001$, $p < 0.001$, and $p = 0.001$, respectively). Moreover, it had a lower threshold value

TABLE 1. Pulpal sensory thresholds with different conductors in electrical pulp test

Conductive material	Pulpal sensory threshold, mean \pm SD (min-max)
Fluoride gel	5.7 \pm 2.0 (2.5-13.5)
Colgate Total	6.8 \pm 2.7 (3.5-15.5)
Tebodont	7.8 \pm 3.3 (4.0-18.5)
Chlorhexidine gel	6.5 \pm 2.4 (3.5-16.5)
Ultrasound gel	5.8 \pm 2.2 (3-17.5)

TABLE 2. Comparison of pulpal sensory thresholds of conductor groups

Conductor groups	p-value
Fluoride gel	
Colgate Total	< 0.001*
Tebodont	< 0.001*
Chlorhexidine gel	0.001*
Ultrasound gel	0.479
Colgate Total	
Tebodont	0.005*
Chlorhexidine gel	0.552
Ultrasound gel	0.001*
Tebodont	
Chlorhexidine gel	< 0.001*
Ultrasound gel	< 0.001*
Chlorhexidine gel	
Ultrasound gel	0.013*

*Statistically significant results

TABLE 3. Comparison of pulpal sensory thresholds of different conductors according to gender

Conductive material	Female (n = 20)	Male (n = 20)	p-value
Fluoride gel	5.6 \pm 2.0	5.8 \pm 2.0	0.678
Colgate Total	7.0 \pm 3.2	6.6 \pm 2.3	0.989
Tebodont	7.5 \pm 3.6	8.1 \pm 3.0	0.221
Chlorhexidine gel	6.4 \pm 2.1	6.6 \pm 2.6	0.799
Ultrasound gel	5.5 \pm 1.4	6.1 \pm 2.8	0.698

than ultrasound gel, but no statistically significant difference was found between the two conductive materials ($p = 0.479$) (Table 2). Colgate Total showed a significantly lower sensory threshold than Tebodont ($p = 0.005$), but a significantly higher sensory level compared to ultrasound gel ($p = 0.001$). No significant difference was found between Colgate Total and chlorhexidine gel (Table 2). Tebodont had a significantly higher thresh-

old value than chlorhexidine gel and ultrasound gel ($p < 0.001$) (Table 2). No statistically significant difference was found between chlorhexidine gel and ultrasound gel ($p = 0.013$) (Table 2).

According to the pulpal sensory threshold measurements obtained by using EPT with different conductors, there was no significant difference between the genders (Table 3).

DISCUSSION

The ideal test evaluating the health of pulp should be non-invasive, reliable, objective, reproducible, easily applicable, inexpensive, and standardized [4]. EPT, similar to other sensitivity tests, cannot fully meet all these features. However, obtaining numerical data as a result of the test give the opportunity to measure the standardization and repeatability of EPT. Some factors affect the threshold of response of the electrical stimulus. These include thickness of enamel and dentin, size of pulp cavity, a response originating from periodontal tissues, and the type of conductor used. Therefore, attention should be paid to these aspects in the evaluation of a response received from EPT [31, 32].

On the other hand, the data obtained from thermal tests depend on a subjective response. It has been suggested that low temperature diagnostic materials, such as ice or dichlorodifluoromethane, cause hypothermic anesthesia. Hypothermic anesthesia is the decrease in excitability of the nerve endings due to the effect of extreme cold, so that the stimulus is felt less by a person. In Pantera *et al.* [33] study, it was shown that hypothermic anesthesia was not achieved when dichlorodifluoromethane was used. Therefore, it can be said that cold test application with dichlorodifluoromethane has no negative effect on the following EPT test.

Petersson *et al.* have described a gold standard method. In their study on 59 teeth, in which sensitivity tests were applied, the content of pulp chambers were directly examined, and the results were compared. They found that the probability of sensitivity reaction was 90% for cold test, 83% for hot test, and 84% for EPT in vital pulp; 89% for cold test, 48% for hot test, and 88% for EPT in non-vital pulp. The accuracy ratio was 86% for cold test, 71% for hot test, and 81% for EPT [26]. In the present study, cold test and EPT were equally reliable in detecting vital and non-vital pulp.

The participants in our study were selected from systematically healthy individuals. It was preferred that the contributors did not have any systemic disease and did not regularly use drugs, because they had no effect on sensory transmission. At the same time, the investigated teeth should totally complete their development; they were selected from clinically and radiologically healthy teeth, without any restoration, decay, previous trauma history, or periodontal disease. This selection minimized the possibility of the pulp being affected for

any reason, and the pulp chamber or root canal narrowed by developing calcific changes. Water-based gels (fluoride gel, chlorhexidine gel, and ultrasound gel) and toothpastes (Colgate Total, Tebodont) were used as conductive media in our study.

Unlike other sensitivity tests, the electrical pulp tester shows the numerical value of electric current, allowing for numerical comparison of the conductors used as interface material during the test.

Martin *et al.* tested EPT with dry environment in different conductive settings, and found that the use of a conductive interface material significantly increases electrical conduction compared to dry environment, but there were no significant differences between conductors used [18].

Cooley *et al.* also tested electrical conduction using dry environment in different conductive settings [17]. They used water, toothpaste, and dental electrode gel as conductors and found that toothpaste conducted the least electricity from conductive settings, but did not find significant differences between conductive materials. Comparing a conductive medium and dry environment, it was found that electricity was transmitted significantly more in the measurements with a conductive medium. As a result, they stated that a conductive environment was required for the test. This study evidently showed that the different conductors used in testing pulp health with EPT could significantly affect the sensory threshold values of investigated teeth. In our study, while the lowest threshold value was obtained with fluoride gel, the highest threshold value was obtained with Tebodont.

In contrast with the studies of Martin and Cooley [17, 18], significant differences were found between the conductors used in our study. The lowest threshold values were obtained from water-based gels. This difference may be due to differences in materials used and EPT device development.

Mickel *et al.* inserted cathode of a voltmeter into the pulp tissue by opening cavity entrance to a newly extracted premolar tooth, and anode was connected to an EPT device. Wax or petroleum-based conductors, water-based gels, toothpaste, and liquids were used as conductive interface media in this study [34]. During the experiment, the data obtained from two different liquid media were found to be the highest. It has been reported that the reason for this would spread to surrounding tissues due to fluidity of the fluids, thus causing a false positive response. Moreover, it has been found that water-based gels conducted electricity well, while wax or petroleum-based media did not conduct electricity. This better conductivity of water-based interface media is compatible with our study.

Chunhacheevachaloke and Ajcharanukul [35] compared the conductivity of water-based gels and toothpastes in their study. A total of 40 healthy central teeth from 40 healthy participants were measured with different conductors. The group of water-based gels were found to be slightly more effective in conducting current than the toothpaste group, except for Colgate Total, while there

were no significant differences between the water-based gels tested. In the threshold value comparison between men and women, it was found that the average sensory threshold value in men was higher than in women. In line with this study, water-based gels produced significantly lower threshold values than toothpastes in our study. Also, significant difference was found between Colgate Total toothpaste and fluoride gel and ultrasound gel, but no significant difference was found between Colgate Total and chlorhexidine gel. This finding contradicts the lack of significant difference between Colgate Total toothpaste and water-based gels in the other study. The reason why water-based gels were better conductive than toothpastes may be due to changes in the viscosity of materials and the surface tension between each conductor and enamel. In the comparison of the threshold value between men and women in our study, although women generally had lower threshold values, no significant difference was found between genders. This difference may be due to the difference between EPT device used and the population measured.

Lin *et al.* investigated the optimum electrode positioning in first molars [32]. They also compared the responses given by female and male participants. Although, male participants generally presented a higher threshold value than women, the authors did not find a significant difference between genders. This result is consistent with our study.

Jespersen *et al.* examined the performance of EPT and cold test, and the effects of tooth type, age, gender, restorative condition, caries, and final analgesic use on diagnostic accuracy of these tests [36]. Similar to our study, it was found that gender did not differ significantly in terms of pulp sensitivity test.

CONCLUSIONS

The present study shows that different conductive materials have an effect on the response of EPT. Water-based gels were shown to have a better conductivity than toothpastes. Regarding the effect of gender on the threshold value, no significant difference was found.

It is necessary to diagnose the current condition of teeth for a correct treatment. It can increase the likelihood of false negative responses in vital teeth, when EPT is applied using a poorly conductive material. It is thought that interface materials, which provide good current transmission would allow the most reliable EPT. Further researches are needed to evaluate the effectiveness of interface environments and gender comparison.

CONFLICT OF INTEREST

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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