

Comparison of Electric Pulp Test Threshold Values at Different Sites in Immature and Mature Permanent Teeth in 6 to 14-year-old Children: A Research Protocol

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ABSTRACT

Introduction: A crucial step in determining the appropriate treatment for a tooth is to assess the viability and overall status. In immature permanent teeth, where innervation is not fully developed, the electric pulp test can still be utilised by adjusting and increasing the threshold values to obtain a reliable response.

Need of the Study: Previous studies on electric pulp testing in immature permanent teeth have shown mixed results due to variations in patient cooperation and differences in testing methodologies, which further contribute to inconsistent threshold values. Due to insufficient evidence in the literature regarding correct site placement, as well as the unavailability of reference threshold values for such immature teeth, this study will be conducted.

Aim: To evaluate and compare the electric pulp test threshold values obtained at different sites in immature and mature permanent incisor and molar teeth.

Materials and Methods: The present cross-sectional study will be carried out at Department of Paediatric and Preventive

Dentistry of Sharad Pawar Dental College and Hospital, Sawangi (Meghe), Wardha, Maharashtra, India from November 2025 to April 2026. Ninety immature and 90 mature permanent teeth will be classified based on the status of root completion of 6 to 14-year-old children. The teeth will be isolated with a rubber dam by an examiner. A standard Electric Pulp Tester (EPT) will be used following the manufacturer's guidelines. The probe with conducting medium will be placed on test sites, and children will signal sensation by raising their hand, the corresponding digital reading will be recorded. A trial on a non-study tooth will ensure the child recognises the stimulus. If no response occurs at maximum output, the tooth will be excluded. EPT will be applied at incisal, middle, and cervical thirds of incisors, and mesiobuccal occlusal, middle, and cervical thirds of molars. Threshold values will be evaluated by comparing immature and mature permanent teeth. EPT thresholds will be analysed using tests based on data distribution: repeated measures Analysis of Variance (ANOVA)/Friedman test for within-tooth comparisons, t-test/Mann-Whitney U for between-group comparisons, and Two-way or mixed ANOVA for multiple factors. A p-value of <0.05 will be considered statistically significant.

Keywords: Immature permanent teeth, Mean threshold values, Pulp sensibility testing, Pulp vitality test, Root maturation

INTRODUCTION

The vitality of a tooth's pulp is largely determined by the vascular supply within. The health of the pulp is crucial for maintaining the structural integrity of the tooth, as well as its ability to respond to external stimuli and resist infections [1]. Early identification of pulp-related diseases enables clinicians to implement conservative management strategies, thus minimising potential complications and associated costs that could arise from delayed diagnosis and treatment [2].

Pulp vitality is typically assessed indirectly by evaluating the neural sensitivity of the pulp. Sensibility tests, which involve applying external stimuli such as cold, heat or electrical current to the tooth surface, trigger the nerves within the pulp to gauge its response. Brännström's hydrodynamic theory suggests that nociceptor activation is triggered by the movement of fluid within the dentinal tubules in response to electrical, thermal, mechanical, or osmotic stimuli [3].

However, a more accurate method for evaluating pulp vitality would involve assessing the vascularity of the pulp. Laser Doppler Flowmetry (LDF) and Pulse Oximetry (PO) are designed to evaluate pulpal blood flow and are considered some of the most reliable vitality tests, yielding the best clinical results. Despite their effectiveness, PO and LDF are not routinely used in clinical practice. The use of PO is limited by the lack of commercially

available dental-specific pulse oximeters, and LDF is hindered by the high cost and the technical expertise required for accurate results [4].

Sensibility testing in immature teeth is challenging because their larger pulp chambers, incomplete root development, and greater sensitivity can produce exaggerated or misleading responses, especially to thermal stimuli. Thermal tests lack graded responses and do not reflect the true level of pulp vitality. An ideal vitality test should be simple, accurate, standardised, and objective. The EPT is widely used to stimulate A-delta fibers and assess neural sensitivity by applying an electric current to the tooth, but it does not provide information on pulpal blood flow. Although it can produce sensations such as pain, warmth, or tingling that indicate a vital pulp, EPT primarily evaluates nerve response rather than true vascular vitality [5]. However, in cases of moderate to severe caries affecting the pulp, the EPT may show a diminished or absent response, signaling pulp necrosis or irreversible damage. Similarly, trauma to the tooth-such as fractures, luxation, or intrusion can result in pulp damage due to nerve injury, bruising, or haemorrhage. These types of injuries may lead to pulp inflammation, necrosis, or infection. EPT is used to assess pulp sensibility after such trauma, providing valuable information regarding the health of the pulp tissue in these situations [6].

REVIEW OF LITERATURE

Accurate assessment of pulp vitality is essential in paediatric dentistry, particularly in immature permanent teeth, where ongoing root development and incomplete neural maturation may influence sensibility test responses. Although the EPT is widely used in clinical practice, its threshold values are affected by factors such as tooth maturity, site of probe placement, and tooth type. Saikiran KV et al., investigated site-wise EPT threshold values in anterior teeth and demonstrated that probe placement significantly affects responses. The lowest threshold values were consistently recorded at the incisal third, emphasising the importance of standardised testing sites for the reliable interpretation of EPT results [6].

Çağırır Dindaroğlu F et al., reported significantly higher EPT threshold values in immature teeth compared to mature teeth, indicating reduced neural responsiveness during root development. A strong correlation was observed between EPT, cold test, and PO findings, while arterial oxygen saturation was significantly higher in immature teeth, confirming the influence of root maturity on pulp sensibility outcomes [7]. Turedi I et al., observed that the EPT threshold values decreased progressively with advancing root development. Regardless of maturity stage, the incisal third exhibited the lowest response thresholds, and mandibular incisors showed lower values than maxillary incisors, reinforcing the combined effect of tooth type, maturity, and testing site [8].

Shahi P et al., reported that EPT was less reliable in immature permanent teeth due to false-negative responses. The study highlighted the limitations of EPT in developing teeth and the need for cautious interpretation of threshold values in paediatric patients [9].

Since previous studies of the electric pulp test on immature teeth showed mixed results [7-9] and due to insufficient evidence in the literature regarding correct site placement, as well as the unavailability of reference threshold values for such immature teeth, the present study aims to compare and evaluate the electric pulp test threshold values between immature and mature permanent incisor and molar teeth.

Primary objectives:

- To evaluate the electric pulp test threshold values of immature permanent incisor and molar teeth at different sites.
- To evaluate the electric pulp test threshold values of mature permanent incisor and molar teeth at different sites.

Secondary objective:

- To compare the electric pulp test threshold values between immature and mature permanent incisor and molar teeth thus obtained at different sites.

Null hypothesis: There will be no statistically significant difference in the EPT threshold values obtained at different sites between immature and mature permanent incisor and molar teeth in children aged 6-14 years.

Alternate hypothesis: There will be a statistically significant difference in the EPT threshold values obtained at different sites between immature and mature permanent incisor and molar teeth in children aged 6-14 years.

MATERIALS AND METHODS

A cross-sectional study will be carried out in the Department of Paediatric and Preventive Dentistry of Sharad Pawar Dental College and Hospital, Sawangi (Meghe), Wardha, Maharashtra, India, from November 2025 to April 2026. IEC Approval was obtained from Datta Meghe Institute of Higher Education and Research (DMIHER(DU)/IEC/2025/555) on 07/02/2025.

Inclusion criteria:

- Healthy children aged 6 to 14 years;
- Requiring a panoramic radiograph to supplement clinical examination;

- Showing an accepted level of cooperation;
- Had at least one permanent incisor or molar tooth indicated for the use of the electric pulp test as a measure of vitality;
- Children who didn't use any analgesics.

Exclusion criteria:

- Teeth with caries, fractures, discolouration, enamel defects, restorations, and root-canal treated;
- Patient presenting with a history of trauma;
- Teeth exhibiting signs or symptoms of pulp infection, such as pain on percussion, mobility, or sinus tract;
- Teeth showing signs of pathology on radiograph.

Sample size calculation: Using the following formula;

$$n \geq \frac{\{Z_{(1-\alpha/2)} + Z_{(1-\beta)}\}^2 * (\sigma_1^2 + \sigma_2^2 / r)}{(\mu_1 - \mu_2)^2}$$

Where:

σ_1^2, σ_2^2 - Variances of Group 1 and Group 2

r: Ratio of Group 2 to Group 1

- Alpha (α): 0.01 =2.57

- Beta (β): 0.01 =2.33

- Mean in Group 1 (μ_1) third Incisal in immature Group: 15.54

- Standard Deviation in Group 1 (σ_1): 0.87

- Mean in Group 2 (μ_2) Incisal in mature Group: 12.96

- Standard Deviation in Group 2 (σ_2): 1.78 [8]

- Ratio (Group 2/Group 1): 1

$$n \geq \frac{\{(2.57 + 2.34)^2 * (12.96^2 + 1.78^2/r)\}}{(15.54 - 12.96)^2}$$

- Total sample size is 30, therefore (n=15) in each subgroup.

A minimum of 15 teeth in each subgroup under Group 1 and Group 2 will be included as under:

The subgroups are:

Group 1 (Immature Permanent Teeth)

1. Maxillary central incisor 15 teeth
2. Maxillary lateral incisor 15 teeth
3. Maxillary first molar 15 teeth
4. Mandibular central incisor 15 teeth
5. Mandibular lateral incisor 15 teeth
6. Mandibular first molar 15 teeth

Therefore, total teeth in Group 1 = 90.

Group 2 (Mature Permanent Teeth)

1. Maxillary central Incisor teeth 15 teeth
2. Maxillary lateral incisor teeth 15 teeth
3. Maxillary first molar teeth 15 teeth
4. Mandibular central incisor teeth 15 teeth
5. Mandibular lateral incisor teeth 15 teeth
6. Mandibular first molar teeth 15 teeth

Therefore, total teeth in Group 2 = 90

Thus, each subgroup required a minimum of 15 teeth, leading to the total number 90 teeth in each group. Therefore, the total sample size is 180 teeth.

Group 1 as immature permanent teeth, and Group 2 includes mature permanent teeth. The allocation of teeth into immature and mature groups will not be randomised, as classification will be determined by evaluating panoramic radiographs. Teeth exhibiting incomplete root formation will be categorised as immature, while those with complete root formation will be categorised as mature.

Study Procedure

The selected teeth will be isolated with a rubber dam by one of the skilled paediatric dentists. A Digitest II electric pulp vitality tester

(Parkell, Inc., Edgewood, NY; range 0-64) will be used following manufacturer guidelines. The current will be increased at the lowest possible rate to ensure accurate identification of the initial sensation. The rise in electric current will be set to the threshold level. Toothpaste (Colgate, New York, NY, USA) will be used as a conducting medium, coated on the tip of the probe and placed on the area to be tested, and the current pathway will be completed as per the manufacturer's guidelines. Children will be instructed to indicate any sensation by raising their hands instantly, and the pulp test's digital display readout at that instance should be recorded. An initial test will be conducted on a tooth excluded from the study to ensure that children accurately recognise the sensation produced by electrical stimulus. If the patient failed to recognise any sensation after the digital display reached its highest level in the initial test, the other tooth will be excluded from the study.

Study outcomes: The threshold values for each tested tooth at three different sites i.e., sites incisal, middle and cervical third, on the facial surface of each incisor, and mesio-occlusal buccal third, buccal middle third, buccal cervical third for molar teeth, will be recorded. To avoid nerve accommodation, a recovery period of 1-2 minutes was maintained between tests. Three EPT readings were recorded at each site, and the mean of the values will be recorded.

STATISTICAL ANALYSIS

The data will be gathered and entered into a Microsoft Excel document, and statistical analysis will be carried out using version 23 of IBM Statistical Package for Social Sciences (SPSS) Statistics for Windows (IBM Corp., Armonk, NY, USA). To evaluate the EPT threshold values at different sites within immature permanent incisor teeth and immature permanent molar teeth, repeated measures ANOVA will be used if the data follow a normal distribution; otherwise, the non-parametric Friedman test will be used as an alternative. For

comparison of EPT threshold values between immature and mature permanent incisor and molar teeth at different sites, independent samples t-tests will be used for normally distributed data to assess differences between groups at each site. The Mann-Whitney U test will be employed in case of non-normal data. If comparisons are made simultaneously across multiple sites and between maturity groups, a two-way ANOVA or mixed ANOVA will be considered to evaluate both interactions and main effects. A p-value of <0.05 will be considered statistically significant.

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