Original Study

OPTIMAL ELECTRODE PLACEMENT SITE FOR ELECTRIC PULP TESTING OF SECOND MOLAR

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ABSTRACT

Aim: In electric pulp testing (EPT) electrode must be placed on an appropriate site to prevent false responses. This study sought to find the most appropriate electrode placement site for EPT of second molars.

Materials & Method: Sound second molars of 30 volunteers were isolated with cotton rolls. The pulp tester electrode tip was lightly coated with topical fluoride gel and placed on seven testing sites (mesiobuccal cusp tip, mesiobuccal cuspal surface, mesiobuccal gingival surface, center of the supporting cusps, distobuccal cuspal surface, distobuccal gingival surface and center of guiding cusps). Two readings were made at each site. To complete the circuit, patients placed their thumb and index finger on the lip clip and were instructed to release the clip upon sensing heat, tingling or pain. The data were analyzed using repeated measured ANOVA, Tukey's test and t-test ($p<0.05$).

Results: The lowest threshold response was recorded at the mesiobuccal cuspal surface. A gradual increase in threshold response was noted by moving the electrode tip from the mesiobuccal gingival surface to mesiobuccal cusp tip, center of supporting cusps, center of guiding cusps, distobuccal gingival surface and distobuccal cuspal surface, respectively ($p<0.001$). Males had a significantly higher threshold than females at the mesiobuccal gingival surface ($p=0.04$) and the center of supporting cusps ($p=0.004$). The mandibular arch showed slightly higher thresholds at all sites except for the center of supporting cusps ($p>0.05$).

Conclusion: Mesiobuccal cuspal surface of second molars was the most appropriate site for placement of pulp tester electrode.

Key words: Optimal Electrode, Electric Pulp Testing

Introduction

Assessment of dental pulp vitality is an important step prior to endodontic treatment, which is often done by taking a thorough medical and dental history, collecting information about the clinical signs and symptoms and patient complaints and conduction of appropriate diagnostic tests. Dental pulp vitality tests are divided into five groups of cold test, heat test, EPT, direct dentin stimulation and assessment of pulpal blood flow. Cold test can detect vital pulp tissue and indicate pulpal inflammation; however, it is not very accurate. Heat test is the least reliable test for assessment of pulp vitality. Assessment of pulpal blood flow is often difficult and more complicated than other methods.[1] Thus, electric pulp testers are commonly used for this purpose and are among the most extensively used diagnostic tools in endodontics. They provide valuable information about the presence of vital nerve fibers in healthy or inflamed pulpal tissue.[2] They provide adequately high electric current to overcome the resistance of enamel and dentin and stimulate A-delta myelinated sensory fibers at the pulp-dentin interface; however, they do not stimulate unmyelinated C fibers of dental pulp since the C fibers have a higher threshold and require a higher current to be stimulated. Pulpal response to electric current only indicates the presence of several vital nerve fibers in the pulp tissue, which are capable of responding to stimuli.[3] Electric pulp testing has high technical sensitivity and requires correct contact of electrode to the tooth surface at an appropriate site to prevent false positive/negative responses.[2] The tooth responds to EPT when adequate number of nerve endings are stimulated at their threshold level. In other words, EPT is performed aiming to determine the sensitivity of teeth at the lowest sensory response threshold. Ideally, the probe tip must be placed in an area with maximum density of nerve fibers in order to overcome the resistance of the enamel and dentin and create a fast and strong response with minimum electric current.[4] Accordingly, some studies attempted to find the most appropriate site for placement of pulp tester electrode on teeth and yielded controversial results; also, it was shown that the ideal site for placement of pulp tester tip may vary depending on the type of tooth, its anatomy, dentin thickness and density of pulpal nerve fibers.[5,6,7] Bender *et al.*[6] showed that placement of pulp tester electrode on the incisal edge of anterior teeth resulted in an optimal response. Michaelson *et al.*[8] showed that the response threshold of the maxillary lateral incisors was higher than that of central incisors. Udoye *et al.*[9] reported that the most appropriate site for placement of electrode varied based on the type of tooth and the maxillary or mandibular arch. Filippatos *et al.*[7] concluded that the buccal cusp tip was the optimal site for placement of electrode on mandibular premolars but no significant difference was noted in terms of site of placement of electrode tip on maxillary premolars. Moreover, it was indicated that the first premolars had a lower response threshold than the second premolars. Lin *et al.*[10] reported that the mesiobuccal cusp tip had the lowest threshold on first molars. However, Mattews *et al.*[11] stated that no significant association existed between the response threshold and the electrode placement site.

No previous study has assessed the most appropriate site for placement of pulp tester electrode on the maxillary and mandibular second molars. Considering the controversy in

the results of previous relevant studies and the effect of type and anatomy of tooth on itssensory response threshold, this study was conducted to determine the most appropriate site for placement of pulp tester electrode on the maxillary and mandibular second molars.

Materials and Method

This study was conducted on sound second molars of 30 volunteers in the age range of 20-25 years, who were randomly selected among dental students of Hamadan University of Medical Sciences, School of Dentistry in 2015. Sample size was calculated to be a minimum of 30 subjects based on a similar previous study.[12] Assuming 95% confidence interval and 80% study power. The inclusion criteria were age range of 20-25 years, presence of four second molar teeth without carious lesions in the oral cavity and no history of orthodontic treatment or trauma to the teeth. The exclusion criteria were caries, restorations or wear of second molars, positive history of orthodontic treatment or dental trauma, presence of periapical lesion in second molars, systemic diseases and use of medications interfering with pain perception. The study protocol was approved by the ethics committee of Hamadan University of Medical Sciences, School of Dentistry (code:IR. UMSHA. REC. 1344.552). Participants signed written informed consent forms prior to participation in the study.

Posterior bitewing radiographs were obtained of all participants to ensure absence of carious lesions in second molars. One second molar tooth was randomly selected from each of the maxillary and mandibular arch and was isolated with cotton rolls. C-PULSE electric pulp tester (Foshan Coxo Medical Instrument Co. Ltd., China) was used according to the manufacturer's instructions to precisely determine the primary perception of stimulus. The pulp tester could apply electric current from 0 to 80 units. The rate of increase was set to 1. The electrode tip was lightly coated with acidulated phosphate fluoride gel (Topical APF Gel; Pascal, Bellevue, WA, USA) and placed on the testing site. Participants placed their thumb and index finger on the lip clip to complete the current. They were instructed to release the clip upon sensing heat, a burning sensation, tingling or pain.

Figure 1: The seven sites tested on second molar crown

Seven sites on the crown of second molars were tested namely the mesiobuccal cusp tip, mesiobuccal cuspal surface, mesiobuccal gingival surface, center of supporting cusps (palatal cusp of maxillary molars and buccal cusp of mandibular molars), distobuccal cuspal surface, distobuccal gingival surface and the center of guiding cusps. [Figure 1] To determine the sequence of tests, participants randomly picked a number from one to seven. At each site, the response threshold was read twice and in-between the tests, the teeth were cleaned and dried with gauze and gentle air spray. A recovery period of one minute was also allowed to prevent nerve accommodation phenomenon. The mean value of the two readings was calculated and used for statistical analyses.

The collected data were analyzed by SPSS version 21 (SPSS Inc., IL, USA) using descriptive statistics and repeated measures ANOVA, Tukey's test, t-test and paired t-test. Normal distribution of data was assessed using Kolmogorov-Smirnov test. $p<0.05$ was considered statistically significant.

Results

Kolmogorov-Smirnov test confirmed normal distribution of data. The mean response thresholds at the seven sites are presented in Table 1.

Site	Mean	SD	p value
Mesiobuccal cusp tip	25.25	6.35	P<0.001
Mesiobuccal cuspal surface	23.35	6.52	
Mesiobuccal gingival surface	24.52	7.77	
Center of supporting cusps	29.04	8.34	
Distobuccal cuspal surface	32.10	8.03	
Distobuccal gingival surface	30.60	6.01	
Center of guiding cusps	30.15	6.47	

Table 1: Comparison of the mean threshold at the seven sites on the crown of second molars.

According to the results of ANOVA, the difference in the mean thresholds at different sites was statistically significant ($p<0.001$). The lowest threshold was noted at the mesiobuccal cuspal surface while the highest threshold was recorded at the distobuccal cuspal surface. Thus, pairwise comparisons were carried out using Tukey's HSD test, which revealed significant differences ($p<0.05$). The results of pairwise comparisons and the respective p values are presented in Table 2.

Figure 2 compares the mean thresholds at the seven sites between males and females. T-test showed that at all sites, males had a higher response threshold and this difference at the mesiobuccal gingival surface ($p=0.04$) and the center of supporting cusps ($p=0.004$) was statistically significant.

Figure 3 compares the mean thresholds at the seven sites between the maxilla and mandible. The results of paired t-test showed that in both dental arches, the lowest response

threshold was noted at the mesiobuccal cuspal surface of second molars. In all sites except for the center of supporting cusps, the mean response threshold of the maxillary arch was higher than that of the mandibular arch; however, these differences did not reach statistical significance (p>0.05). The results of t-test showed that in both dental arches and at all sites, except for the center of supporting cusps, males had a higher response threshold. However, this difference was not statistically significant (p>0.05). The difference in response threshold of males and females in the mesiobuccal gingival surface of the mandibular arch, distobuccal cuspal surface of the maxillary arch and the center of guiding cusps of the mandible was statistically significant. [p=0.046, p=0.025 and p=0.002, respectively; Figure 4].

Site A	Site B	Mean Difference	Standard Error	p value
Mesiobuccal cusp tip	Mesiobuccal cuspal surface	1.89	1.30	0.722
	Mesiobuccal gingival surface	0.72	1.30	0.998
	Center of supporting cusps	3.79	1.30	0.057
	Distobuccal cuspal surface	6.85	1.30	0.000*
	Distobuccal gingival surface	5.35	1.30	0.001*
	Center of guiding cusps	4.90	1.30	0.004*
Mesiobuccal cuspal surface	Mesiobuccal gingival surface	1.16	1.30	0.973
	Center of supporting cusps	5.68	1.30	0.000*
	Distobuccal cuspal surface	8.74	1.30	0.000*
	Distobuccal gingival surface	7.25	1.30	0.000*
	Center of guiding cusps	6.79	1.30	0.000*
Mesiobuccal gingival surface	Center of supporting cusps	4.51	1.30	0.010*
	Distobuccal cuspal surface	7.57	1.30	0.000*
	Distobuccal gingival surface	6.08	1.30	0.000*
	Center of guiding cusps	5.62	1.30	0.000*
Center of supporting cusps	Distobuccal cuspal surface	3.05	1.30	0.223
	Distobuccal gingival surface	1.56	1.30	0.893
	Center of guiding cusps	1.10	1.30	0.979
Distobuccal cuspal surface	Distobuccal gingival surface	1.49	1.30	0.913
	Center of guiding cusps	1.95	1.30	0.746
Distobuccal gingival surface	Center of guiding cusps	0.45	1.30	1.000

Table 2: Pairwise comparisons of the mean thresholds at the seven sites.

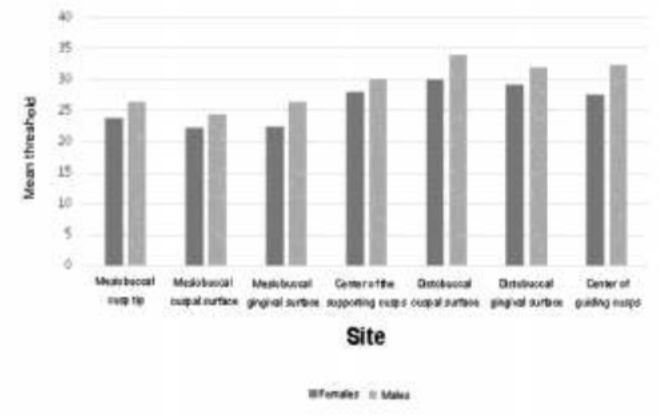

Figure 2: Comparison of the mean threshold at the seven sites between males and females

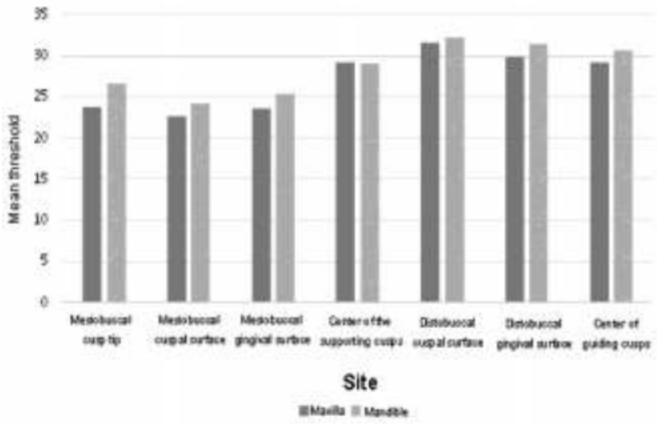

Figure 3: Comparison of the mean threshold at the seven sites between the maxilla and mandible

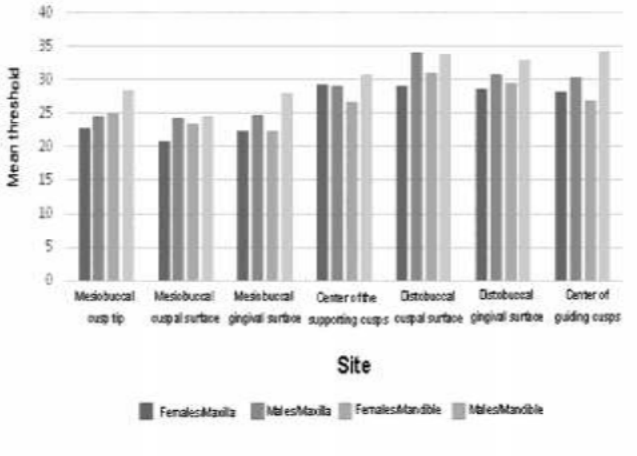

Figure 4: Comparison of the mean threshold in males and females in the maxilla and mandible

The mean response threshold in different age groups is presented in Table 3.

Age	Mean	SD	p value
20	26.64	8.20	0.118
21	26.67	4.17	
22	28.48	7.75	
23	27.45	8.26	
24	29.09	7.33	
25	29.13	7.12	

Table 3: Comparison of the mean threshold values in different age groups.

According to ANOVA, by an increase in age, the response threshold increased but not significantly (p=0.118). However, 23 year olds responded at a lower threshold compared to their previous group.

Discussion

Most pains in the maxillofacial region are due to pulpitis.[11] However, localization of pain is difficult and requires the conduction of several diagnostic tests and a thorough clinical examination along with a complete history taking. Electric pulp testing is commonly performed along with a cold test to determine the pulp vitality status. Proper placement of pulp tester electrode on an appropriate site is an important factor that needs to be taken into account when using this tool. Electrodes placed on inappropriate sites require higher electric current to generate a response and higher current can result in false positive responses. Appropriate site of electrode placement on different teeth has been the topic of many previous studies yielding controversial results.[7-11] Some researchers did not find a significant correlation between the response threshold and the electrode placement site.[11]

Considering the variability in morphology of teeth, proper site of electrode placement must be separately determined for each tooth. Considering the lack of such studies on second molars, this study assessed the proper location of electrode placement on second molars and recorded the lowest threshold in the mesiobuccal cuspal surface. A gradual increase in threshold was noted from the mesiobuccal gingival surface to the mesiobuccal cusp tip, center of supporting cusps, center of guiding cusps, distobuccal gingival surface and distobuccal cuspal surface, respectively. At all sites, the mean threshold was higher in males than females. Also, at all sites, thresholds were higher in the mandible compared to the maxilla except for the center of supporting cusps.

By an increase in age, a gradual increase in threshold was noted. In the current study, participants in the age range of 20-25 years were included to prevent variations in sensibility due to dentin deposition, reduction in size of pulp chamber or occlusal wear. Rate of increase was 1 unit in this study since Wahab and Kennedy showed that a mild gradually increasing current yielded more accurate reproducible results.[13] Cotton roll isolation of teeth was performed according to Cooley and Robinson.[3] We used C-Pulse pulp tester, which was also used by Samson *et al*, [14] to determine the vitality of teeth at the fracture line.

This tool has optimal features, which enhance its use for the operator and patient. For instance, it enables the use of three speeds of low, moderate and high for increase of current. High-speed option was used in this study. Following placement of electrode on the tooth, the current gradually increases. Upon perception of stimulus by the patient and release of clip, the current immediately stops. The rate of increase in current of this pulp tester was 1 unit, which was an advantage compared to previous studies using a rate of increase of 2 units because a lower rate enhances the first perception of stimulus.[10,15] A medium must be used between the electrode tip and the enamel surface. Topical fluoride gel was used in this study as a medium. The same material was used by Lin *et al*, and Bargale and Padmanabh.[10,15]

In the current study, mesiobuccal cuspal surface yielded the lowest mean threshold followed by the mesiobuccal gingival surface, mesiobuccal cusp tip, center of supporting cusps and center of guiding cusps, respectively. Distobuccal gingival surface and distobuccal cuspal surface had the least resistance to electric current and thus, required a lower current to generate a response. Several factors can affect the results of EPT including the thickness of enamel and dentin, density of sensory fibers, orientation of dentinal tubules and size of pulp chamber.[6,9,10,16]

Innervation of coronal dentin is denser than that of root dentin and the dentin surrounding the pulp horns has the highest density of nerve fibers.[17] Dentinal tubules at the incisal edge and cuspal areas have a straight path[18] while they have S-shaped path in other areas.[6]

Since the dentinal fluid transfers the current from the electric pulp tester to dental pulp.[19] Straight path of dentinal tubules decreases the distance between the electrode and the pulp. The thicker the enamel, the higher the threshold because the enamel has greater resistance against the passage of current compared to dentin since water comprises 22% of dentin versus 1% of enamel.[2,6,20] Higher thickness of enamel at the occlusal surface[21] and significant increase in enamel thickness from the first to the third molar teeth due to significant increase in enamel coverage of maxillary molars and decreased thickness of dentin in mandibular molars[22] also explain the lower threshold of the mesiobuccal cuspal surface compared to the mesiobuccal gingival surface. However, it cannot explain the lower threshold of the mesiobuccal gingival surface compared to the mesiobuccal cusp tip. In a similar study by Lin *et al*,[10] in 2007 on first molars, the lowest threshold was obtained at the mesiobuccal cusp tip followed by the mesiobuccal cuspal surface. In another study by Jacobson *et al*,[5] appropriate location for placement of pulp tester electrode was reported to be at the occlusal two-thirds of the buccal surface of incisors and maxillary premolars. However, West[23] reported that the gingival third of the buccal surface was the best location for placement of electrode. Filippatos *et al*.[7] reported that in the maxillary and mandibular second premolars, cervical third required lower current while middle third and cusp tip had almost equal thresholds.

Comparison of response thresholds between males and females revealed that at all tested sites, males required higher current to generate a response, which was in agreement with the findings of Lin and Chandler and Bargaleand and Padmanabh.[15,16] However, opposite results were obtained at the center of supporting cusps in the maxillary dental arch and females showed a lower threshold than males, which may be due to lower pain threshold in females.[24]

Assessment of the effect of age on sensory response threshold in the current study showed that by an increase in age, a higher current was required to generate a response. However, 23 year-old participants showed lower threshold than their previous group, which may be due to smaller

number of subjects in this age group. However, in general, the mean threshold increased from group one to five; which was in agreement with the results of Filippatos *et al*,[7] and Udoye *et al*,[9] indicating that the threshold was not necessarily related to pulp pathology. Increase in age enhances dentin sclerosis and increases the deposition of secondary dentin and coronal calcification and decreases the frequency of nerve fibers in the pulp chamber.[7] As expected, by an increase in distance from the electrode to the pulp chamber due to dentin deposition and sclerosis (which decrease the dentinal fluid flow), the threshold increased. However, Moody *et al*.[25] stated that pulp stones and disseminated calcification did not affect the EPT response threshold.

Comparison of response threshold of the maxilla and mandible revealed that although the threshold of mandibular teeth was higher than that of maxillary teeth at all sites except for the center of supporting cusps, the difference did not reach statistical significance. This finding was in accordance with the results of Lin *et al*.[10]

Inclusion of participants in a small age range was a strength of this study. Large sample size was another strength of this study, which was larger than the sample size of a similar previous study.[10] Also, this study was the first to evaluate the appropriate location of pulp tester electrode on second molars. Not being able to perform rubber dam isolation (to match the oral clinical conditions of the subjects) due to lack of eruption of third molars in most participants was a limitation of this study. For this reason, we isolated the teeth using cotton rolls. Moreover, due to morphological differences of first and second molars and higher possibility of absence of distolingual cusp in second molars, placement of electrode at the center of supporting cusps of maxillary second molars was not ideally possible in some cases, which was another limitation of this study.

Future studies are required on teeth with carious lesions and restorations to assess the effect of these factors on the response threshold. Moreover, the threshold of first and second molars must be compared in the same individuals in future studies.

Conclusion

Within the limitations of this study, the results showed that the mesiobuccal cuspal surface of second molars in the maxillary and mandibular dental arches was optimal for placement of pulp tester electrode. Males had a higher threshold than females and teeth in the mandibular arch showed higher threshold than those in the maxillary arch.

Reference

1. Torabinejad M, Fouad A, Walton R. Endodontics: Principles and Practice, 5th edn; 2014; Philadelphia: WB. Saunders.
2. Hargreaves K, Berman L. Cohen's Pathways of the Pulp Expert Consult, 11th edn: 2016; St. Louis, Mosby Inc.
3. Cooley RL, Robison SF. Variables associated with electric pulp testing. Oral Surg Oral Med Oral Pathol 1980;50(1):66-73.
4. Mickel AK, Lindquist KA, Chogle S, Jones JJ, Curd F. Electric pulp tester conductance through various interface media. J Endod 2006;32(12):1178-1180.
5. Jacobson JJ. Probe placement during electric pulp-testing procedures. Oral Surg Oral Med Oral Pathol 1984;58(2):242-247.
6. Bender IB, Landau MA, Fonsecca S, Trowbridge HO. The optimum placement-site of the electrode in electric pulp testing of the 12 anterior teeth. J Am Dent Assoc 1989;118(3):305-310.
7. Filippatos CG, Tsatsoulis IN, Floratos S, Kontakiotis EG. The variability of electric pulp response threshold in premolars: a clinical study. J Endod 2012;38(2):144-147.
8. Michaelson RE, Seidberg BH, Guttuso J. An in vivo evaluation of interface media used with the electric pulp tester. J Am Dent Assoc 1975;91(1):118-121.
9. Udoye CI, Jafarzadeh H, Okechi UC, Aguwa EN. Appropriate electrode placement site for electric pulp testing of anterior teeth in Nigerian adults: a clinical study. J Oral Sci 2010;52(2):287-292.
10. Lin J, Chandler N, Purton D, Monteith B. Appropriate electrode placement site for electric pulp testing first molar teeth. J Endod 2007;33(11):1296-1298.
11. Matthews B, Searle BN. Electrical stimulation of teeth. Pain 1976;2(3):245-251.
12. Kalhoro FA, Khoso NA, Salem MA, Shaikh MA. Selecting the appropriate electrode placement site for pulp tester on first premolar teeth. Pakistan Oral Dent J 2012;32(1):132-135.
13. Abdel Wahab MH, Kennedy JG. The effect of rate of increase of electrical current on the sensation thresholds of teeth. J Dent Res 1987;66(3):799-801.
14. Samson J, John R, Jayakumar S. Teeth in the line of fracture: to retain or remove? Craniomaxillofac Trauma Reconstr 2010;3(4):177-184.
15. Bargale SD, Davangere Padmanabh SK. Appropriate electrode placement site of electric pulp tester for the premolars: a clinical study. J Indian Soc Pedod Prev Dent 2015;33(2):138-142.
16. Lin J, Chandler NP. Electric pulp testing: a review. Int Endod J. 2008;41(5):365-374.
17. Lilja J, Fagerberg-Mohlin B. Dentinal innervation of impacted human third molars. Scand J Dent Res 1984;92(6):485-488.
18. Gopikrishna V, Pradeep G, Venkateshbabu N. Assessment of pulp vitality: a review. Int J Paediatr Dent 2009;19(1):3-15.
19. Byers MR. Dental sensory receptors. Int Rev Neurobiol 1984;25:39-94.
20. Penna KJ, Sadoff RS. Simplified approach to use of electrical pulp tester. N Y State Dent J 1995;61(1):30-31.
21. Skinner MM, Alemseged Z, Gaunitz C, Hublin JJ. Enamel thickness trends in Plio-Pleistocene hominin mandibular molars. J Hum Evol 2015;85:35-45.

22. Smith TM, Olejniczak AJ, Reid DJ, Ferrell RJ, Hublin JJ. Modern human molar enamel thickness and enamel-dentine junction shape. Arch Oral Biol 2006;51(11):974-995.
23. West NM. The analytic pulp tester self-instructional package. Va Dent J 1982;59(1):24-31.
24. Udoye C, Aguwa E. Dental anxiety and pain in clinical practice: a survey among urban adults. Niger J Med 2006;47(4):81-84.
25. Moody AB, Browne RM, Robinson PP. A comparison of monopolar and bipolar electrical stimuli and thermal stimuli in determining the vitality of human teeth. Arch Oral Biol 1989;34(9):701-705.

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