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**Original**

# Appropriate electrode placement site for electric pulp testing of anterior teeth in Nigerian adults: a clinical study

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**Abstract: Electric pulp testing is one of the pulp vitality tests which aid dentists in diagnosis of the pulp status. This test is technique sensitive and hence may elicit false responses. There are some concerns regarding the optimal placement of the probe tip. The threshold value (the lowest electric current at which sensation is perceived) is reached when an adequate number of nerve fibers are stimulated, so the sensation would be greatest where the density of neural distribution is the highest. The purpose of this study was to identify the optimum site for electrode placement in anterior teeth of adults, the threshold values of these teeth using an electric pulp test, and to determine the influence of sex, age, and arch on the outcome. The optimum electrode placement sites and threshold values varied with type of tooth and arch. The maxillary teeth, canines, male gender and increasing age required higher electric current to evoke a sensation, while incisal edges required lower current to evoke a sensation. (J Oral Sci 52, 287-292, 2010)**

Keywords: electric pulp test; electrode; placement site; endodontics.

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## Introduction

The assessment of pulp vitality is an important procedure in endodontics and clinical dentistry at large (1-3). The conventional methods for this purpose are cold tests such as $CO_2$ snow, ice sticks, refrigerant sprays, and ethyl chloride and warm tests such as heated gutta-percha, warmed hand instruments, and also laser Doppler flowmetry, dual wavelength spectrophotometry, measurement of tooth temperature, and pulse oximetry (1-5).

Electric pulp test (EPT) is one of such useful tools for pulp assessment. The use of electricity in dentistry is ascribed to Magitot (6), whereas Marshall (7) in 1891 actually used it to test pulp vitality. When EPT is properly used, it is a safe clinical test that can provide useful information on pulp status. Both EPT and thermal tests are sensibility tests (8), but EPT only registers the sensitivity of the pulpal nerve and does not assess the vascular status of pulp. On the other hand, thermal testing methods help to determine whether the pulp is reversibly or irreversibly affected. Both methods are commonly used in practice, though Abdullah (9) reported that EPT is more reliable than thermal testing. The EPT acts by delivering sufficient electric current to overcome enamel and dentine resistance in order to stimulate myelinated A (Beta and Delta) fibers near the pulpo-dentinal junction (10,11).

The factors important in EPT include the thickness of enamel and dentine, concentration of pulpal neural elements, direction of dentinal tubules, and the distance between the electrode tip and the pulp (12-14).

The main shortcoming of EPT is its inability to provide information on the pulp's vascular supply (15,16). Furthermore, besides being technique sensitive, false positive and negative results may be obtained (17).

Opinions differ among authors as to the optimum electrode placement site (14). Jacobson (18) reported that the middle third region of anterior teeth required the lowest level of electric current to evoke a sensation, while Cooley and Robison (19) reported the cervical third area. However, Bender et al. (14) found that the incisal edge required the lowest current to evoke a reaction. Among anterior teeth, canines had the highest threshold value, while maxillary teeth had higher threshold value than mandibular teeth.

Data on this subject is scarce in the African population. Besides aiding comparison between studies, clinicians will be better guided in determining the best electrode placement site on anterior teeth where the least amount of electric current is required to evoke a sensation. Unlike in the present study, Bender et al. (14) included subjects with immature teeth in their sample. They pointed out that EPT may be unreliable in immature teeth, because the plexus of Rashkow is not yet fully developed.

The purpose of this study was to identify the optimum or appropriate electrode placement site in anterior teeth of Nigerian adults, and threshold values of these teeth using an EPT and to determine the influence of sex, age, and arch on the outcome.

## Materials and Methods

This clinical study recruited 21 odd numbered healthy attendees in the 18-71-year age band, at the endodontic and restorative clinic of the University of Nigeria Teaching Hospital (UNTH) over 3 months. Ethical clearance for the study was obtained from the Research and Ethics Committee of the UNTH.

Three pristine anterior teeth from one side of each arch (six from each subject, three maxillary and three mandibular) were selected. The arch side, right or left, was selected at random.

Baseline bitewing and periapical radiographs were taken of teeth which had neither history of orthodontic treatment nor trauma. The presence of periapical radiolucencies or radiopacities, cracks, and interproximal caries was evaluated in these radiographs. Subjects taking narcotics, alcohol or nonsteroidal anti-inflammatory drugs (NSAIDs), as well as those with a history of mental and emotional instability were excluded from the study.

The six selected anterior teeth (three maxillary and three mandibular from the left or right side) were isolated and dried with cotton rolls, but not with air blasts. The test was conducted with a Digitest EPT (Parkell, Farmingdale, NY, USA) in accordance with the manufacturer's instructions (the stimulus range was 0 to 10) (a monopolar EPT with anodal electrode probe tip and diameter of 2 mm was used in the study). The circuit was completed when the subject rested a finger on the metal sheath of the EPT, while the gloved researcher conducted the test.

A gentle pulsed stimulus was applied to the tooth until the subject felt and noted a sensation such as tingling, stinging, warmth, or heat. The digital display readout of the pulp tester at which the subject first noted the above-mentioned sensation was defined as the threshold.

Four sites (incisal edge, incisal third, middle third and cervical third, labially) on each tooth were tested, using toothpaste (Colgate, New York, NY, USA) as the conducting medium. This medium was applied lightly to the tip of the electrode. As reported in a previous study, the testing was started from any site, maintaining consistency in sequence provided that the phenomenon of nerve accommodation is observed (14).

Four recordings were made on the labial surface of each site in sequence, starting from the cervical third. To eliminate the phenomenon of nerve accommodation, at least one minute was allowed to elapse before the tooth was revisited. The means of the four recordings from each site were scored.

The data were analyzed with SPSS, version 6. Means of variables from each location were compared using a *t*-test while the critical level of significance was set at $P < 0.05$.

## Results

From 21 subjects recruited in this study, 126 teeth and 504 electrode placement sites were studied and analyzed statistically. A total of 504 readings and a grand mean of 25.65 ± 22.33 EPT values were recorded from the 21 subjects (females = 14 or 77.7% and males = 7 or 33.3%) whose ages ranged from 18 to 71 years.

The mean threshold value for females ranged from 16.54 to 54.54, while that for males was 14.08 to 51.62.

The mean values at the electrode placement sites are shown in Table 1. Although the condition of each tooth tested differed in both arches, the lowest threshold values were recorded on the incisal edges. The threshold values were not statistically significant. On the other hand, the cervical third of all teeth in both arches responded at the highest threshold. A trend was observed in the mandibular canines and lateral incisors and in the maxillary canines, where threshold values increased progressively from incisal edge to cervical region.

The females responded at lower thresholds than males in both arches ($P = 0.012$). In the mandible, the mean

Table 1 The mean threshold EPT value to evoke sensation by tooth and arch types

| Arch | Tooth type ($n$) | Optimum electrode placement site | | | |
|---|---|---|---|---|---|
| | | Incisal edge | Incisal third | Middle third | Cervical third |
| Mandible | Central incisor (21) | 6.43 ± 6.38 | 19.52 ± 19.69 | 17.43 ± 21.19 | 17.33 ± 16.24 |
| | Lateral incisor (21) | 8.76 ± 6.47 | 18.10 ± 17.77 | 25.38 ± 21.76 | 25.76 ± 21.79 |
| | Canine (21) | 20.67 ± 21.46 | 27.62 ± 21.68 | 39.90 ± 21.98 | 36.76 ± 23.10 |
| Maxilla | Central incisor (21) | 6.86 ± 7.43 | 23.00 ± 23.36 | 21.62 ± 21.46 | 31.76 ± 23.18 |
| | Lateral incisor (21) | 18.71 ± 22.06 | 28.48 ± 23.79 | 25.29 ± 21.21 | 33.19 ± 21.99 |
| | Canine (21) | 18.29 ± 17.67 | 41.19 ± 22.38 | 42.70 ± 20.84 | 45.29 ± 18.66 |
| | $P$-Value | $P = 0.43$<br>$t = 0.81$ | $P = 0.94$<br>$t = 0.06$ | $P = 0.45$<br>$t = 0.50$ | $P = 0.57$<br>$t = 0.53$ |

Table 2 The mean threshold EPT value to evoke sensation by gender and arch (*: $P < 0.05$)

| Gender | Arch | | $P$-value |
|---|---|---|---|
| | Mandible | Maxilla | |
| Female (14) | 20.20 ± 19.42 | 26.02 ± 22.54 | $t = 2.53$, df = 334, $P = 0.012$* |
| Male (7) | 25.50 ± 23.51 | 32.06 ± 23.73 | $t = 1.80$, df = 166, $P = 0.70$ |
| $P$-value | $t = 1.90$, df = 250, $P = 0.05$* | $t = 1.97$, df = 250, $P = 0.05$* | |

Table 3 The mean optimum electrode placement site to evoke sensation by arch (*: $P < 0.05$)

| Arch | Incisal edge | Incisal third | Middle third | Cervical third |
|---|---|---|---|---|
| Maxilla (21 patients, 63 teeth) | 14.62 ± 17.49 | 20.89 ± 24.07 | 29.87 ± 22.07 | 36.75 ± 21.89 |
| Mandible (21 patients, 63 teeth) | 11.95 ± 14.61 | 21.75 ± 19.91 | 27.57 ± 23.07 | 26.62 ± 21.79 |
| $P$-value | $t = 0.93$, df = 124<br>$P = 0.35$ | $t = 3.32$, df = 124<br>$P = 0.02$* | $t = 0.57$, df = 124<br>$P = 0.57$ | $t = 2.60$, df = 124<br>$P = 0.010$* |

threshold value for females was lower than for males. The same tendency was observed in the maxillary arch (Table 2).

The mean threshold value for mandibular teeth was lower than the values for the maxillary teeth at all placement sites, except at the incisal third placement where the threshold value was evoked at a much lower value in the maxillary teeth than in the mandibular teeth ($P = 0.02$) (Table 3). However, the difference at the cervical one third was statistically significant, whereas it was not at the incisal third.

In both arches, the subjects in the 41-50-year age band required the lowest amount of electric current to evoke a sensation, though this was not statistically proven ($P = 0.87$). After the 50th year, subjects required higher electric current to evoke a sensation, and the greatest amount was required in the 61-71-year age band. Surprisingly, the 18-20-year age band required higher current ($P = 0.02$) than the 21-30-year age band ($P = 0.01$) to evoke a sensation (Table 4).

Table 4 The mean threshold value of EPT to evoke sensation by age band, arch and gender

| Age (Years) | Arch | | *P*-value |
|---|---|---|---|
| | Mandible | Maxilla | |
| 18-20 (3)<br>F = 2, M = 1 | 31.81 ± 21.74 | 22.10 ± 17.45 | $t$ = 2.4, df = 94, $P$ = 0.02* |
| 21-30 (4)<br>F = 2, M = 2 | 17.55 ± 17.29 | 28.87 ± 22.76 | $t$ = 2.67, df = 70, $P$ = 0.01* |
| 31-40 (3)<br>F = 1, M = 2 | 22.42 ± 23.34 | 28.69 ± 24.54 | $t$ = 1.10, df = 70, $P$ = 2.74 |
| 41-50 (6)<br>F=5, M=1 | 16.00 ± 13.96 | 15.38 ± 11.49 | $t$ = 0.17, df = 46, $P$ = 0.86 |
| 51-60 (3)<br>F = 2, M = 1 | 25.17 ± 25.63 | 29.25 ± 23.60 | $t$ = 0.70, df = 70, $P$ = 0.48 |
| 61-71 (2)<br>F = 2, M = 0 | 37.71 ± 25.81 | 37.88 ± 27.80 | $t$ = 0.02, df = 46, $P$ = 0.98 |
| Female (14) | 20.20 ± 19.42 | 26.02 ± 22.54 | $t$ = 2.53, df = 334, $P$ = 0.012* |
| Male (7) | 25.50 ± 23.51 | 32.06 ± 23.73 | $t$ = 1.80, df = 166, $P$ = 0.70 |
| *P*-value | $t$ = 1.90, df = 250, $P$ = 0.05* | $t$ = 1.97, df = 250, $P$ = 0.05* | |

## Discussion

Research replication is one of the instruments used in advancing knowledge. While there may be an avalanche of existing literature on a subject, we must not fail to recall that no two studies are ever the same. The present study typifies this scenario. In the present study, the sample size, population characteristics and study design, differ from those of Bender et al. (14), Al-Salman (20), and Lin et al. (8). Twenty-one subjects were employed in the present work, while Bender et al. (14), Al Salman (20), and Lin et al. (8) recruited 53, 20, and 20 subjects, respectively. Concerning population characteristics, the age range of 18-71 years of the present study differs from that of the above three studies, which were 11-81 years, 20-41 years, and 20-25 years, respectively. Moreover, gender distribution in all the studies varied. Furthermore, the design of the present study is peculiar, because all subjects taking narcotics, alcohol or NSAIDs, as well as those with history of mental and emotional instability were excluded from the study. Most importantly, and above all, the present study is the first of its kind in Black Africa and it is hoped that this will be beneficial to the clinicians in the continent.

However, works of this nature are not exempt from limitations of debatable validity, especially when many variants in the oral environment and teeth are involved (21). Moreover, various physical factors such as enamel and dentine morphology, tooth surface conditions, and the complex oral environment may result in false positive and negative data (21,22).

There are some concerns regarding the optimal point for placement of the probe tip. The threshold value is reached when adequate number of nerve fibers are stimulated, so the sensation would be greater where the density of neural distribution is higher (10,14). Even in the same subject and same tooth, previous authors (12,14) showed that the basic differences among the four test sites are the thickness of enamel and the number of nerve fibers in the underlying pulp. Lilja (12) has shown that enamel is thinnest incisally with the highest concentration of neural elements in the pulp horns, while in the cervical area, the number of nerve fibers decrease. This explains why the threshold value was lower at the incisal region than in the cervical area (13,23).

There is no consistency among studies regarding the optimal placement site of the probe. However, several authors have shown that EPT produces the most consistent results when the probe is placed on the incisal/cuspal edge of the teeth (8,14,18,24,25). Other studies have shown that the optimal placement is the incisal third (22,26), the middle third (26,27), or the cervical third (28,29).

The reasons given by authors (12-14) to explain why the incisal-edge placement of the electrode gave the lowest value of the readout include the thin enamel at the incisal edge, high concentration of neural elements, and the straight course of dentinal tubules at this edge. When the EPT probe tip touches the incisal edge, electric current causes an ionic change across the neural membrane thereby inducing an action potential with a rapid hopping action at the myelinated nerves (30). As in the present study, the pathway for the electric current is thought to be along the lines of the enamel prisms and dentinal tubules, and then through the pulp tissues (31). The thin enamel at the incisal edge offers the least resistance which is overcome easily by electric current. The high concentration of neural elements ensures an early summation effect to be reached, while the straight course of dentinal tubules offers faster flow rate to the electric current. This manifests clinically during the test as the lowest threshold value of the readout.

The grand mean recording of EPT values for all teeth in the present study was lower than that of Bender et al. (14). The age range in the latter study was 11-81 years. The upper age range in that study was high, and immature teeth which lack full development of the plexus of Rashkow were involved (30).

In the present study, the appropriate electrode placement site in anterior teeth was at the incisal edge. This is the site which requires the least amount of electric current to evoke a sensation. The finding of a lower threshold value at incisal edge placement sites and a higher threshold value at cervical third of all teeth in both arches agrees with the reports of Bender et al. (14), but not with those of others (18,19). The incisal edges need the least electric current to evoke sensation probably due to the thinness of the enamel. The electric current applied to the incisal edge of a tooth that has thin enamel encounters less resistance and shorter distance to travel to reach the pulp than in a tooth with thick enamel (14). Enamel belt or decay may be other causes. Lower electric resistance is presented by thin enamel layer (31). The higher threshold value at the cervical region may be due to the lower concentration of neural elements, which decreases progressively from incisal edge to the cervical and radicular areas (11,12). It may be that threshold values are related to the course of dentinal tubules. The orientation of tubules is straight from the incisal edge to the pulp horn, but elsewhere the course of the tubules is somewhat curved and resembles an S in shape (14).

The faster response of mandibular teeth to electric current stimulation agrees with other reports. This may be related to the thinner enamel layer of mandibular teeth. The lower current required to evoke sensation at the maxillary incisal third in the present study may be due to higher neural elements concentration or due to the comparatively thinner enamel layer at the site. Moreover, in this study, canines required higher current to evoke a sensation compared to the other teeth which may be due to their thicker dentin compared to the other teeth (14).

The report of the present work agrees with the report of Bender et al. (14) that increasing age might affect the threshold value. It was beyond the scope of the present work to explain why subjects in the 41-50-year age band required least amount of current to evoke a sensation. The relationship was not statistically significant to require further probing. However, females constituted about 66.7% of the sample population in the present work and the majority of them fell in the 41-50-year age band. The females significantly reacted at lower threshold values than males coupled with their lower pain threshold, which may explain why subjects in this age band required the least amount of current to evoke a sensation in the present study. The authors are conducting ongoing research which may provide more detailed explanations regarding the issue.

The sensation at higher electric currents seen with advancing age may be due to calcification of the root canal system (22) associated with aging or irritation. The present study is unaware of any report suggesting that the sensation of the pulpal afferents is reduced due to calcification of root canal system. Rather, Bender et al. (14) reported that with age, there is a gradual decrease in size of the pulp chamber and the number of nerve fibers of the pulp, probably because of increased reparative dentine deposition. On the other hand, Moody et al. (32) reported that presence of pulp stone or diffuse calcifications does not affect the threshold of the EPT. However, Segura-Egea et al. (33) warns that age-related increase in threshold value is not to be attributed to changes in the physiological pain system. The lower threshold values seen in females than in males may be due to the lower pain threshold levels of females (34).

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