# ELECTRIC PULP TESTER RESPONSE THRESHOLDS ACROSS ELECTRODE PLACEMENT SITES IN MAXILLARY AND MANDIBULAR ANTERIOR TEETH: A CROSS-SECTIONAL STUDY

Shafqat Ali Shah[1], Fawad Ali Shah[2], Laila Gul[3], Rizwan Ullah Afridi[4], Ayesha Noor[5]

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[1]Professor, Department of Operative Dentistry & Endodontics, Khyber College of Dentistry
[3]PGR, Department of Operative Dentistry & Endodontics, Khyber College of Dentistry, Peshawar
[4]Ex-PGR, Operative Dentistry & Endodontics, Khyber College of Dentistry
[5]PGR-Operative Dentistry & Endodontics, Khyber College of Dentistry, Peshawar

**Correspondence**

[2]Fawad Ali Shah, Assistant Professor, Department of Operative Dentistry & Endodontics, Khyber Collegeof Dentistry, Peshawar
: +92-332-2197090
: drfawada@yahoo.com

***ABSTRACT***

***OBJECTIVES***

*To compare the Electric Pulp Tester (EPT) response thresholds at different electrode placement sites (incisal edge, third, middle third, and cervical third) in maxillary and mandibular anterior teeth.*

***METHODOLOGY***

*This cross-sectional study was carried out from December 2022 to March 2023. This study included individuals from the age range of 18 – 60 years. Six teeth of 60 individuals were assessed in the study. Randomly, either the right or left side of the arch was selected. EPT was performed on each tooth at four different sites (incisal edge, incisal third, middle third, cervical third, labially). The reading was noted when the individual felt tingling or warmth in the tooth. The digital readout at which the participant felt the sensation was considered the threshold. The data was analyzed using R/RStudio. Means of variables from each location were compared using ANOVA and Pair sample t Test while the critical level of significance was set at $p \leq 0.05$.*

***RESULTS***

*No statistically significant differences were observed in EPT readings between maxillary and mandibular teeth across the tested regions ($p > 0.05$). In maxillary anterior teeth, significant differences were found across the four areas, with the middle third of central and lateral incisors ($15.77 \pm 8.13$, $p = 0.045$; $16.30 \pm 8.70$, $p = 0.032$) and the cervical third of canines ($17.58 \pm 10.76$, $p = 0.028$) showing the lowest threshold values. In contrast, no significant variations were observed in the mandibular anterior teeth across the four regions ($p > 0.05$).*

***CONCLUSION***

*The middle third of maxillary anterior teeth may be an optimal site for EPT electrode placement. However, no significant differences were noted across regions for mandibular anterior teeth.*

***KEYWORDS:*** *Dental Pulp, Electric Pulp Tester, Electrode Placement Site, Mandibular Anterior Teeth, Maxillary Anterior Teeth, Pulp Sensory Threshold, Response Threshold*

## INTRODUCTION

The accurate assessment of pulp health is a major diagnostic challenge endodontically. Different methods are available for testing the pulpal status depending on clinical situations.[1] Examples are thermal tests, such as cold and warm tests, laser Doppler flowmeter, dual wavelength spectrophotometry, measurement of tooth temperature, and pulse oximetry.[2] The electric pulp test (EPT) is a pulp sensitivity test used to assess the health of the dental pulp.[3] The A beta and delta fibers, which are the pulp's myelinated nerve fibers, are stimulated when a current is delivered from the electric pulp tester through the enamel and dentin.[4] A current of more excellent value is needed to promote the unmyelinated C-fibers in the core of the pulp.[5] The electric pulp tester is a sensitivity test, i.e., it is based on assessing the response of the sensory fibers to electric current. The vascular supply to the pulp cannot be measured with this test.[6] The Electric Pulp Test is a sensitive technique that will give false responses if improperly performed. The most essential requirements for conducting this test include a suitable probe application method, sufficient stimulation by the current, and careful interpretation of results.[7] The tooth should be isolated individually, ideally with the rubber dam to stop the flow of current to the gingiva, and a medium should be applied to the tooth to ensure the conduction of maximum current.[8] Care should be exercised in the presence of metallic restorations on adjacent teeth as electric current can be conducted through these contacting metallic restorations.[9] Factors relating to the patients also affect the results of EPT, e.g., a false positive response may be produced in a young or anxious patient due to the expectation of feeling an unpleasant sensation. Different Narcotic drugs and alcohol can also affect EPT responses.[10] Some concerns remain regarding the most suitable site for placing the

probe tip. Ideally, the probe tip should be placed at a site with the highest density of neural distribution. This will lead to the stimulation of sufficient nerve fibers at the lowest electric current.[11] Different sites are proposed as the most suitable sites for probe placement.[12] The middle thirds of the crowns of anterior teeth were found to be stimulated by minimum electric current, as reported by Jacobson.[13] However, Cooley and Robinson found the cervical area the most suitable probe placement.[14] However, Bender found that in anterior teeth, the incisal edge is the ideal place for the electrode to stimulate nerve fibers at the lowest current.[15] The tip of the buccal cusp was found to be an appropriate site for electrode placement on first molar teeth in a study by Kalhoro et al.[16] There is a lack of literature identifying the most suitable placement site for the EPT electrode in anterior teeth among the Pakistani population. Furthermore, international studies provide conflicting evidence regarding the optimal site. In addition to the suitable site for electrode place, This study also explored the influence of age and sex on electric pulp response within the context of our population.

## METHODOLOGY

This study was carried out in the department of Operative Dentistry and Endodontics, Khyber College of Dentistry, Peshawar, over a 4 4-month from March 2023 to June 2023. Approval from the ethical committee of the Khyber College of Dentistry, vide letter No 18/ADR/KCD, was obtained. The sample size for this study was determined based on previous literature and statistical considerations. Bender et al.[15] analyzed 12 anterior teeth in 53 subjects, while Kalhoro *et al*.[16] conducted their study on 40 subjects, focusing on premolar teeth. To ensure adequate power and generalizability of findings, the sample size calculation was done using Epi Info, considering a 95% confidence level, 80% power, and an expected effect size based on prior studies. It was calculated as 60 subjects, with six anterior teeth per subject. The age range for the study was 18 – 60 years. Subjects were selected using a consecutive sampling technique from the Operative Dentistry and Endodontics outpatient department, Khyber College of Dentistry. Patients having three Periodontally sound permanent maxillary and three permanent mandibular anterior teeth, which are free of restorations and caries, were included in the study. While teeth having a history of orthodontic treatment or trauma, individuals who were on narcotics, alcohol or non-steroidal anti-inflammatory drugs (NSAIDS) and individuals suffering from mental or emotional instability were excluded from the study. Each subject was examined, and three maxillary anterior teeth and three mandibular anterior teeth (a total of 6 teeth) were selected for the procedure from each subject. Using a simple random method by lottery, the side of the arch (either left or right maxillary or mandibular arch) was selected. Cotton rolls were used to isolate and dry the six anterior teeth. The same electric pulp tester (C-pulse, Foshan COXO Medical Instrument Co. Ltd, Guangdong, China) was used on all subjects according to the manufacturer's instructions. The machine read from 0–80 units, and the rate of increase was set to 2 to allow accurate determination of the first perception of the stimulus. The electrode tip was coated with fluoride gel (Fluocal; Septodont, France). The circuit was completed with a lip clip attached to the individual's lip, and the gloved researcher conducted the test. A gentle stimulus was applied to the tooth until the individual felt a tingling, stinging, warmth or heat in the tested tooth. The digital display readout of the pulp tester at which the individual felt the sensations was defined as the threshold. Four sites (incisal edge, incisal third, middle third, and cervical third), labially on each tooth, were tested. Four recordings were made on the labial surface of each site in sequence, starting from the incisal edge. At least one minute was allowed to elapse before the tooth was revisited to eliminate the phenomenon of nerve accommodation. The means of the four recordings from each site were scored. Data Was analyzed using R/R Studio for statistical analysis. Descriptive statistics, including mean and standard deviation, were calculated for the EPT readings at each site. To compare between maxillary and mandibular teeth, A paired sample t-test was conducted to assess differences in EPT readings for corresponding regions between maxillary and mandibular teeth One-way ANOV A was performed for each tooth type to evaluate the suitable site for electrode placement. A linear regression model was applied by adding a Scatter Plot with a Regression Line to assess the relationship between age and EPT readings, including a 95% confidence interval to highlight uncertainty. A significance level of $p \leq 0.05$ was set for all statistical tests.

## RESULTS

Out of 60 participants, the mean age was 30.68 ± 10.93 years. Most participants were male (37, 61.67%) compared to females (23, 38.33%). The comparison of Electric Pulp Testing (EPT) readings between maxillary and mandibular teeth across different regions revealed no statistically significant differences. For the maxillary central incisors, the EPT readings in the incisal edge, incisal third, middle third, and cervical third regions showed mean values of 22.12 ± 10.37, 17.55 ± 8.50, 15.77 ± 8.13, and 15.90 ± 9.36, respectively, compared

to 19.37 ± 8.93, 17.98 ± 8.71, 16.00 ± 8.39, and 16.05 ± 9.95 for the mandibular central incisors ($p > 0.05$). Similar trends were observed for the lateral incisors and canines, with no significant differences in EPT readings across all regions ($p > 0.05$). These findings indicate no notable variation in pulp responsiveness between maxillary and mandibular teeth across the areas tested. Detailed results are presented in Table 1, while Table 2 compares EPT readings across different tooth types and regions. When analyzing EPT readings across different tooth types and regions, statistically significant differences were observed in maxillary teeth. For the maxillary central incisors, lateral incisors, and canines, EPT readings varied significantly among the incisal edge, incisal third, middle third, and cervical third regions, with p-values of 0.045, 0.032, and 0.028, respectively. In contrast, no statistically significant variation in EPT readings was observed across the areas for mandibular teeth, including central incisors, lateral incisors, and canines ($p > 0.05$). Figure 1 demonstrates a positive linear relationship between age and the mean EPT readings. A regression line with a slight upward slope indicates that EPT readings increase with age. The shaded area around the regression line represents the 95% confidence interval, emphasizing the range of uncertainty in the predicted values. Despite the positive trend, the scattered data points suggest considerable variability, indicating that factors other than age may influence EPT values. Figure 2 illustrates the distribution of EPT readings for male and female participants. The median EPT reading for males is slightly higher than for females, though both groups exhibit considerable variability. The interquartile range (IQR) for females is broader, indicating more significant variability in readings than males. Outliers are present in both groups, with males showing several high values reaching approximately 80. While the distribution for males is more concentrated, the readings for females are more dispersed, with most clustered below 40.

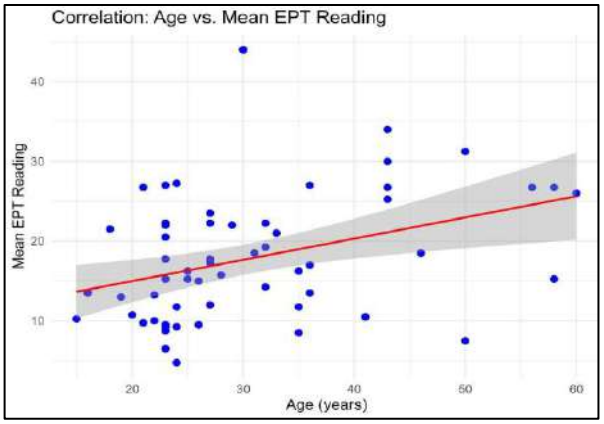


**Figure 1: Correlation Age vs Mean EPT Reading**

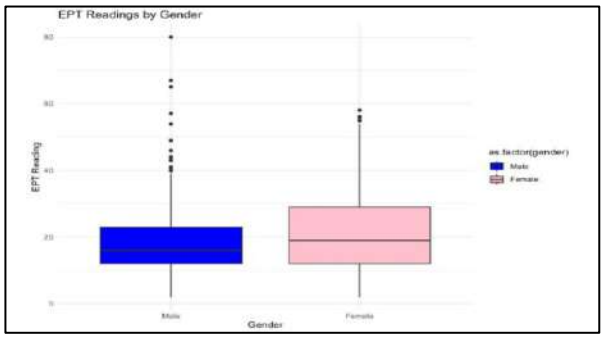


**Figure 2: Gender-Based Differences in Electronic Pulp Testing (EPT) Readings**

**Table 1: Comparison of Electric Pulp Testing (EPT) Readings between Maxillary and Mandibular Teeth**

| Tooth | Region | Maxillary | Mandibular | p-Value* |
|---|---|---|---|---|
| | | Mean ± SD | Mean ± SD | |
| Central Incisor | Incisal Edge | 22.12 ± 10.37 | 19.37 ± 8.93 | 0.26 |
| | Incisal Third | 17.55 ± 8.50 | 17.98 ± 8.71 | 0.20 |
| | Middle Third | 15.77 ± 8.13 | 16.00 ± 8.39 | 0.81 |
| | Cervical Third | 15.90 ± 9.36 | 16.05 ± 9.95 | 0.82 |
| Lateral Incisor | Incisal Edge | 21.15 ± 9.23 | 18.78 ± 8.35 | 0.15 |
| | Incisal Third | 18.53 ± 8.85 | 18.53 ± 9.51 | 0.14 |
| | Middle Third | 16.30 ± 8.70 | 17.68 ± 9.70 | 0.18 |
| | Cervical Third | 16.63 ± 10.43 | 15.67 ± 9.39 | 0.29 |
| Canine | Incisal Edge | 24.55 ± 11.67 | 23.55 ± 10.46 | 0.82 |
| | Incisal Third | 21.90 ± 12.10 | 20.83 ± 9.84 | 0.92 |
| | Middle Third | 19.73 ± 10.21 | 18.12 ± 10.29 | 0.15 |
| | Cervical Third | 17.58 ± 10.76 | 18.15 ± 11.00 | 0.97 |

*Pair Sample t Test

**Table 2: Comparison of Electric Pulp Test Readings Across Different Tooth Types and Regions**

| | Incisal Edge | Incisal Third | Middle Third | Cervical Third | P value* |
|---|---|---|---|---|---|
| **Maxillary Central Incisor** | 22.12 ± 10.37 | 17.55 ± 8.50 | 15.77 ± 8.13 | 15.90 ± 9.36 | 0.045 |
| **Maxillary Lateral Incisor** | 21.15 ± 9.23 | 18.53 ± 8.85 | 16.30 ± 8.70 | 16.63 ± 10.43 | 0.032 |
| **Maxillary Canine** | 24.55 ± 11.67 | 21.90 ±12.10 | 19.73 ± 10.21 | 17.58 ± 10.76 | 0.028 |
| **Mandibular Central Incisor** | 19.37 ± 8.93 | 17.98 ± 8.71 | 16.00 ± 8.39 | 16.05 ± 9.95 | 0.067 |
| **Mandibular Lateral Incisor** | 18.78 ± 8.35 | 18.53 ± 9.51 | 17.68 ± 9.70 | 15.67 ± 9.39 | 0.082 |
| **Mandibular Canine** | 23.55 ± 10.46 | 20.83 ± 9.84 | 18.12 ± 10.29 | 18.15 ± 11.00 | 0.052 |

*One-way ANOVA

## DISCUSSION

This study compared Electric Pulp Tester (EPT) response thresholds at different electrode placement sites (incisal edge, third, middle third, and cervical third) in maxillary and mandibular anterior teeth. Our findings revealed statistically significant differences in EPT thresholds across the four regions of anterior maxillary teeth, with the middle third of central and lateral incisors and the cervical third of canines exhibiting the lowest threshold values. In contrast, no significant differences were observed among the tested regions of mandibular anterior teeth. Additionally, a positive linear relationship was noted between age and EPT thresholds, suggesting a slight increase in response values with advancing age. However, considerable variability indicates that other factors may also influence pulp response. Different views and thoughts about the appropriate location for placing EPT tip exist. Upon reaching sufficient nerve fiber stimulation, a threshold value is reached.[12] Different authors have demonstrated that the difference in the four sites for EPT testing is due to the number of nerve fibers and the enamel thickness.[10] Lilja[27] found that the enamel is fragile in the incisal area and has a high concentration of nerve fibers in the pulp horns. At the same time, the neural element decreases in the cervical region. There is no correspondence between the studies about the optimal placement site of the probe. Some researchers[7] have reported duplicate records when EPT is placed on the incisal/ cuspal edge of the teeth. Several other authorshave reported that the incisal third, the middle third, or the cervical third are the optimal sites for EPT probes.[10,12,16] Thin enamel at the incisal edge, high density of nerve fibers, and linear course of dentinal tubules are main factors postulated by the authors13, 17 to demonstrate why the incisal edge produces lower threshold values when the probe tip of EPT is placed at the incisal edge. Statistically significant differences were found in maxillary teeth, demonstrating that the middle third responds at a lower EPT reading in the maxillary central and lateral incisor. In contrast, the cervical third of maxillary canine responds to lower values. The mandibular teeth showed no statistically significant result concerning different sites. A study conducted by Harikumar et al. showed that the incisal edge was the optimal site for electrode placement in anterior teeth, in contrast to the present study. This may be due to electric pulp testing in teeth having fluorosis in the mentioned study because enamel is hyper-mineralized in fluorosis, due to which fluid concentration in the dentinal tubules may be influenced, which is considered to play a significant part in the electric impulse conduction. An in vitro study was conducted by Jacobson to evaluate the optimum site for the placement of electrodes with incisors and premolars that were extracted with measurements from an oscilloscope.[12] He proposed that the optimum site for applying EPT probe for maxillary teeth was the incisal 2/3 of the incisors and the occlusal 2/3 of the buccal surface of premolars. These results are in contrast to the present study. This might be because the survey was in vitro, and the neural concentration was not well thought-out. Christopher et al.[13] had done a clinical study on suitable placement of the electrode for EPT of anterior teeth in the Nigerian population, which showed that the incisal edge is the optimal site of placement of the electrode in anterior teeth. While in the present study, there is no statistically significant difference for electrode placement between different sites in mandibular anterior teeth, there is a statically significant difference in maxillary anterior teeth. This difference may be due to the difference in the population and, secondly, the small sample size of 21 as compared to the present study. Aging or irritation may cause calcification, leading to a higher current required for feeling EPT sensations.[28] This study showed that with increasing age, the threshold level of EPT current with which the tooth responded increased slightly, showing a correlation between age and EPT readings. This is in contrast to the study done by Moody et al[29], who concluded that neither pulp stones in the pulp chamber nor diffuse calcification in the root canal influence the EPT threshold However, study done by Segura-Egea et al.[20] had suggested that variations in the threshold values due to ageing should not accredit to changes in the physiology of the pain system.

## LIMITATIONS

This study has an ethnicity, diet, and the drug effects on metabolic syndrome in schizophrenic patients were not determined.

## CONCLUSIONS

This study concluded that regional differences in EPT thresholds are significant in anterior maxillary teeth, with the middle third showing lower thresholds for central and lateral incisors and the cervical third for canines. No significant differences were observed across regions in the mandibular anterior teeth. Further research with larger sample sizes and diverse populations is recommended to validate these findings and explore additional factors influencing EPT thresholds.

**CONFLICT OF INTEREST:** None

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## CONTRIBUTORS

1. ***Shafqat Ali Shah*** **-** *Concept & Design; Supervision; Final Approval*
2. ***Fawad Ali Shah*** **-** *Data Analysis/Interpretation*
3. ***Laila Gul*** **-** *Data Acquisition*
4. ***Rizwan Ullah Afridi*** **-** *Drafting Manuscript*
5. ***Ayesha Noor*** **-** *Data Acquisition; Critical Revision*