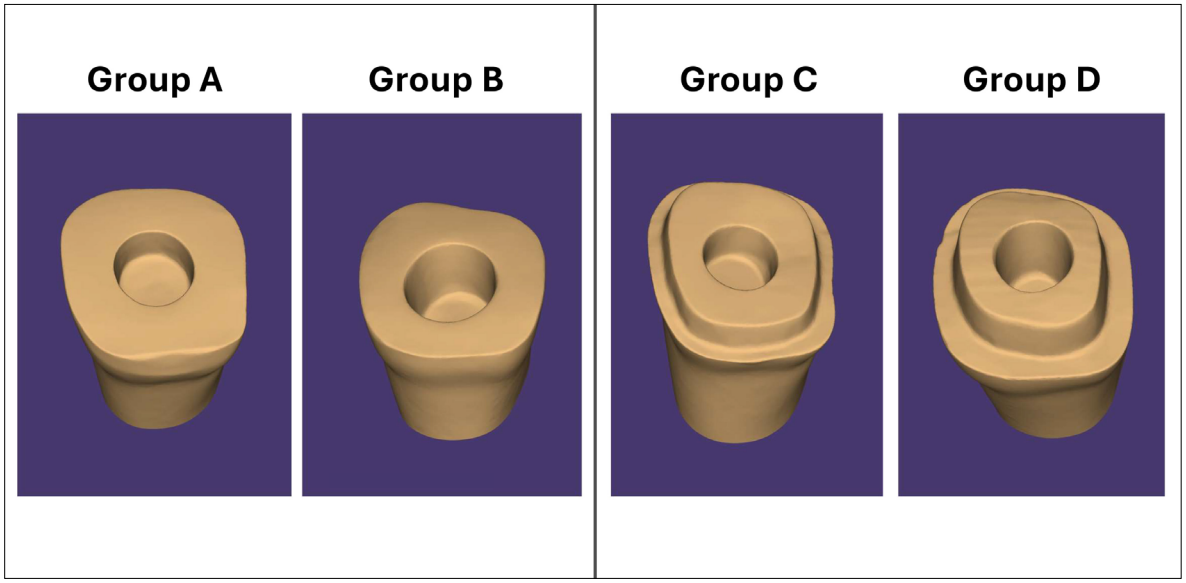
VOLUME: 10 ISSUE: 2 YEAR: 2025

TURKISH ENDODONTIC JOURNAL

E-ISSN 2459-1726



The official Journal of Turkish Endodontic Society

e-ISSN 2459-1726

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ORIGINAL ARTICLE

Turk Endod J 2025;10(2):69–74
doi: 10.14744/TEJ.2025.94830

Women's representation at Turkish endodontic society meetings

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Purpose: This observational study aimed to evaluate the percentage of women invited to speak or present oral presentations at the Turkish Endodontic Society's scientific meetings over a 10-year period (2014–2024).

Methods: The number of male and female keynote or oral presentation speakers from the society's scientific meetings was recorded. Gender distribution and yearly ratios were analyzed using SPSS 25 with Binomial test, Chi-square, and Fisher's Exact test ($p < 0.05$).

Results: A total of 136 speakers from the Turkish Endodontic Society's scientific meetings between 2014 and 2024 were analyzed. Of these, 103 (75.7%) were men, and 33 (24.3%) were women, highlighting a significant gender disparity ($p < 0.001$). No significant change was observed in the proportion of women speakers over the analyzed timeframe ($p = 0.134$).

Conclusion: Regardless of the timeframe, the number of women speakers at scientific meetings organized by the Turkish Endodontic Society remains consistently lower than that of men. While the proportion of women presenting oral sessions was relatively higher, their representation as keynote speakers on the main stage consistently remained low throughout the analyzed period.

Keywords: Endodontics; gender disparity; prensenter; speaker; women representation.

Introduction

Gender equity is not only a fundamental human right (1) but also a key determinant of health and economic development (2). However, societal norms influenced by gender inequality continue to pose challenges to the healthcare sector worldwide (3). These disparities often arise from ingrained social values, biases within healthcare and education systems, and implicit or explicit gender-related influences in scientific research. This issue remains prevalent, particularly in fields such as health and medical sciences (2). These inequalities are also clearly evident in dentistry and dental research (4). The World Health Organization (WHO) defines gender as the socially constructed roles, behaviors, and norms associated with women, men, girls, and boys, which vary across cultures and over time (5).

Despite the increasing participation of women in dental education globally, only 30% to 40% of registered dentists in Europe, Oceania, Asia, and Africa are women (6). Similarly, although the representation of women in academia has improved, full gender equality has not yet been achieved in dental research or professional career pathways (7). Systemic barriers, such as the lack of mentorship, limited peer support, and biases in leadership selection hinder women's advancement. These challenges are compounded

Cite this article as: Karadayı A, Altıntaş El, Basturk FB. Women's representation at Turkish endodontic society meetings. Turk Endod J 2025;10:69-74.

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Submitted: February 12, 2025 Revised: March 13, 2025 Accepted: March 14, 2025 Published: August 13, 2025

by stereotypes and implicit biases, reflecting the struggles faced by other underrepresented groups (8,9).

Particularly in academic leadership positions and among recipients of competitive research grants, the proportion of women remains significantly low (10). Individuals who serve as role models for underrepresented groups in science contribute substantially to their fields by holding influential positions such as key opinion leaders, deans, or department chairs (11-13).

Women's leadership is crucial for organizational success and societal progress, especially in dentistry, where they introduce innovation and inclusive leadership styles (8). Despite these contributions, gender disparities persist, limiting women's access to senior academic roles and reducing their visibility as role models (14,15). Moreover, restricted speaking opportunities reinforce stereotypes of male dominance and discourage women from pursuing leadership (16,17).

In dentistry, leadership frequently involves engagement in professional organizations through committee work, authoritative roles, and speaking engagements (16). Public speaking, particularly at conferences hosted by global organizations, serves as a critical avenue for building credibility, fostering collaboration, and inspiring individuals from similar backgrounds (18,19).

Given the significance of role models in advancing women and underrepresented minorities, this study examines the representation of women as oral presenters and invited speakers on the main stage at Turkish Endodontic Society meetings. It further investigates whether their representation has changed significantly over the past decade. The null hypothesis posits no significant differences in the number of male and female speakers, either as oral presenters or as invited speakers, over time.

Materials and Methods

Study Design

This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines to maintain methodological clarity and transparency (20,21) (Fig. 1).

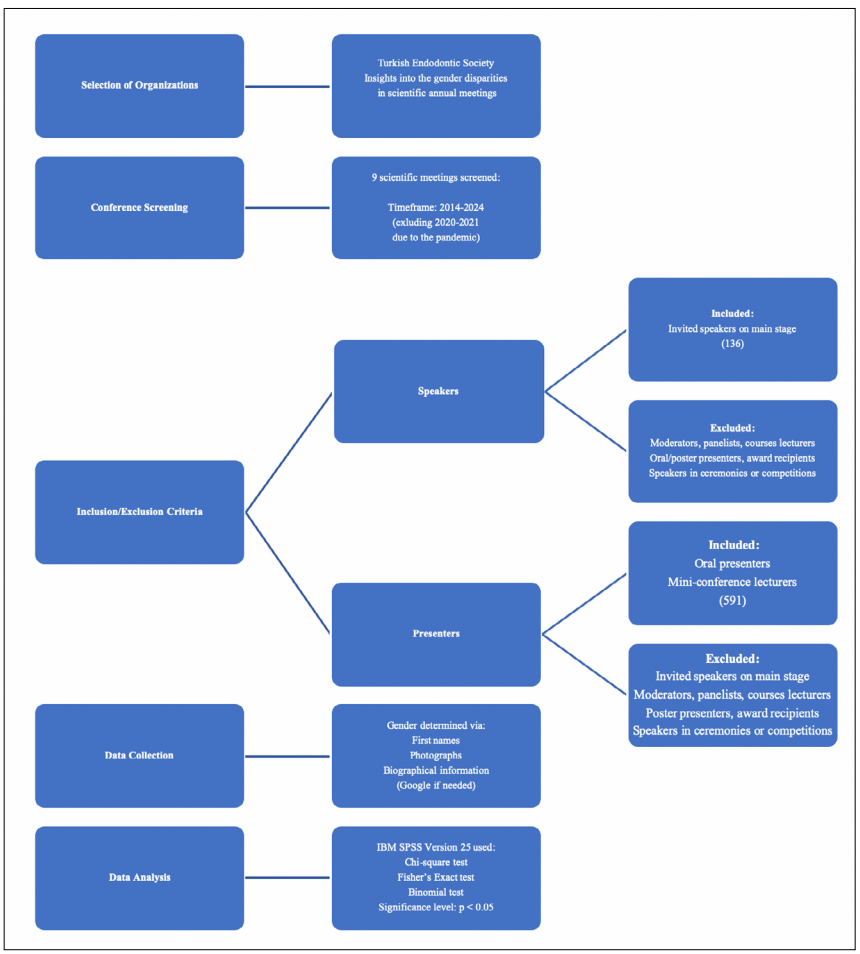

Fig. 1. Study methodology flowchart.

Selection Criteria

This study focused on the Turkish Endodontic Society's congresses and symposiums held over the past 10 years. These events were selected based on their relevance to the study objectives, their inclusion of diverse endodontic topics, and their role in bringing together national and international speakers.

Data Collection

A total of eight events organized by the Turkish Endodontic Society were reviewed, comprising four congresses and four symposiums held between 2014 and 2024. These events alternated annually, with congresses held in one year and symposiums in the next. The analysis included two categories: oral presentations and main-stage invited keynote speeches. Oral presentations, which encompass short conferences, were evaluated separately as they were submitted through individual applications. In contrast, main-stage invited keynote speeches were analyzed independently. Moderators, panelists, country representatives, and speakers participating in poster presentations, award acceptance speeches, opening/closing ceremonies, and competitions were excluded from the analysis.

Gender Identification

Speaker gender was identified using details from the scientific programs of each event. Gender was determined primarily through photographs, and when these were unavailable or unclear, biographical information was sourced through Google searches for confirmation.

Statistical Analysis

Data analysis was performed using IBM SPSS Version 25. One sample Binominal test was applied to compare the ratios of male to female speakers, and presenters. Chi-square and Monte Carlo corrected Fisher's Exact tests were used to analyse gender distribution by years. Statistical significance was set at $p < 0.05$.

Results

Between 2014 and 2024, 136 speakers on main stage meeting the inclusion criteria were analyzed from the Turkish Endodontic Society organization. A significant gender disparity was observed over this 10-year period ($p < 0.001$). Of the 136 speakers on main stage, 103 (75.7%) were men, while 33 (24.3%) were women (Table 1).

Between 2014 and 2024, 591 presenters meeting the inclusion criteria were analyzed from the Turkish Endodontic Society organization. A significant gender disparity was observed over this 11-year period ($p < 0.001$). Of the 591 presenters, 380 (64.3%) were women, while 211 (35.7%) were men (Table 2).

No significant difference in gender distribution for speakers was observed across the years ($p = 0.134$). The proportion of male and female speakers are listed in the Table 3.

A significant difference in gender distribution for oral presenters was observed across the years ($p < 0.001$). The proportion of male and female presenters are listed in the Table 4.

Discussion

The null hypothesis, which proposed no significant difference in the number of male and female speakers over time at Turkish Endodontic Society events, was partially rejected. Statistical analysis revealed that oral presentations favored women, while main-stage invited speeches displayed a male-dominated trend. Also over the ten-year

Table 1. Comparison of male and female speakers on main stage ratios over a 10-year period

Gender	Frequency (n)	Percentage (%)	Test Statistic	p*
Male	103	75.7	33.000	< 0.001
Female	33	24.3		
Total	136	100		

*One sample Binominal Test.

Table 2. Comparison of Male and Female Presenters Ratios Over a 11-Year Period

Gender	Frequency (n)	Percentage (%)	Test Statistic	p*
Male	211	35.7	380.000	< 0.001
Female	380	64.3		
Total	591	100		

*One sample Binominal Test.

Table 3. Gender distribution by year for speakers on main stage

Year	Meeting Type	Male	Female	Test Statistic	p
2014	Congress	7 (50%)	7 (50%)	11.655	0.134
2015	Symposium	8 (88.9%)	1 (11.1%)		
2016	Congress	6 (54.5%)	5 (45.5%)		
2017	Symposium	10 (90.9%)	1 (9.1%)		
2018	Symposium	15 (88.2%)	2 (11.8%)		
2019	Congress	32 (78%)	9 (22%)		
2022	Symposium	7 (87.5%)	1 (12.5%)		
2023	Congress	11 (78.6%)	3 (21.4%)		
2024	Symposium	7 (63.6%)	4 (36.4%)		
Total		103 (75.7%)	33 (24.3%)		

* Monte Carlo Corrected Fisher's Exact Test, Frequency (Percentage)

Table 4. Gender distribution by year for presenters

Year	Meeting Type	Male	Female	Test Statistic	p
2014	Congress	32 (54.2%)	27 (45.8%)	52.176	<0.001
2015	Symposium	9 (64.3%)	5 (35.7%)		
2016	Congress	41 (56.9%)	31 (43.1%)		
2017	Symposium	13 (36.1%)	23 (63.9%)		
2018	Symposium	29 (37.7%)	48 (62.3%)		
2019	Congress	43 (37.1%)	73 (62.9%)		
2022	Symposium	13 (17.3%)	62 (82.7%)		
2023	Congress	18 (26.1%)	51 (73.9%)		
2024	Symposium	13 (17.8%)	60 (82.2%)		
Total		211 (35.7%)	380 (64.3%)		

* Monte Carlo Corrected Fisher's Exact Test, Frequency (Percentage).

period, no significant change was observed for main-stage invited speeches, while an increasing trend was found for female speakers in oral presentations. Although the Turkish Endodontic Society has 313 male and 538 female registered members, which provides valuable demographic insight, it is important to note that not all endodontists in Turkey are necessarily registered with the society, presenting a potential limitation.

This study analyzed the scientific meetings organized by the Turkish Endodontic Society between 2014 and 2024, including both congresses and symposiums. No distinction was made between these event types, as both are considered key scientific gatherings of the society. Due to the COVID-19 pandemic, no congresses or symposiums were held in 2020 and 2021 in Turkey. Despite this interruption, trends in female representation were evaluated across the available years within the study period. Table 3 and Table 4 outlines the years in which these events took place.

The average female representation among main stage speakers during the evaluated years was 24.3%, reflecting a significant gender imbalance. Similar trends have been observed in other academic (22), medical (23) and dental fields (14,24) such as prosthodontics (25), orthodontics (26). A study analyzing 14 conferences found that female representation was generally low, with only three events classified as gender-balanced, including endodontics (14). However, our study did not confirm a balanced representation in endodontic conferences. Consistent with this pattern, a study in orthodontics also confirmed a significant gender disparity among invited speakers at annual conferences, while no significant gender differences were observed in oral presentations (26). These findings align with the results of our study.

Our analysis revealed significant gender differences in representation during the study period. Women were more frequently represented in oral presentations, while men predominated in main-stage invited speeches. This disparity highlights the contrasting dynamics between individually driven submissions for oral presentations and com-

mittee-selected main-stage speakers. Oral presentations, being based on personal initiative, tend to show greater gender diversity. In contrast, the selection of main-stage speakers, managed by scientific program committees predominantly led by men, perpetuates male dominance in key speaking roles (25). It has been previously reported that an increased representation of women on medical conference organising committees may have a positive impact on the gender balance of invited speakers (27).

The persistent underrepresentation of women in dentistry reinforces gender inequities in leadership (15). Achieving gender equality requires balanced representation in scientific organizations and decision-making processes. This begins with recognizing existing disparities and implementing targeted policies to promote inclusivity. Clear guidelines for speaker selection and leadership appointments, along with efforts to raise awareness of diversity's value, can enhance equitable participation.

Incentives are also essential. Offering benefits such as prestige, financial support, and professional growth opportunities can encourage organizations to prioritize gender diversity (13). Enforcing accountability measures, such as reputational consequences for failing to meet diversity standards, is crucial for driving meaningful change. The lack of structured incentives and accountability has significantly slowed progress in addressing gender imbalances.

By implementing targeted strategies, dental organizations can expand career opportunities for women while strengthening the field through a more diverse workforce, improved research outcomes, and enhanced education. A key step toward gender equity is ensuring that the proportion of female speakers reflects their representation in the field. This approach not only addresses immediate disparities but also paves the way for long-term leadership opportunities, fostering an inclusive and balanced scientific community.

Conclusion

This study revealed a persistent gender imbalance in speaker representation at Turkish Endodontic Society meetings, with women favorably represented in oral presentations but underrepresented on the main stage. While no significant changes were observed in the representation of invited speakers over the selected time frame, an increasing trend in female participation was noted in oral presentations. These findings highlight the need for targeted efforts to further promote gender equity in conference representation.

Authorship Contributions: Concept: A.K., F.B.B.; Design: A.K., F.B.B.; Supervision: F.B.B.; Materials: A.K., E.I.A.; Data: A.K., E.I.A.; Analysis: A.K.; Literature Search: A.K., E.I.A., F.B.B.; Writing: A.K.; Critical Revision: F.B.B.

Acknowledgements: We sincerely thank Prof. Dr. Ali Keleş, Assoc. Prof. Ayça Yılmaz, and Ayçıl Yeşilırmak for their valuable support in providing access to the association-related data.

Use of AI for Writing Assistance: Not declared

Source of Funding: None declared.

Conflict of Interest: None declared.

Ethical Approval: Ethical approval was not required for this study.

Informed consent: Written informed consent was obtained from patients who participated in this study.

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ORIGINAL ARTICLE

Turk Endod J 2025;10(2):75–79
doi: 10.14744/TEJ.2025.56933

The evaluation of pulse oximetry measurement in determining the health status of pulp in primary molar teeth

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Purpose: The purpose of this study is to establish whether there is any correlation between the health status of pulp and the oxygen saturation values measured by pulse oximetry in primary molar teeth. It is aimed to evaluate the effectiveness of the oxygen saturation values in diagnosing the pulp status.

Methods: The study was conducted on 95 lower second primary molar teeth from 77 patients (aged between 6–9 years). Teeth were assigned into four groups: healthy pulp (positive control, n = 25), reversible pulpitis (n = 25), irreversible pulpitis (n = 25), and negative control (n = 20). The oxygen saturation levels of all teeth in the four groups were measured using pulse oximetry.

Results: The paired comparisons revealed that the positive control group had a higher average value compared to the pulpitis groups (reversible and irreversible; $p < 0.001$). There was no significant difference between the reversible and irreversible pulpitis groups ($p = 0.275$).

Conclusion: Pulse oximetry can be used for the distinction of healthy pulp and pulpitis; however, the stage of the pulpitis cannot be determined through this method in primary molar teeth.

Keywords: Diagnosis; inflammation; primary teeth; pulse oximetry; pulpitis.

Introduction

The pathological status of the pulp must be correctly diagnosed so that the treatment method can be accurately determined in teeth with deep dentin caries and affected pulp (1-3). In current clinical practice, this is performed through vitality tests in addition to extensive medical history, extraoral, intraoral, and radiographic examinations (4).

The vitality tests commonly used for the diagnosis of the pulpal status are only able to provide subjective information about the neural status of the pulp but no information about the vascular structure of the tooth. During inflammatory processes, the neural structures of the pulp are more resistant to infections compared to vascular structures. Thus, false-positive results can be obtained from a conventional vitality test due to intact nervous tissue, although inflammation has started in the pulp. Furthermore, the difficulty of performing such tests, especially in young children, the inability of children to describe subjective symptoms, and the fear of painful stimuli in children can limit the use of conventional pulp tests (5-9).

Another commonly used criterion for determining a healthy dental pulp is the characteristics of pulpal bleeding (the amount, duration, and quality of the bleeding) (10-

Cite this article as: Sert T, Arıkan V. The evaluation of pulse oximetry measurement in determining the health status of pulp in primary molar teeth. Turk Endod J 2025;10:75-79.
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Submitted: March 19, 2025 Revised: March 26, 2025 Accepted: March 28, 2025 Published: August 13, 2025

12). However, among the criteria for the characteristics of pulpal bleeding, only the duration of bleeding is an objective finding. Also, recent studies indicate that hemostasis may not be an accurate indicator of dental pulp condition (10,13,14).

The combined result of the inaccuracy of vitality tests and the subjectivity of the operative diagnostic methods makes it difficult to make a definite diagnosis in primary teeth. In recent years, researchers have focused on developing a new method that can directly provide information regarding the vascularization of the tooth for the diagnosis of the pulp (5,7,9). Several studies have tried to develop a non-invasive (15), practical, reliable, and reproducible method (7). Pulse oximetry (PO) has come to prominence among these practical methods in dentistry.

Researchers indicate that the pulse oximetry method can be used to determine the vitality of primary and permanent teeth. Also, it is suggested that the obtained oxygen saturation (SaO_2) levels can be used to establish the diagnosis/prognosis of dental pulp pathologies (6,8,16,17). The current literature suggests that pulse oximetry can successfully diagnose the status of the dental pulp (17,18).

Although there are prior studies conducted on permanent teeth on the topic (15-17), it is unclear whether this method is effective for the diagnosis of the pathological status of primary teeth. In light of this data, this study aims to determine the possible relationship between the oxygen saturation levels (measured with the pulse oximeter) and the pathological condition of the dental pulp in primary molar teeth. Our null hypothesis was that there was no relationship between oxygen saturation levels and pulpal status of primary teeth.

Materials and Methods

Ethical Approval

Ethical approval for this study was obtained from the Ethical Committee for Clinical Research, Kırıkkale University, Kırıkkale, Türkiye (Date: 04/04/2017, No:2017–09/05). Before the procedure, all patients and their parents were informed about the study and signed informed consent forms after the necessary permits were obtained. The study was conducted under the principles of the Declaration of Helsinki.

Patient Selection, Inclusion, and Exclusion Criteria

This in vivo study was conducted on lower second primary molars of patients with parental cooperation, aged between 6–9 years old, and without any systemic diseases who were referred to K.U. Department of Pedodontics between April 2017 and October 2017.

Cooperated patients with intact crowns on the lower second primary molars were involved in the study to measure the oxygen saturation of the pulp. The exclusion criteria were as follows: teeth with brackets, bands, or crowns; discoloration (due to fluorosis, trauma, etc.); hypoplasia; hypocalcification or trauma; cervical defect that prohibits measurement; unhealthy periodontium or root resorption; and teeth diagnosed with the aforementioned defects during the procedure were excluded from the study to provide more reliable and standard results.

The Formation of the Study Groups

The power analysis revealed that the required number of teeth was 19 for each group (95% confidence interval, 0.4 effect size) for the study that was planned to include 2 study and 2 control groups (76 teeth in total; $\alpha = 0.05$, Power = 0.80).

Considering possible dropouts during measurements, the study was conducted on a total of 95 primary mandibular second molar teeth. The groups and the teeth to be included in the study were determined based on the data obtained from the anamnesis, together with the clinical and radiographic examinations. Both the anamnesis and clinical examination were performed by the same researcher (T.S.).

The study groups, their inclusion criteria, and the number of teeth assigned to each group were as follows:

1. Healthy Pulp (HP): Healthy teeth without caries, fractures, structural deformities (hypoplasia, hypocalcification), any pathological findings affecting the pulp, any signs, symptoms, radiologic pathology, or any sign of physiological root resorption on X-rays obtained with parallel technique.

2. Reversible Pulpitis (RP): Teeth having a carious lesion that is very close to the dental pulp without spontaneous pain. No percussion or palpation sensitivity complaints. Presence of sharp pain that is provoked by thermal and other stimuli that disappears after stimulus removal. Absence of pathological mobility or any pathological findings in the surrounding soft tissues (color changes, fistulas, or swelling). No indication of pathological root resorption, inter-radicular or periapical lesions, or loss of lamina dura in radiographic examination.

3. Irreversible Pulpitis (IP): Teeth with at least two of the following symptoms: severe, spontaneous, prolonged, percussion sensitivity or pathological mobility. No necrotic or gangrenous pulp. No pathologies in the surrounding structures (edema, fistula). No physiological or pathological root resorption or lesion in radiographic examination.

4. Negative Control (ET): Teeth with prior root canal

treatment due to a previous carious lesion. No clinical or radiographic pathologies.

Pulse Oximetry Measurements

The oxygen saturation levels of all teeth in the four groups included in the study were measured using pulse oximetry.

The PO measurements were made with a bedside monitor (Multiparameter Bedside Monitor, MASIMO RADICAL-7, US) and the infant probe compatible with this device (MASIMO Infant Probe, US). Prior to the measurements, the infant probe was modified for application on the children's primary molars. This process was modeled on the probes and probe holders used by Gopikrishna et al. (19-21).

The teeth chosen for the study were isolated with cotton rolls. The sensors were placed on the vestibular and lingual surfaces (so that they were parallel to each other) on the cervical 1/3 of the teeth. After a 30-second wait period, the measured values were recorded.

Statistical Analysis

The SaO_2 measurements were recorded together with the age, gender, clinical diagnosis, and teeth numbers. The data were analyzed using the Statistical Package for the Social Sciences (SPSS) 21.0 software (SPSS Inc., Chicago, IL, USA). Shapiro–Wilk, independent sample t-test, ANOVA, Tukey, Mann–Whitney U, and Spearman correlation tests were used for statistical analysis. A p-value of less than 0.05 was considered statistically significant.

Results

The study included 95 teeth in 77 children (30 females [39%] and 47 males [61%]) aged between 6 and 9 years (mean age: 6.7). Fifty-six (59.6%) out of 95 teeth were primary mandibular right second molars, and the remaining 39 (40.4%) teeth were primary mandibular left second molars.

The mean O_2 saturation levels in study and control groups are presented in Table 1. The mean values were 0 for the negative control group, 90.12 ± 3.50 for the healthy pulp group, 83.52 ± 3.29 for the reversible pulpitis group, and 82.12 ± 2.74 for the irreversible pulpitis group. As the mean O_2 saturation level was 0 for the 20 teeth that had previous root canal treatment (negative control group), they were excluded from the statistical analysis. The paired comparisons between the remaining three groups revealed that the O_2 saturation was higher in the positive control group compared to both reversible and irreversible pulpitis groups ($p < 0.001$). There was no significant difference between reversible and irreversible pulpitis groups ($p = 0.275$).

Discussion

The lack of an accurate diagnostic tool that can diagnose pulp inflammation in primary teeth can lead to failure in pulp therapy (10). Although histological analysis is the "gold standard" in deciding the pathological state of the pulp, it is not possible to perform a histological examination prior to treatment (22), and the current diagnostic methods (clinical and operative methods, vitality tests) are not able to accurately determine the state of the pulp in primary teeth. These factors lead to diagnostic errors, especially when trying to understand the reversibility of the inflammation in the dental pulp.

As current diagnostic methods are insufficient in determining the dental pulp's condition, researchers have started to investigate novel methods that can assess the vascular structure of the dental pulp, and these investigations have focused on pulse oximetry in recent years. There are in vivo and in vitro studies that examine the vitality of the dental pulp through pulse oximetry (6,8,20,23,24). There are also a limited number of studies that examined the relationship between the pathological condition and the oxygen saturation of the dental pulp of permanent teeth (17,18). However, there are no studies conducted on primary teeth on this topic. Thus, this study aimed to evaluate the ability of the pulse oximetry method to determine dental pathologies in primary teeth.

Table 1. Comparison of SaO_2 levels in study and control groups. Values with the same letters indicate statistical significance

	Mean ± SD	Min-Max	Median
Healthy Pulp (Positive Control) (n=25)	90.12 ± 3.50a,b	85-96	90
Reversible Pulpitis(n=25)	83.52 ± 3.29a	77-90	84
Irreversible Pulpitis(n=25)	82.12 ± 2.74b	78-88	82
Teeth with Root Canal Treatment (Negative Control) (n=20)	-	0-0	0

*The significant differences are shown with different superscript capital letters and lowercase letters in column and row, respectively.

Similar to previous studies (5,17,20,24), in the present study, the pulse oximetry results obtained from root canal treatment performed teeth were recorded as 0, confirming that oxygenation or pulse data cannot be obtained from teeth without vascular support.

According to the results of the present study, it was found that the SaO_2 values were significantly higher in the positive control group compared to both the reversible and irreversible pulpitis groups. This indicates that the vascularity and blood support decrease in case of pulpitis and that this change can be measured through pulse oximetry. This finding is compatible with previous research conducted on permanent teeth. Setzer et al. (17) have found the SaO_2 levels to be 92% for healthy teeth, 88% for the reversible pulpitis group, and 83.5% for the irreversible pulpitis group; Anusha et al. (18) have found that these values were 94%, 85%, and 81% for anterior teeth, respectively. For both studies, the SaO_2 levels were significantly higher in healthy teeth.

We found that the SaO_2 levels were higher in the reversible pulpitis group compared to the irreversible pulpitis group. However, this finding was not statistically significant. This finding in contrast with previous research conducted on permanent teeth, where researchers have found that the PO SaO_2 levels were significantly different for the reversible and irreversible pulpitis groups and reported that this finding may be useful for determining the level of inflammation in the dental pulp (17,18). The decreased oxygen saturation in the teeth diagnosed with pulpitis (reversible or irreversible) can be explained by the decreased vascularity in the dental pulp parallel to the degree of inflammation (17). As the PO measurement in our study completely depended on vascularization and blood support, it is possible that similar results to reversible pulpitis could have been obtained from teeth with irreversible pulpitis during the initial phase where the vascular deformation is not severe. Also, as the pulp is more voluminous in permanent teeth, the vascular changes may have been easier to measure in studies where permanent teeth were used. Additionally, since caries lesions progress more quickly in primary teeth due to their histological and anatomical structures and pulp tissue sometimes can be infected before the lesion reaches the dental pulp, reversible pulpitis may turn into irreversible pulpitis before the emergence of clinical symptoms (14,25-27). This may have led to similar saturation level measurements in our study.

One of the limitations of the present study was the standardization of the teeth included in the study. Since the pulp is surrounded by hard tissue the accuracy of the readings can be affected by the thickness of the enamel and dentin, which is hard to standardize in the teeth included. Also, the pulpal status of the teeth included were determined with clinical and radiographic information. Although histological analysis is the gold standard, it was impossible to use due to the nature of the study design. Within the limitations of the present study, in light of our findings, we conclude that the pulse oximetry method can be used to distinguish healthy pulp from pulpitis in primary molar teeth. Thus, pulse oximetry can be used as an assisting method together with clinical symptoms and operative diagnostic methods when deciding the treatment in cases where the caries has penetrated the pulp; however, it was not useful in distinguishing reversible and irreversible pulpitis cases. Further studies are needed to investigate and compare the saturation levels with treatment success rates, which may shed more light on the issue.

Conclusion

Based on this study's findings, the following conclusions can be made:

1. Pulse oximetry can be used as an assisting method when deciding the treatment in cases where the decay has penetrated the pulp.

2. Pulse oximetry was not found to be useful for the distinction between reversible and irreversible pulpitis.

Authorship Contributions: Concept: V.A.; Design: V.A.; Supervision: V.A.; Fundings: V.A.; Materials: V.A., T.S.; Data: T.S.; Analysis: V.A., T.S.; Literature search: V.A., T.S.; Writing: V.A., T.S.; Critical revision: V.A., T.S.

Use of AI for Writing Assistance: Not declared

Source of Funding: None declared.

Conflict of Interest: None declared.

Ethical Approval: The study protocol was approved by the Clinical Research, Kırıkkale University Ethics Committee (date: 04.04.2017 protocol no: 2017–09/05).

Informed consent: Written informed consent was obtained from patients who participated in this study.

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ORIGINAL ARTICLE

Turk Endod J 2025;10(2):80–88
doi: 10.14744/TEJ.2025.88597

Apical periodontitis and endodontic status in a Trakya population with cancer and autoimmune diseases: A cross-sectional study

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Purpose: The aim of this cross-sectional study was to compare the endodontic and periapical status of patients with cancer or autoimmune diseases (AD) with that of healthy patients matched by age and sex. Additionally, the cancer and AD groups were compared.

Methods: Digital radiographs of 100 patients with cancer, 100 patients with autoimmune diseases, and healthy patients (200) matched for age and gender were evaluated. The total number of teeth, root canal-filling teeth (RCFT), quality, presence and number of apical periodontitis (AP) were examined.

Results: No significant differences were observed in terms of teeth with AP periodontitis between the cancer and control groups, as well as between AD and control groups. The results of the univariate logistic regression analysis revealed a positive association between cancer and the values of RCFTs and inadequate RCFTs (iRCFT) (RCFT $p < 0.001$; iRCFT $p = 0.018$), as well as a positive association between autoimmune disease and RCFTs ($p = 0.001$).

Conclusion: The results showed that AP was similar between the cancer and AD and control groups. Patients with a history of cancer or AD who are clinically considered high-risk should attend regular dental visits.

Keywords: Autoimmune diseases; neoplasms; observational study; periapical periodontitis; risk factors.

Introduction

Apical periodontitis (AP) is the local tissue response to pulp infection caused by dental caries, trauma, and abrasion (1). A 2021 systematic review investigating the prevalence of AP reported that 52% of adults worldwide had at least one tooth with AP (2). The pathological process of AP is related to the relationship between host immunity and the virulence of the infectious pathogens (3), and the role of host immunity is important (4). The relationship between AP and systemic disease has been frequently investigated, and the concept of endodontic medicine has emerged (5). Apical periodontitis occurs in response to endodontic infection, initiating an immune response, and the patient's systemic status may be affected (6). Previous studies have shown that microorganisms and toxins in the periapical tissue can pass from the root canal system into the bloodstream during/after endodontic treatment of tooth (7,8). Conversely, systemic diseases can alter the

Cite this article as: Gökduman CT, Öztürk EA, Aktaş Ş, Çanakçi BC. Apical periodontitis and endodontic status in a Trakya population with cancer and autoimmune diseases: A cross-sectional study. Turk Endod J 2025;10:80-88.
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Submitted: February 07, 2025 Revised: March 18, 2025 Accepted: March 28, 2025 Published: August 13, 2025

inflammatory response in the localized lesion, increasing the destruction of periapical tissues (6).

The relationship between the oral microbiota and systemic diseases has been frequently investigated in recent years (9). Oral microbiota is associated with many diseases, including cancer, bacterial endocarditis, rheumatoid arthritis, and cardiovascular disease (10-13).

Cancer is a disease characterized by the uncontrolled proliferation of abnormal cells that invade normal tissues and spread throughout the body (14). Oral complications of cancer and cancer treatments cause acute and late symptoms. Acute oral complications include salivary changes, mucositis, and infection. Complications in survivors include neurosensory changes; salivary, gustatory, and functional changes; oral and dental infections; and necrosis of the jaw (15). These complications are important for the quality of life of the cancer survivors. Chemotherapy involves the use of chemotherapeutic drugs that act by destroying and/or controlling the growth of cancer cells. Chemotherapy can predispose to mucosal deterioration, ulceration, and secondary infections (16). Radiation and chemotherapy, together or separately, can significantly damage oral and surrounding tissues (16).

Autoimmune Disorders (AD) are a group of disorders with variable clinical manifestations that exhibit self-reactive immune response (17). The etiology of autoimmune diseases includes genetic and environmental factors (18). Today, 100 autoimmune diseases have been identified (19). Some of these include those specific to certain organs, such as inflammatory bowel disease, autoimmune hepatitis, and Sjögren syndrome, or those that affect more than one organ, such as systemic lupus erythematosus, rheumatoid arthritis, and dermatomyositis (19). The long-term presence of chronic inflammatory disease causes immune system disorders and affects the levels of circulating inflammatory cytokines (20). Therefore, AP, which depends on the balance between microorganisms and host immunity, may be affected (21). In addition, immunosuppressive agents used to treat autoimmune diseases are associated with AP (22).

Periodontal and endodontic diseases are similar in terms of pathogenesis. Both diseases are generally chronic and have similar microbiota. The aim of treatment for both diseases is to control microbial factors, stop local chronic inflammation, and ensure tissue repair (6). Therefore, apical periodontitis may also be affected by the systemic conditions associated with periodontal disease. As observed in autoimmune diseases, impaired immune response may negatively affect pulp and periapical tissue repair (6). It has been reported that patients with periodontitis, a common gum disease, have a 2-5 times higher risk of developing any cancer than healthy individuals (9). Women with periodontitis are two to three times more likely to develop breast cancer than women without periodontitis (23). Previous studies have examined the relationship between periapical disease and autoimmune disease (22) or between periodontal disease and cancer (23). However, no studies have examined and compared the overall relationship between autoimmune diseases and periapical disease, cancer and periapical disease, and cancer and autoimmune disease.

The aim of this study was to evaluate the endodontic and periapical status of patients with cancer or autoimmune disease by comparing them with age- and sex-matched healthy patient groups. In addition, cancer and autoimmune disease groups were compared.

The null hypothesis was that there would be no association between cancer and autoimmune disease and endodontic/periapical status.

Materials and Methods

Ethical approval was obtained from The Ethics Committee of the University of Trakya. (Decision no : 05/30, Date: 18/03/2024). The study was conducted under the principles of the Declaration of Helsinki.

The STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) checklist and statement were followed.

The medical and dental records of patients at the Trakya University Faculty of Dentistry Hospital who underwent a dental check-up and a panoramic radiography taken between 2020 and 2024 were reviewed.

Medical/dental records and radiographic data were anonymized electronically.

Case selection

Study group 1 (Autoimmune diseases): One hundred patients (male or female) who were at least 18 years old, diagnosed with an autoimmune disease, had no history of systemic diseases other than autoimmune disorders, and had digital panoramic radiography were in the experimental group. Patients diagnosed with autoimmune diseases and who had been using immunomodulatory drugs for at least 3 months were included in the study. The diseases and number of patients included in the current study were as follows: Rheumatoid arthritis, 39 patients; Multiple Sclerosis, 19 patients; Systemic Lupus Erythematosus, 18 patients; Sjögren syndrome, 10 patients; Myasthenia Gravis, 14 patients. A total of 100 healthy age- and sex-matched participants who reported no history of systemic diseases were selected to form the control group.

Study group 2 (Cancer): 100 patients (male or female) who were at least 18 years old, diagnosed with cancer, received at least 6 months of radiotherapy/chemotherapy, had no active cancer/treatment and no additional systemic disease, and had digital panoramic radiography. The diseases and number of patients included in the current study were as follows: Head and neck region cancers, 12 patients; breast cancer, 45 patients; lung cancer, 12 patients; lymphoma, 10 patients; leukemia, 13 patients; and colon cancer, 8 patients. 100 healthy age- and sex-matched participants who reported no history of systemic diseases were selected to form the control group. Only those who had not undergone dental examination before starting radiotherapy and had no dental follow-up after radiotherapy were selected.

Exclusion criteria

Patients with systemic diseases such as diabetes and hypertension were excluded from the study.

Patients receiving drug treatment for different diseases were excluded, and patients with poor or incomplete clinical documentation were excluded from the study.

Data collection

The patients' medical and dental histories were obtained from the records, including the patient's sociodemographic variables (age, gender). All patients were radiographically examined.

The following information was recorded:

- Systemic status of patients (cancer or autoimmune disease)
- Age
- Sex
- The number of teeth present
- Number and presence of Root Canal Filling Teeth (RCFT)
- Number and presence of teeth with AP
- Number and presence of RCFT with AP
- Number and presence of inadequate RCFT (iRCFT)
- Number and presence of iRCFT with AP

Radiographic Assesment

The panoramic radiographs were analyzed by an endodontist and an experienced dentist using a standard examination method to determine the periapical and endodontic status of the patients.The examiners were masked and blinded to whether the radiograph was a test or control group. As in previous similar studies (24,25), the 2 reviewers were calibrated according to the criteria established before their evaluation. All radiographs were analyzed simultaneously to ensure consensus in the interpretation of radiographic findings. In case of disagreement between observers, a 3rd experienced specialist endodontist was consulted.

All teeth were recorded (except for impacted teeth).

The radiographs were viewed by the same technician using the same device (Vatech PaX-i3D; South Korea) without changing the contrast and brightness.

Teeth were defined as RCFTs in the presence of radiopaque material in the root canals.

The quality of the RCFT was assessed according to the length and taper of the root filling (26). If all canals are filled without voids, if the root canal fillings are 0-2 mm shorter than the radiographic apex, and if there is a consistent taper from the orifice to the apex, RCFT is considered adequate. If any of the required criteria are missing, the root canal treatment is considered inadequate.

The periapical status was evaluated using the periapical index (PAI) according to previously defined criteria (27). Each tooth was assigned a PAI point based on visual references from the five categories on the scale. If the width of the periodontal ligament space was within normal limits and there was no break in the continuity of the lamina dura, PAI scores were defined as 1 and 2, whereas widening of the periodontal ligament and a break in the lamina dura and/or periapical tissues were defined as PAI 3 to 5. In multirooted teeth, the root with the highest score was used as reference.

Teeth with a PAI score > 2 were considered to have AP.

Statistical Analysis

The statistical analysis of the data was performed using IBM SPSS Statistics software. Pearson's chi-square test was used to compare categorical variables, and Mann–Whitney U statistical analyses were used to compare continuous variables between two groups because they were not normally distributed (Kolmogorov-Smirnov $p < 0.05$). The relationship between diseases and dental characteristics was evaluated using logistic regression analysis. $P < 0.05$ was considered statistically significant.

Results

The study included all patients with cancer and autoimmune diseases who met the inclusion and exclusion criteria.

There were 100 patients with autoimmune diseases included in our study, 33 men and 67 women, ranging in age from 17 to 78 years (mean ± SD: 49.45 ± 15.18 years), and 100 patients with cancer, 19 men and 81 wom-

en, ranging in age from 22 to 89 years (mean ± SD: 57.31 ± 12.07 years).

A total of 200 systemically healthy patients (52 males and 148 females) aged between 17 and 89 years were included.

The mean total number of teeth was 20.76 ± 7.57 in cancer patients, 19.89 ± 8.33 in the cancer control group, 22.63 ± 6.67 in autoimmune patients, and 22.97 ± 8.07 in the autoimmune control group.

The number and presence of RCFTs were significantly higher in the autoimmune disease group than in the control group (p = 0.001) (Table 1).

No significant differences were observed between the autoimmune disease and control groups in terms of teeth with AP periodontitis or other variables (p > 0.05) (Table 1) .

The results of the univariate logistic regression analysis showed a positive association between autoimmune disease and RCFTs (p = 0.001) (Table 2).

Each additional tooth with RCFT, patients had an increased risk of being in the autoimmune disease group (for number of RCFT OR, 4.125; 95% CI, 2.122 to 8.018; p = 0.001) (Table 2).

The number and presence of RCFTs and iRCFTs were significantly higher in the cancer group than in the control group (RCFTnumber&presence; p = 0.001, p = 0.001; iRCFTnumber; p = 0.03; iRCFTpresence; p = 0.018) (Table 3).

No significant differences were observed between the cancer group and control group in terms of teeth with AP periodontitis or other variables (p > 0.05) (Table 3) .

The results of the univariate logistic regression analysis re-

Table 1. The mean, standard deviation, and p values of the amount of removed dentin thickness in experimental groups (%)

	Control Group	AD	p
RCFT (Mean±SD (Min.-Max.)	1.39 ± 1.93 (0-13)	2.6 ± 2.19 (0-8)	0.001
RCFT (n, %)			
None	44 (44%)	16 (16%)	0.001
Any	56 (56%)	84 (84%)	
Teeth with AP (Mean ± SD (Min.-Max.)	0.71 ± 0.96 (0-4)	0.74 ± 0.91 (0-4)	0.619
Teeth with AP (n, %)			
None	55 (55%)	50 (50%)	0.479
Any	45 (45%)	50 (50%)	
RCFT+AP (Mean ± SD (Min.-Max.)	0.33 ± 0.65 (0-4)	0.39 ± 0.69 (0-3)	0.621
RCFT+AP (n, %)			
None	74 (74%)	72 (72%)	0.750
Any	26 (26%)	28 (28%)	
iRCFT (Mean ± SD (Min.-Max.)	0.55 ± 0.9 (0-4)	0.7 ± 1.11 (0-4)	0.464
iRCFT (n, %)			
None	66 (66%)	62 (62%)	0.556
Any	34 (34%)	38 (38%)	
iRCFT+AP (Mean ± SD (Min.-Max.)	0.4 ± 0.72 (0-4)	0.42 ± 0.65 (0-3)	0.587
iRCFT+AP (n, %)			
None	70 (70%)	66 (66%)	0.544
Any	30 (30%)	34 (34%)	

Pearson Chi-Square, Mann Whitney U. (AD: Autoimmune Disease; RCFT: Root Canal Filling Teeth; AP: Apical Periodontitis; iRFCT: inadequate Root Canal Filling Teeth).

Table 2. Association of endodontic and periapical conditions with independent variables: a univariate logistic regression analysis

Groups	Variable	p	ODDS RATIO (95% C.I.)
Cancer	RCFT	0.001	6.143 (3.089 - 12.217)
Autoimmune Disease	RCFT	0.001	4.125 (2.122 - 8.018)
Cancer	iRCFT	0.018	2.04 (1.127 - 3.69)

(RCFT: Root Canal Filling Teeth; iRFCT: inadequate Root Canal Filling Teeth)

Table 3. Comparison of endodontic and periapical conditions between the cancer and control groups

	Control Group	Cancer	p
RCFT (Mean ± SD (Min.-Max.)	1.33 ± 2.05 (0-11)	2.6 ± 2.4 (0-11)	0.001
RCFT (n, %)			
None	50 (50%)	14 (14%)	0.001
Any	50 (50%)	86 (86%)	
Teeth with AP (Mean ± SD (Min.-Max.)	0.83 ± 1.07 (0-4)	0.9 ± 1.07 (0-4)	0.522
Teeth with AP (n, %)			
None	51 (51%)	45 (45%)	0.396
Any	49 (49%)	55 (55%)	
RCFT+AP (Mean ± SD (Min.-Max.)	0.33 ± 0.64 (0-3)	0.54 ± 0.83 (0-4)	0.056
RCFT+AP (n, %)			
None	75 (75%)	63 (63%)	0.067
Any	25 (25%)	37 (37%)	
iRCFT (Mean ± SD (Min.-Max.)	0.47 ± 0.95 (0-5)	0.7 ± 1.07 (0-5)	0.03
iRCFT (n, %)			
None	73 (73%)	57 (57%)	0.018
Any	27 (27%)	43 (43%)	
iRCFT+AP (Mean ± SD (Min.-Max.)	0.47 ± 0.8 (0-3)	0.49 ± 0.73 (0-3)	0.565
iRCFT+AP (n, %)			
None	68 (68%)	63 (63%)	0.457
Any	32 (32%)	37 (37%)	

Pearson Chi-Square, Mann Whitney U.(RCFT): Root Canal Filling Teeth; AP: Apical Periodontitis; iRFCT: inadequate Root Canal Filling Teeth).

vealed a positive association between cancer and the values of RCFTs and iRCFTs (Table 2).

Each additional tooth with the values of RCFT and iRCFT was associated with an increased risk of being in the cancer group (for values of RCFT OR, 6.143; 95% CI, 3.089 to 12.217; p = 0.001; For values of iRCFT OR, 2.040; 95% CI, 1.127 to 3.69; p = 0,018 (Table 2).

There were no differences in endodontic and periapical conditions between the autoimmune disease and cancer group without age and gender matching (p > 0.05).

Discussion

This study investigated the apical periodontitis/endodontic status in patients with autoimmune diseases or cancer and healthy controls. Participants in the control group were matched by sex and age to reduce potential risk factors. Also, autoimmune diseases and cancer were compared in terms of endodontic status and apical periodontitis.

According to the current study, the number and presence of RCFT were significantly higher in the autoimmune disease group than in the control group, whereas the number and presence of RCFT and iRCFT were significantly higher in the cancer group than in the control group. No association was found between AP and cancer or autoimmune disease.

The pathogenesis, progression, and resolution of AP depend on the host immune response and the balance of proinflammatory and proresolution mediators (28). AP may develop due to primary infection in teeth with necrotic pulp or infection in teeth with inadequately treated root canal fillings. The risk of systemic infection spread after root canal treatment increases in patients with immune system suppress (29).

Cancer or cancer treatment may affect the immune response by suppressing the immune system (30). Radiotherapy can cause structural changes in dentin by generating free radicals and can also cause microbial changes (31). It can also change the pH by xerostomia, causing the growth of cariogenic bacteria (31). A study on oral changes in patients with cancer reported that the salivary microbiological profile and salivary pH differed between the cancer and healthy groups (32). The prevalence of dental caries increases with xerostomia and changes in the oral flora of patients undergoing radiation to the head and neck region (33). Because of the aggressive progression of tooth decay, bacteria can reach the pulp, leading to AP (34). According to the results of this study, the AP rate in patients with cancer was similar to that in the control group. Hommez et al. (35) reported that the incidence of AP after head and neck radiotherapy was similar between the groups. However, in a previous study examining the relationship between the dose received after head

and neck radiotherapy and AP, the incidence of AP increased significantly as the dose increased (34). In this study, the similarity in AP rates between the cancer and control groups can be explained by the limited number of patients who received head and neck radiotherapy and the unknown amount of dose received.

The risk of oral side effects is higher among patients receiving chemotherapy (36). The ideal situation is to complete the necessary dental treatment before starting chemotherapy (37). However, this is not always possible because of time constraints, patient's medical condition, and the urgency to start chemotherapy (37). Because the current study evaluated only patients who were at least 6 months post-cancer treatment, dental treatments before or during the illness were unknown. Treatment preferences at dental visits before the patients' cancer history may have influenced the current results.

According to the results, the RCFT and iRCFT rates increased in patients with cancer. As patients undergoing cancer treatment suffer from depressive symptoms, their self-care, including oral hygiene habits, is negatively affected, which can result in caries, periodontal disease, and tooth loss (38). The physical and mental fatigue they experienced during the disease process and their inadequate attention to dental care may explain this result (39).

In this study, 55% of 100 patients with cancer (55 patients) had at least one tooth with AP. These results are consistent with those reported in epidemiological studies (40). According to the results of the study, AP rates were similar between the cancer and control groups. Ding et al. (41) found that breast cancer had no effect on AP. Conversely, another study showed that the number of apical lesions was higher among patients with cancer (42). The reason for the different results may be that the study included patients undergoing active cancer treatment and that the diagnosis of AP was evaluated by clinical examination of the patients in addition to radiographic examination.

Although RCFT and iRCFT values were significantly higher in the cancer group than in the control group, the reason for the similarity of AP may be that dentists make more radical decisions in patients with a history of cancer. Dentists may be inclined to extract teeth with lesions after root canal treatment (43). This condition may occur frequently in patients with cancer in whom the inflammatory response may change.

Apical periodontitis and autoimmune diseases have similar pathological features. Chronic inflammation is common in autoimmune diseases and apical periodontitis and is characterized by the destruction of connective tissue and bone (44).

According to the results, the number and presence of RCFTs were significantly higher in the autoimmune disease group than in the control group. However, no association was found between autoimmune diseases and the AP rate.

Similar to our results, another study reported that patients with Rheumatoid Arthritis (RA) tend to develop AP (45). Previously, Jalali et al. (44) reported no statistically significant difference between RA and control patients in their retrospective study comparing RA patients and controls in terms of the prevalence of periapical rarefying osteitis. In contrast, another cross-sectional study suggested that individuals with RD have at least twice the risk of AP compared with controls (24). In another study, the incidence of AP was significantly higher in patients with autoimmune diseases than in controls (46). Variations in study type and sample size may explain the differences between the studies. Furthermore, these differences between the included studies may be attributed to methodological differences, especially in the diagnosis of AP. In this study, AP was defined only by radiographic examination. Because radiographic changes in cancellous bone are not detected until bone loss reaches the cortical plate, radiographic examination alone may not be sufficient for evaluation, and the results may have been affected by this situation. It is suggested that immunosuppressive agents weaken resistance by decreasing the number of leukocytes and increase the risk of opportunistic oral infections and AP (47). The different findings may be related to the dose and duration of the immunosuppressive agents used and the virulence of the bacteria (48).

Inflammatory and immunological responses are affected by genetic factors and can be explained by the fact that individuals may respond differently to environmental stimuli (46). Genetic polymorphisms may play a role in the etiology of complex diseases (49) .

Cotti et al. (50) showed that existing apical periodontitis healed more rapidly in patients receiving biologics compared with those in the control group, suggesting that treatment that modulates the immune response may affect the healing of apical periodontitis after endodontic treatment. Immunomodulatory therapy and altered immune response in patients with autoimmune disorders may affect the prevalence and prognosis of apical periodontitis after endodontic treatment (51).

Limitations

The current study is a retrospective study that examined patient records. It is difficult to distinguish whether the results are due to the disease, treatment processes, the medication used, or all of them. In addition, since differ-

ent diseases are examined, the diseases studied may show heterogeneity under common immune pathogenesis, and this can affect the endodontic and apical status to different degrees.

The presence of undiagnosed systemic diseases that can affect dental health may have affected the results. Prospective controlled clinical studies are needed because confounding factors cannot be controlled.

Because this was a retrospective study, the time since completion of endodontic treatment could not be assessed. In this cross-sectional study, Whether the lesions were active or healing, and the quality of the coronal restoration was not examined. The quality of the coronal restoration may have affected the outcome of the root canal treatment and therefore the present results.

The presence of periapical lesions and quality of the root canal treatment were evaluated using panoramic radiography. Untreated canals may be missed on panoramic radiographs, or the quality of the canal filling may not be evaluated well due to distortions. During the early stages of AP, changes may not be visible on radiography. Panoramic radiography may cause an underestimation of the lesion because radiographic changes in the cancellous bone are not detected until bone loss reaches the cortical plate (52). Therefore, some teeth with AP in the current study may not have been diagnosed. Additionally, anatomical noise masking of the region of interest to varying degrees on panoramic radiographs may negatively affect the assessment of AP and the quality of the root canal filling. Full mouth periapical radiography and cone beam computed tomography are recommended for root canal and apical status evaluation in subsequent studies.

Conclusion

The results showed that AP was similar between the cancer and autoimmune disease and control groups. Since the current study used a cross-sectional design, the generalizability of the findings is limited. The results of this study require larger prospective studies. Clinically, we recommend that patients with a history of cancer and cancer treatment or autoimmune disease should be considered high-risk patients and should be included in a strict dentist recall system.

Authorship Contributions: Concept: E.A.Ö, C.T.G.; Design: E.A.Ö., C.T.G., B.C.Ç; Supervision: E.A.Ö., B.C.Ç.; Materials: C.T.G., Ş.A.; Data: C.T.G., Ş.A.; Analysis: E.A.Ö., C.T.G.; Literature search: E.A.Ö., C.T.G.; Writing: E.A.Ö., C.T.G.; Critical revision: B.C.Ç.

Use of AI for Writing Assistance: Not declared

Source of Funding: None declared.

Conflict of Interest: None declared.

Ethical Approval: The study protocol was approved by the University of Trakya Ethics Commitee (date: 18.03.2024 protocol no: 05/30).

Informed consent: Written informed consent was obtained from patients who participated in this study.

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ORIGINAL ARTICLE

Turk Endod J 2025;10(2):89–96
doi: 10.14744/TEJ.2025.02419

Determination of materials, techniques, and application methods preferred by Turkish dentists in endodontic treatment

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Purpose: This study aimed to examine the materials, methods, and application techniques used by general dentists in root canal treatment through a survey and to compare the findings with previous studies conducted in Turkey and globally.

Methods: A survey consisting of 21 questions was administered to 691 general dentists working in private clinics and public institutions in İzmir. Participation was voluntary, and data were analyzed using the Chi-Square test with IBM SPSS Statistics 23 software.

Results: Among the participants, 22.7% did not perform root canal treatment. The electric pulp test was the most preferred vitality test (47%), while electronic apex locators were widely used for determining the working length. Sodium hypochlorite (91.6%) was the most common irrigation solution, and calcium hydroxide (91.4%) was the preferred intracanal medication. Nickel-titanium rotary files were used by 85.6% of dentists, and 72.1% employed the single-cone technique for root canal filling. Notably, only 1.5% used a rubber dam.

Conclusion: Older dentists tended to favor conventional methods, while no standardization was observed in material and method selection across demographic groups. The use of rubber dams was significantly lower than international standards.

Keywords: Endodontic treatment; root canal treatment; survey.

Introduction

The primary goal in dentistry is to maintain the functions of teeth while ensuring their long-term health in the oral cavity. Tooth loss not only leads to aesthetic and functional deficits but also causes various complications, including malposition of adjacent teeth, occlusal problems, periodontal issues, increased risk of caries, and chewing difficulties (1). One of the most effective methods to prevent these adverse effects and preserve the tooth in the oral cavity is root canal treatment.

Root canal treatment is a complex procedure that involves the removal of infected or necrotic pulp tissue, mechanical and chemical cleaning of the root canals, disinfection, and hermetic sealing of the canals. The success of this treatment depends not only on biological and mechanical principles but also on the effectiveness of the materials and techniques used by dentists (2).

Endodontics is a dynamic field of dentistry where new knowledge and technologies are developed within short time intervals. With advancing technology, the production

Cite this article as: Çekiç EC, Aktener BO, Tavşan O. Determination of materials, techniques, and application methods preferred by Turkish dentists in endodontic treatment. Turk Endod J 2025;10:89-96.
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Submitted: February 24, 2025 Revised: March 20, 2025 Accepted: April 03, 2025 Published: August 13, 2025

of new materials and the continuous evaluation of their effectiveness are essential aspects of scientific progress. The success of endodontic treatment depends not only on the clinician's skills but also on their access to up-to-date information and innovations (3).

The success of endodontic treatment relies on the accurate and effective execution of multiple interdependent steps. Key factors include establishing a correct diagnosis, preventing complications during access cavity preparation, accurately determining the working length, ensuring proper isolation, effectively shaping the root canals (4), performing irrigation with appropriate solutions and activation techniques (5), and achieving a hermetic seal during canal obturation. The selection and proper application of different techniques and materials for each step play a crucial role in determining the overall success of the treatment (6).

The aim of this study is to identify the materials, techniques, and application methods preferred by general dentists in root canal treatment and to compare these findings with current literature. Through this comparison, the study aims to enhance the understanding of existing clinical practices and contribute to the development of future educational and clinical strategies.

Materials and Methods

This study was initiated following the approval of the Ethics Committee of Ege University Faculty of Medicine (Decision No: 16-12.1/15). The study was conducted under the principles of the Declaration of Helsinki. To collect data, a questionnaire consisting of 21 questions was designed. The first section of the questionnaire included four questions to gather demographic information about the participants (gender, age, years of clinical experience, and workplace). The second section comprised 17 multiple-choice questions aimed at evaluating the materials, techniques, and applications used in root canal treatment.

The study focused on general dentists. A total of 691 general dentists working in private clinics and public institutions in the central and district areas of İzmir voluntarily participated in the study.

The questionnaire was administered face-to-face by a single researcher at the participants' workplaces. The purpose of the study was explained to the participants, voluntary participation was ensured, and the questionnaires were completed independently, without any external influence.

The collected data were analyzed using IBM SPSS Statistics 23 software. The Chi-Square test was used for comparisons between groups, and all hypothesis tests were conducted at a significance level of $p < 0.05$.

Results

The distribution rates of the participants' demographic characteristics are presented in Table 1.

The distribution of dentists' root canal treatment and radiography usage rates based on their workplace, years of experience, and age is presented in Table 2.

Among the surveyed dentists, 22.7% reported that they do not perform root canal treatment. Additionally, it was observed that the rate of performing root canal treatment significantly decreased with increasing age ($p < 0.001$). Furthermore, dentists working in private clinics were found to have a higher rate of performing root canal treatment compared to their colleagues in the public sector ($p < 0.001$).

It was observed that as the dentists' years of experience and age increased, the routine use of radiography during examinations decreased ($p < 0.001$).

The distribution of the survey results of dentists performing root canal treatment based on their workplace, years of experience, and age is presented in Table 3.

No significant difference was observed among participants regarding the use of radiography during endodontic treatment ($p > 0.05$). Similarly, no significant difference was found in the isolation technique used for treated teeth during endodontic procedures ($p > 0.05$).

Among dentists performing root canal treatment, the use of conventional radiography, tactile sensitivity, and paper point methods for determining working length significantly increased with age and years of experience ($p < 0.001$), while the use of electronic apex locators decreased ($p < 0.001$).

Table 1. Demographic characteristics of participants (n = 691)

Variable	n	%
Age		
≤ 35	242	35
36-50	323	46.7
> 50	126	18.2
Gender		
Female	375	54.3
Male	316	45.7
Years of Medical Practice		
≤ 10	232	33.6
11-25	303	43.7
> 26	156	22.5
Institution of Employment		
Public Institution	349	50.5
Private Practice	309	44.7
Public + Private	33	4.8

Table 2. Distribution of root canal treatment and radiography acquisition rates by workplace, average years of practice, and age (%) (n = 691)

Variable	Institution of Employment			Average Years of Practice			Age		
	Public Institution	Private Practice	Public-Private	< 10 Years	11-25 Years	> 26 Years	< 35	36-50	> 51
Root Canal Treatment Frequency									
Always	33.2	79.9*	63.6	57.8	57.8	48.1	56.6	58.8	45.2*
Frequently	20.3	5.8	6.1	12.5	14.9	10.9	12.4	14.6	11.1
Rarely	14.3	2.3	6.1	4.3	8.6	14.7	4.1	10.5	11.9
Never	33.1	12	24.2	25.4	18.8	26.3	26.9	16.1	31.7
Radiography Acquisition Rate									
Yes	86.8	78.6	81.8	90.5	83.2	71.2*	90.9	81.4	71.4*
No	13.2	21.4	18.2	9.5	16.8	28.8	9.1	18.6	28.6*

*The Chi-Square test with a significance level of $p < 0.05$.

No significant difference was observed among participants regarding the instruments used for root canal shaping ($p > 0.05$).

Regarding irrigation solutions, the use of EDTA decreased with age and years of experience ($p = 0.047$), whereas the use of hydrogen peroxide increased ($p = 0.015$).

Among dentists who reported performing root canal treatment, as age and years of experience increased, the use of dental syringes for irrigation solutions also increased ($p < 0.05$), while the use of special irrigation needles decreased ($p < 0.05$). Additionally, dentists working in public institutions were significantly more likely to use dental syringes for irrigation solutions compared to those in private practice ($p = 0.001$), whereas their use of special irrigation needles was significantly lower ($p = 0.004$).

No significant difference was found between the ages and years of experience of dentists performing root canal treatment and the types of root canal sealers they used ($p > 0.05$). However, the use of bioceramic-based sealers was significantly higher among dentists working in private practice compared to those in public institutions ($p = 0.002$).

Additionally, as age and years of experience increased, the preference for the cold lateral compaction technique significantly decreased ($p = 0.004$), while the use of sealer-only obturation significantly increased ($p < 0.001$).

Discussion

In our study, the questionnaires were administered face-to-face to general dentists who voluntarily participated, unlike many other survey-based studies. This approach allowed for a more accurate representation of clinicians' treatment habits by minimizing potential misunderstandings or misinterpretations in responses.

With the evolving societal structure and increasing aesthetic expectations of patients, the demand for preserving natural teeth has made root canal treatment more popular in recent years (7,8). In our study, it was observed that younger dentists preferred performing root canal treatment more frequently compared to their older colleagues ($p < 0.001$). This situation may be attributed to the ability of young dentists to adapt more quickly to changing societal structures and patient expectations, their graduation with an up-to-date curriculum designed following advancing technologies, and their provision of treatment options to patients in line with these developments. Additionally, our study found that root canal treatment was performed at a significantly higher rate in private clinics compared to public institutions ($p < 0.001$). In public institutions, general dentists are typically allocated short appointment slots averaging around 20 minutes per patient through the Central Physician Appointment System (MHRS). The significantly lower rate of root canal treatment among general dentists in public institutions may be due to the lack of sufficient time to complete this multi-step procedure.

Radiographs allow for the examination of radicular and periradicular structures, aiding in the identification of potential causes of patient discomfort (9). In our study, 82.9% of participants reported routinely taking radiographs during examinations. In contrast, a study by Tan et al. (10) reported that 99.7% of dentists routinely used radiographs during examinations. It was also observed that younger dentists were more likely to take routine radiographs compared to their older colleagues ($p < 0.001$). The reasons cited by participants for not taking routine radiographs during examinations included: 27% believed routine radiography was unnecessary, 35% considered that

Table 3. Distribution of outcomes based on the institution, average years of practice, and age of practitioners performing root canal treatment (%) (n = 534)

Variable	Institution of Employment (%)			Years of Medical Practice			Age		
	Public Institution	Private Practice	Public-Private	< 10 Years	11-25 Years	> 26 Years	< 35	36-50	> 51
Radiography Acquisition Stage (Multiple responses were allowed)									
Preoperative	99.6	87.1	96.0	94.2	91.5	94.8	93.8	91.5	96.5
Working Length Determination	36.7	48.5	52.0	36.4	43.1	54.8	37.3	44.3	53.5
Gutta-Percha Trial	50.2	51.5	48.0	60.1	43.9	51.3	59.9	45.4	50.7
Postoperative	95.8	77.6	92.0	85.5	86.2	87.8	84.2	87.1	88.4
Isolation Methods (Multiple responses were allowed)									
Cotton Rolls and Pellets	96.6	86.4	92.0	87.9	94.7	88.7	88.7	94.1	87.2
Suction and Aspirator	92.4	88.2	84.0	87.3	89.8	93.9	87.6	90.4	93.0
Rubber Dam	8.0	23.5	16.0	21.4	13.4	14.8	22.0	12.5	16.3
Working Length Determination Methods (Multiple responses were allowed)									
Conventional Radiographs	14.8	17.6	28.0	12.1	15.9	26.1*	11.9	15.9	30.2*
Digital Radiographs	35.0	45.2	44.0	44.5	39.8	36.5	46.9	37.6	37.2
Electronic Apex Locators	74.7	68.8	64.0	82.7*	69.9	56.5	80.8*	70.5	53.5
Tactile Sensation	30.0	13.2	24.0	17.9	21.5	25.2*	18.6	20.3	29.1*
Paper Point	9.7	9.6	0.0	4.0	10.6	13.9*	4.5	10.7	14.0*
Selection of Endodontic Instruments (Multiple responses were allowed)									
Tirnerf	38.0	43.0	48.0	41.6	38.6	45.2	42.4	36.9	51.2
K-Type File	7.2	12.9	12.0	12.1	10.2	7.8	11.3	10.7	7.0
K-Type Reamer	56.1	57.4	64.0	68.2	47.2	61.7	65.5	50.2	61.6
H-Type File	55.7	52.6	52.0	64.2	49.2	48.7	64.4	49.1	47.7
Gates-Glidden	10.5	18.4	16.0	19.1	13.4	11.3	19.8	12.9	10.5
Peeso Reamer	1.3	2.9	4.0	2.9	2.4	0.9	2.8	2.6	0.0
Ni-Ti Rotary File	87.3	84.2	84.0	90.2	86.6	76.5	90.4	86.7	72.1
Use of Irrigation Solutions (Multiple responses were allowed)									
Sodium Hypochlorite	91.1	91.5	96.0	91.3	92.3	90.4	91.0	93.0	88.4
EDTA or Other Chelating Agents	63.3	72.8	64.0	75.1	64.6	65.2	75.1	65.3	62.8*
Distilled Water	47.3	50.7	48.0	57.8	44.3	46.1	58.8	45.8	39.5
Hydrogen Peroxide	10.1	17.6	8.0	9.8	13.0	21.7	10.2	13.3	23.3*
Chlorhexidine	66.2	58.8	52.0	63.0	58.9	66.1	63.3	59.4	66.3
Irrigation Activation Methods Multiple responses were allowed)									
Syringe Irrigation	82.7	68.8*	84.0	67.0	74.8	82.7*	68.6	72.7	83.6*
Special Irrigation Needles	30.8	45.2*	40.0	48.7*	40.2	29.5	47.7*	42.4	28.2
Sonic-Ultrasonic Irrigation	4.6	9.6	8.0	7.5	7.7	6.1	6.8	8.5	4.7
Negative-Positive Pressure Irrigation (EndoVac etc.)	0.8	1.8	8.0	2.3	1.2	1.7	2.3	1.1	2.3
Irrigation Brushes (EndoBrush etc.)	0.0	0.7	4.0	0.0	0.4	1.7	0.0	0.7	1.2
Ozone Irrigation	0.0	1.8	0.0	0.0	0.8	2.6	0.0	0.7	3.5
Selection of Root Canal Sealers (Multiple responses were allowed)									
Zinc Oxide-Based Sealers	11.8	19.1	24.0	18.5	15.4	13.9	18.1	14.4	17.4
Chloropercha	0.4	2.2	0.0	1.2	0.8	2.6	1.1	0.7	3.5
Calcium Hydroxide-Based Sealers	43.9	38.6	44.0	40.5	38.6	47.8	40.1	38.4	52.3
Glass Ionomer-Based Sealers	3.8	8.5	4.0	6.9	6.1	5.2	6.8	6.7	3.5
Polymer-Based Sealers	54.0	39.3	48.0	45.7	48.0	43.5	45.8	47.6	43.0
Bioceramic-Based Sealers	5.9	15.8*	16.0	10.4	13.0	9.6	10.2	12.9	9.3
Root Canal Filling Techniques (Multiple responses were allowed)									
Single Cone Technique	75.5	68.8	76.0	78.6	68.7	69.6	78.5	69.0	68.6
Cold Lateral Compaction Technique	63.1	59.9	72.0	72.3	56.7	57.4*	71.8	57.4	55.8*
Filling with Sealer Alone	2.1	6.3	4.0	1.7	4.1	8.7	1.7	4.4	9.3*
Intracanal Heating	0.4	2.9	8.0	0.6	1.6	5.2	0.6	2.2	4.7
Extraoral Heating	0.0	2.2	4.0	0.6	1.6	1.7	0.0	1.8	2.3

*The Chi-Square test with a significance level of $p < 0.05$.

indications could be determined through intraoral examination alone, and 25% mentioned that radiographs were not reimbursed during examinations. However, no significant difference was found in the frequency of radiograph use during endodontic procedures between different age groups or work environments ($p > 0.05$).

Although no significant difference was found between the groups in terms of isolation ($p > 0.05$), it was determined that the overall use of rubber dams was quite low across all groups. The main reasons cited by dentists for not using rubber dams included the perception that the application is impractical, time-consuming, and that patients may not tolerate it (11,12). In our study, 45.7% of the participants found rubber dam usage difficult, while 44.1% stated that they could not use it because it was not available in their work environment. However, considering its advantages in infection control, prevention of cross-contamination, and protection of patients from instruments used during the procedure, rubber dam application holds significance beyond these concerns (13). Studies conducted worldwide indicate that the usage rates of rubber dams are higher in developed countries compared to developing ones (14,15).

When evaluating the methods used to determine working length during endodontic treatment, it was observed that as age and years of experience increased, the use of conventional radiography, tactile sensitivity, and paper point methods also increased ($p < 0.001$), whereas the use of electronic apex locators decreased ($p < 0.001$). This decline in the use of electronic apex locators may be attributed to their relatively new and costly technology, the insufficient participation of older dentists in postgraduate education and training courses, or their reluctance to adapt to new technologies. The increased reliance on tactile sensitivity for determining working length with age suggests that dentists may find it difficult to change their established habits. Although experienced clinicians may rely on tactile perception to determine canal length, it should not be overlooked that anatomical obstacles and canal constrictions may cause the instrument to become stuck or lead to apical perforation (16). The literature indicates that electronic apex locators are more successful in determining working length compared to radiographic and tactile sensitivity methods (17,18). Additionally, it has been reported that electronic apex locators eliminate radiation exposure, unlike radiographic methods (19).

From past to present, root canal shaping has been performed using various file materials and systems. With technological advancements, Ni-Ti rotary file systems have gained significant popularity in recent years. In our study, Ni-Ti rotary files were preferred at a higher rate across all age groups and work environments compared to other systems. This trend may be attributed to the increased variety of Ni-Ti rotary instruments, their proven reliability through in-vitro and in-vivo studies, and their ability to reduce complications such as ledge formation, apical transportation, and perforation (20,21). The high usage rate of Ni-Ti file systems in our study is also consistent with findings from other studies in the literature (22,23).

Bacteria play a fundamental role in the development of pulpal and periapical diseases. Therefore, infection control is considered a primary goal of root canal treatment for the prevention and management of endodontic pathologies (24). Irrigation has been adopted as the primary method for cleaning and disinfecting the root canal system (5). Sodium hypochlorite (NaOCl) is widely used as an irrigation solution due to its superior antimicrobial efficacy against biofilm formation (25) and its ability to dissolve organic tissue remnants (26). In our study, 91.6% of participants reported using NaOCl for root canal irrigation, a rate consistent with findings from other studies in the literature (27,28).

Although sodium hypochlorite is a widely preferred irrigant, it lacks the ability to dissolve hard tissue debris or the inorganic components of the smear layer formed during root canal shaping. EDTA is the most commonly used irrigant for this purpose (5,29). In our study, 68.2% of participants reported using EDTA, a rate higher than that reported in other studies in the literature (14,30). The use of EDTA was found to be significantly higher among younger dentists compared to their older colleagues ($p = 0.047$), which may be attributed to the lack of engagement with current literature among older practitioners after graduation. Additionally, the use of hydrogen peroxide increased with age and years of professional experience ($p = 0.015$). These findings are consistent with the results of a study conducted in 2015 (29).

Syringe irrigation remains the most commonly used technique for delivering irrigants into root canals among both endodontists and general dentists (15,31). The effectiveness of this method depends on the proximity of the needle to the apical end of the root canal. In endodontic treatment, two different types of needles are used for irrigation: open-ended and side-vented closed-ended needles (5). The optimal position for open-ended needles is reported to be 2–3 mm short of the working length, while for closed-ended needles, it is 1 mm short of the working length (32). Open-ended needles pose a higher risk of apical extrusion of irrigants (33). In our study, the use of special irrigation needles was significantly higher among younger dentists ($p < 0.05$) and those working in the private sector ($p = 0.004$). These findings suggest that

younger dentists may follow the literature more frequently after graduation compared to their older colleagues, or that dentists in general may not sufficiently update their knowledge after completing their education. The more frequent use of special irrigation syringes by dentists in private practice compared to those in public institutions may be due to limited access to this equipment in public healthcare settings.

In root canal treatment, after the cleaning and shaping of the canal system, achieving a completely hermetic seal is crucial to prevent oral pathogens from colonizing the root and periapical tissues, thereby reducing the risk of reinfection (34). Root canal sealers used in endodontic treatment fill gaps between the root filling material and dentin walls, covering canal irregularities and ensuring a hermetic seal along the entire canal, including the apical foramen. This seal prevents leakage, reducing the risk of residual bacteria spreading to periapical tissues and contributing to the healing of periapical lesions (35). Currently, a variety of endodontic sealers, including glass ionomer, zinc oxide-eugenol, resin, calcium hydroxide, silicone, and bioceramic-based materials, are used in clinical practice (36). In our study, no significant difference was found among age groups in terms of sealer preference. However, resin-based sealers were significantly more preferred compared to other types ($p < 0.05$), a finding consistent with literature data (14). Additionally, dentists in private practice preferred bioceramic-based sealers more frequently than those working in public institutions ($p < 0.05$). This difference may be attributed to limited access to these materials in public healthcare settings.

Numerous root canal obturation techniques have been described in the literature (37). Studies comparing the single cone technique and lateral compaction technique have found no significant difference in terms of radiographic healing outcomes (38,39). Similarly, studies comparing warm techniques with cold lateral compaction have also reported comparable healing results (40). In this study, the most frequently preferred root canal obturation technique was the single cone technique, used by 72.1% of participants. When comparing obturation techniques, it was observed that younger dentists preferred the cold lateral compaction technique more frequently than their older colleagues. This preference may be attributed to younger dentists having received more recent education and being more open to modern techniques. On the other hand, experienced dentists tend to rely on the methods they have used for many years, maintaining their clinical habits.

Conclusion

The results of our study indicate that older dentists use modern techniques less frequently compared to their younger colleagues. This may be due to their continued reliance on traditional methods and their failure to update the theoretical and practical knowledge acquired during their undergraduate education.

Supporting dentists in attending post-graduate practical and theoretical courses, seminars, and improving access to scientific publications could facilitate the adoption of modern techniques, even among more experienced practitioners. Additionally, enhancing access to modern equipment in public institutions and allowing longer appointment durations through the Central Physician Appointment System (MHRS) may increase the application of more current and effective approaches in root canal treatment.

Authorship Contributions: Concept: B.O.A., E.C.Ç.; Design: B.O.A., E.C.Ç.; Supervision: B.O.A.; Data: B.O.A., E.C.Ç.; Analysis: B.O.A., E.C.Ç.; Literature search: E.C.Ç., O.T.; Writing: E.C.Ç., O.T.; Critical revision: B.O.A., E.C.Ç., O.T.

Use of AI for Writing Assistance: Not declared

Source of Funding: None declared.

Conflict of Interest: None declared.

Ethical Approval: The study protocol was approved by the Ege University Faculty of Medicine Medical Research Ethics Committee (date: 13.01.2017 protocol no: 16-12.1/15).

Informed consent: Written informed consent was obtained from patients who participated in this study.

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ORIGINAL ARTICLE

Turk Endod J 2025;10(2):97–101
doi: 10.14744/TEJ.2025.85520

Evaluation of root and canal morphology of permanent first molars with cone-beam computed tomography: A retrospective study

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Purpose: This retrospective study is aimed to analyze and characterize the root canal morphology of mandibular and maxillary first molars in a Turkish population by analyzing cone-beam computed tomography (CBCT) images.

Methods: 460 maxillary first molars and 432 mandibular first molars from patients, 228 females and 232 males aged 18–72 years were included in this study. The number of root canals and the canal configurations were investigated and then classified according to Vertucci's classification. The data were analyzed with the Pearson Chi square test.

Results: The Type Ⅳ canal configuration was most prevalent in the maxillary first molar 99(42.67%) 100(43.85%) Repectively. Type Ⅳ canal configuration was most prevalent in the mandibular first molar 100 (50.50%) 112 (52.09%). Eight cases of radix entomolaris were found (four males and four females).

Conclusion: Among distal roots, males had a significantly higher incidence of a single canal compared to females.

Keywords: CBCT; mandibular; maxillar; root canal congiguration; Vertucci.

Introduction

Before starting endodontic treatment, it is essential to have a detailed understanding of root and canal anatomy. Successful root canal treatment relies on thorough cleaning and filling the entire root canal system. Treatment failure can occur if anatomical variations are overlooked. The current understanding of root canal anatomy is derived from individual case reports and in vitro research findings (1). Understanding the variations in dental anatomy and the distinctive traits of various racial groups is important, as such information can assist in locating canals.

Numerous studies have investigated the root canal systems of the first molars in both the maxilla and the mandible (2-4). It is rare to have three roots in the lower molars. This variant occurs less frequently than 5% in Caucasian, African, and Eurasian populations, but it rises to over 40% in East Asian populations which includes the Chinese population (5). Traditional root and canal morphology analysis methods like sectioning, canal staining, and clearing techniques are invasive and require special preparations. Also this methods can be applied only on extracted teeth. In endodontic treatment, conventional periapical radiography is an essential diagnostic tool. However, as

Cite this article as: Çelik N, Edebal TH. Evaluation of root and canal morphology of permanent first molars with cone-beam computed tomography: A retrospective study. Turk Endod J 2025;10:97-101.

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Submitted: March 19, 2025 Revised: April 10, 2025 Accepted: April 11, 2025 Published: August 13, 2025

this imaging method provides information only in two dimensions, it cannot accurately reflect the complexity of root canal morphology. Cone-Beam Computed Tomography (CBCT) has been employed in endodontics since 1990. It allows for the qualitative and quantitative evaluation of tooth characteristics with a 360-degree axis and a three-dimensional view from different angles (6). The aim of this investigation was to evaluate the root and canal anatomy of first molars in a Turkish subpopulation with the aid of CBCT, a noninvasive tool.

The null hypothesis of this study is there is no significant variation in the root and canal anatomy of first molars in the Turkish subpopulation as observed using Cone-Beam Computed Tomography (CBCT).

Materials and Methods

This study was approved by the ethics committee of Harran University (HRU/24.03.30). The study was conducted under the principles of the Declaration of Helsinki All CBCT images were used, which were obtained for various reasons at the Faculty of Dentistry, Harran University, between 2022 and 2024. Maxillary and mandibular molars with good periapical health, fully developed roots, and no prior dental treatment were included in this study. Teeth with poor digital image quality, incompletely erupted or resorbed were excluded. 460 maxillary first molars and 418 mandibular first molars from patients 228 females and 232 males aged 18–72 years were included in this study. The images were Acquired using a Castellini X Radius Trioplus (Imola, Italy) CBCT device. Scans were performed at 90 kVp, 13–16 mA, with Field-of-view (FOV) sizes of 13 × 16 cm and 13 ×10 cm, and a voxel size of 0.03 mm. All scans were performed by Oral and Maxillofacial Radiology technicians. Multiplanar reconstruction images were obtained using IRYS 15.0 software for image evaluation. Root numbers and canal configurations of all CBCT images were evaluated by two endodontists with at least 3 years of experience using the CBCT and its own software and classified according to Vertucci's classification.

Statistical analysis

The data were analyzed using IBM SPSS Statistics (Version 22). Descriptive statistics were used to calculate values such as n and (%). The Chi-square test was applied for intergroup comparison. A p-value of $p < 0.05$ was considered statistically significant for differences between the parameters studied. Wilcoxon matched-pairs signed-rank test was used for intra-observer reliability. For inter-observer reliability was determined by the intraclass correlation coefficient (ICC) and the coefficient of variation (CV). Values for the ICC range were 0 to 1. ICC values higher than 0.75 show good reliability, and low CV demonstrates the precision error as an indicator of reproducibility.

Results

Patients aged between 18 and 72 were included in the study. The average age of the males was 42 years, whereas that of the females was 39.3 years. Four hundred sixty maxillary first molars (232 in males and 228 in females) and 419 mandibular first molars were examined (204 in males and 215 in females). The right and left jaws were not differentiated (Table 1).

Table 1. The classification of first and secondmolar root canal anatomy according to Vertucci classification. (Grey: male, white: female)

No teeth*	Type of canal **	Number of roots	1-1	2-1	1-2-1	2-2	1-2	2-1-2	1-2-1-2	3-3
16-26										
	MB	232	83(35.7%)	48(20.68%)		99(42.67%)	2(0.86%)			
		228	81(35.52%)	50(21.92%)	0	100(43.85%)	1(0.43%)	0	0	
	DB	232	232 (100%)	0	0	0	0	0	0	
		228	228 (100%)	0	0	0	0	0	0	
	PAL	232	232 (100%)	0	0	0	0	0	0	
		228	228 (100%)	0	0	0	0	0	0	
36-46										
	M	210	0	98(46.66%)		106(50.47%)				6(2.85%)
		222	0	95(42.79%)		121(54.50%)				6(2.70%)
	D	210	166(79.04%)	16(7.61%)		22(10.47%)	4(1.90%)			2(0.95%)
		222	95(42.79%)	32(14.41%)	1(0.45%)	83(37.38%)	2(0.90%)			3(1.3%)
	DL	4	4(100%)							
		4	4100%)							

*Numeration accordingtoFDI. ** MB: Mesiobuccal, DB: Distobuccal, PAL: Palatinal, M: Mesial, D: Distal, DL: Distolingual.

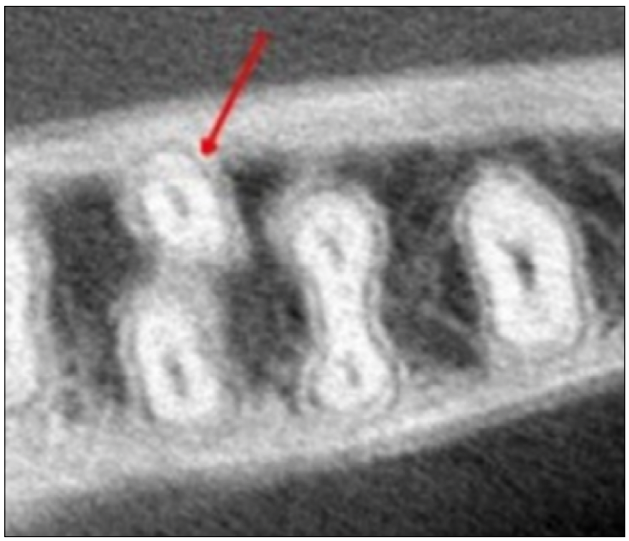

Fig. 1. Radix entomolaris.

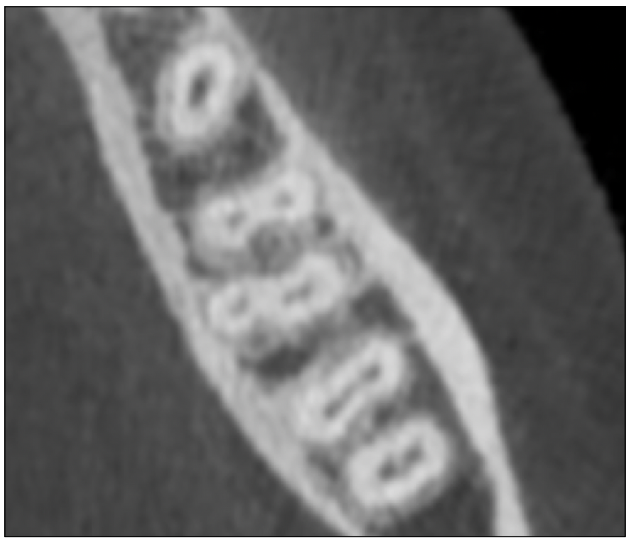

Fig. 2. Mandibular distal root vertucci type 3-3.

Maxillary first molar

All maxillary first molars had three roots in both males and females. A second canal in mesiobuccal (MB) roots was observed in 64.2 % of males (232 teeth) and 66.2 % of females (228 teeth). In males, the second canal in the mesiobuccal root was identified as Type II according to Vertucci's classification in 48 cases (20.68%), as Type IV in 99 cases (42.67 %), and as Type V in 2 cases (0.86 %). In females, the second canal in the mesiobuccal root was identified as Type I according to Vertucci's classification in 81 cases (35.52%), as Type II in 50 cases (21.92%), as Type IV in 100 cases (43.85%), and as Type V in 1 case (0.43%) In distal roots, no additional canal or morphological variation was observed in either males or females, with all distal roots showing a Vertucci Type I canal configuration. In palatal roots, all 560 teeth examined in both males and females had a single root and a single canal (Table 1).

Mandibular first molars

Among mandibular first molars, two roots were present in 98.0% of males and 98.1% of females, with one mesial and one distal root. Eight cases of radix entomolaris were found (four males and four females) (Fig. 1). The number of roots was similar in males and females. In males, the mesial root was identified as Type II according to Vertucci's classification in 98 cases (46.66%), as Type IV in 106 cases (50.47%), and as Type VIII in 6 cases (2.85%). In females, the mesial root was identified as Type II according to Vertucci's classification in 95 cases (42.79%), as Type IV in 121 cases (54.50%), and as Type VIII in 6 cases (2.70%). In males, the distal root was identified as Type I according to Vertucci's classification in 166 cases (79,04%), as Type II in 16 cases (7.61%), as Type IV in 22 cases (10.47%), and as Type V in 4 cases (1,90%) and as type Ⅷ in 2 cases (0,95) (Fig. 2). In females, the distal root was identified as Type I according to Vertucci's classification in 95 cases (42.79%), as Type II in 32 cases (14.41%), as Type III in 1 case (0.45%), as Type IV in 83 cases (37.38%), as Type V in 2 cases (0.90%) and as type Ⅷ in 3 cases (1.3%). According to these results, the Distal 1 canal was statistically significant and observed more frequently in males compared to females (P = 0.000). In both males and females, an additional root was observed in the distolingual root in four cases. All canal configurations in this root were identified as Type I (Table 1).

Discussion

A comprehensive understanding of root and canal anatomy is essential for successful endodontic treatment. Ignoring anatomical variations is one of the most common reasons underlying unsuccessful endodontic treatment (7,8). CBCT is an excellent imaging method for detecting internal and external anatomical variations without surgery or any invasive procedure, using multiplanar scans obtained from axial sections of the tooth (9). In this study, CBCT was used to visualize the internal and external anatomy of teeth in three dimensions.

Maxillary first molars are considered one of the most challenging teeth to treat due to the complexity of their root and canal structures, particularly the frequency of mesiobuccal (MB) canals (10). According to the results of our study, in both males and females (100%), all maxillary first molars had three roots, like the findings of other studies (11,12). In a previous study on a Turkish population, 99%

of maxillary first molars had three roots in males and 99.1% had three roots in females, which is consistent with our findings (13). Regarding root and canal morphologies, in our study, all palatal and distobuccal roots of maxillary first molars had a single root and a single canal (Vertucci Type I). Previous studies have found a 98-100% incidence of single roots and canals in the palatal and distobuccal roots of maxillary first molars, which are like our results (14,11). In our study, mesiobuccal roots had a Type I canal configuration in 35.7% of males and 35.5% of females. A Type II canal configuration was present in 48(20.68%) of males and 50(21.92%) of females. Type IV canal configuration was observed in 99(42.67%) of males and 100 (43.85%) of females. Type V canal configuration was found 2(0.86%) and 1(0.43%) in males and females respectively. These findings are like those of Altunsoy et al. (13), who found that Type IV canals were most common among mesiobuccal roots. The presence of second MB canal was found as %64.3 in our study. Our findings are smilar to the studies of Aktan et al. (15) and Ratanajisarut et al. (16) in which they found %63.25 and %63.6 respectively.

Mandibular first molars typically have two roots, one mesial and one distal. In our study, 98.14% of mandibular molars in males and 98.24% of mandibular molars in females had two separate roots. An additional distal root (Type I) was found in mandibular molars of 1.86% of males and 1.76% of females. No significant difference in the number of roots was observed between males and females. In previous studies, the incidence of an extra distal root in populations in Japan, China, and Hong Kong was reported to be 22.7%, 29%, and 15%, respectively (17). The extra root in the distolingual region is considered a normal variant in Asian populations with Mongoloid traits (9). Fabra-Campos (18) reported a prevalence of four canals in mandibular molars in males and females ranging from 26.0% to 57.7%. Males were found to have distal roots with one canal at a significantly higher rate than females in our study (79.04%) compared to females (42.79%) (Table 1). Our results are consistent with those of previous studies in the Turkish population, which reported an incidence of extra distal roots of 0.5–2.06% (9,19). Skidmore and Bjorndal reported that one-third of mandibular first molars of males and females have four canals (20). In a study of Demirbuga et al. (9), distal root configurations are smilar between male and female patients. This can be explained by ethnical variation of the patient pool used in these studies. Among mesial roots, Type IV canal morphology was observed in 50.47% of males and 54.50% of females. Çelikten et al. (21), in their study on the Cypriot population, found that in the mesial root of mandibular first molars, type IV canal frequency was 61.3% in females and 64.2% in males. A third canal (Type VIII) was found in 2.9% of males and 2.8% of females.

The analysis of the data obtained in this study revealed that the findings closely parallel those of other studies conducted on the general population. But distal root canal morphology differences between male and female patients are shown in this study and this is different from other studies. Therefore, the null hypothesis of this study has been partially confirmed.

Conclusion

This study does have several limitations. The sample size was small; the sample population was only representative of the patient pool at the Harran University Faculty of Dentistry. Of the 419 mandibular molars examined, the most common canal configuration in mesial roots among both males and females was Vertucci Type IV. Among distal roots, males had a significantly higher incidence of a single canal compared to females. Among maxillary molars, the most common canal morphology in mesiobuccal roots was Type IV. A comprehensive understanding of root canal anatomy, is crucial for the success of endodontic treatment. This study highlights the high prevalence of second mesiobuccal canals in maxillary first molars and complex canal morphologies in mandibular molars among a Turkish subpopulation. The findings emphasize the importance of using advanced imaging techniques like CBCT in endodontic diagnosis and treatment planning, as conventional radiographs may fail to reveal such anatomical complexities. Recognizing these variations can help clinicians avoid missed canals, reduce treatment failures, and improve long-term outcomes.This study should be supported by future studies conducted with larger populations.

Authorship Contributions: Concept: N.Ç.; Design: N.Ç.; Supervision: N.Ç.; Fundings: T.H.E.; Materials: T.H.E.; Data: T.H.E.; Analysis: N.Ç.; Literature search: T.H.E.; Writing: T.H.E.; Critical revision: N.Ç.

Use of AI for Writing Assistance: Not declared

Source of Funding: None declared.

Conflict of Interest: None declared.

Ethical Approval: The study protocol was approved by the Harran University Ethics Commitee (Protocol no: HRU/24.03.30).

Informed consent: Written informed consent was obtained from patients who participated in this study.

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ORIGINAL ARTICLE

Turk Endod J 2025;10(2):102–108
doi: 10.14744/TEJ.2025.08379

Evaluation of the effects of differences in preclinical education on endodontic clinical practice

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Purpose: This survey study aims to evaluate the effects of differences in preclinical education on endodontic clinical practice.

Methods: Students who are currently studying in the fifth year of dentistry faculty have practiced on extracted teeth in their endodontics preclinical training. Students studying in the fourth year have practiced on extracted teeth and phantom jaws and taken exams in the OSCE/OSPE laboratory. The survey was applied to a total of 199 students, 104 of whom were fourth year students and 95 of whom were fifth year students, who were actively continuing their education on a voluntary basis. The survey consisted of a total of 12 questions, the first two of which addressed gender and academic year. The remaining 10 questions evaluated the impact of differences in preclinical education on clinical education. Data were analyzed using Pearson's Chi-Square test and Fisher's Exact test.

Results: The relationship between academic year and gender distribution was examined. The analysis revealed no statistically significant relationship between these variables ($p > 0.05$). The relationship between academic year and survey responses was examined. The analysis revealed a statistically significant relationship ($p < 0.05$) between academic year and the survey question, "Did you experience difficulty applying the rubber dam during endodontic treatment?".

Conclusion: The group of students who received training in OSCE/OSPE and phantom laboratory practices found their preclinical applications to be similar to clinical applications and reported feeling more successful and prepared in treating patients.

Keywords: OSCE/OSPE; phantom laboratory; preclinical education.

Introduction

For dental students, traditional sources of fundamental knowledge have been textbooks and lectures, while technical and communication skills are acquired through simulation laboratories and clinical training (1). Laboratory and clinical settings are essential components of dental education. The integration of these two environments is crucial for applying and incorporating different learning domains, including cognitive (thinking), affective (emotion/feeling), and psychomotor (physical/kinesthetic) skills. Traditionally, before practicing on patients, students receive preclinical theoretical courses in which procedures and concepts are introduced, followed by laboratory-based practical training. Practicing on dental simulators

Cite this article as: Ateş MO, Dinger E, Yılmaz ÖS. Evaluation of the effects of differences in preclinical education on endodontic clinical practice. Turk Endod J 2025;10:102-108.

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Submitted: March 10, 2025 Revised: April 24, 2025 Accepted: April 25, 2025 Published: August 13, 2025

helps students master their skills in a controlled and safe environment while preventing harm to patients (2).

Simulation is an experiential learning tool designed to replicate "real-life" situations, and dental simulations can be defined as practices that recreate or imitate clinical conditions in dentistry. Traditionally, simulation-based education has involved performing clinical procedures using extracted or artificial teeth placed in phantom heads. More recently, the scope of simulation has expanded to include commercially available jaw models that replicate primary, mixed, or permanent dentition, as well as dental hard tissues (enamel, dentin, and pulp), carious lesions, and periodontal, endodontic, or surgical conditions. To better mimic clinical scenarios, simulator equipment such as phantom heads with jaws and torso-mounted dental operation units, as well as specially designed dental units replicating the clinical environment, have been developed (3). These types of model-based applications and simulated clinical environments are incorporated into Objective Structured Clinical Examination (OSCE) and Objective Structured Practical Examination (OSPE) laboratories. Through these simulated scenarios, students can enhance their diagnostic skills, treatment planning abilities, and patient communication competencies.

In Turkey, dental education consists of a five-year program, including both preclinical and clinical training. The first three years comprise basic science courses, professional theoretical courses, and preclinical practical training. During the preclinical education phase, students develop their clinical skills by performing treatment procedures on extracted teeth, phantom jaws, and within OSCE/OSPE laboratories. The fourth and fifth years place a greater emphasis on clinical training. During these years, students gain hands-on experience by treating patients in various clinical settings (4). By the end of this process, they acquire the ability to perform uncomplicated clinical dental procedures independently. Dentists who have successfully completed both the theoretical and practical components of their education are awarded the title of dentist (5).

Dental faculties structure their curricula in alignment with the National Core Education Program to ensure that graduates attain the fundamental competencies and skills required for the profession (6). As a result, dental education in Turkey is designed as an integrated system in which theoretical knowledge and practical skills are developed in a complementary manner through preclinical and clinical training.

OSCE and OSPE are educational methods that have started to be implemented in our country in recent years, and there are limited studies on them. To improve this educational system, more research is needed. At our faculty, current fifth year students performed their endodontic preclinical training on extracted teeth. In contrast, fourth year students conducted their preclinical training on both extracted teeth and phantom jaws and were evaluated in OSPE and OSCE laboratory exams. This study, which includes a 12-question survey, aims to evaluate the effects of differences in preclinical education on endodontic clinical practice. The null hypothesis (H0) of the study is formulated as: "Differences in preclinical education do not affect endodontic clinical practice."

Materials and Methods

Ethical approval was obtained from Non-Interventional Clinical Research Ethics Committee of Bolu Abant Izzet Baysal University. (No: 2025/48, Date: 04/02/2025). The study was conducted under the principles of the Declaration of Helsinki

Sample Size Calculation

In this study, using the "G. Power-3.1.9.2" program, the standardized effect size was taken as 0.30, as suggested by Cohen (7), with the originality of the study (8) at a 95% confidence level ($\alpha = 0.05$), and the minimum sample size was calculated as 172 with a theoretical power of 0.90.

This survey study was conducted with students registered at Bolu Abant Izzet Baysal University Faculty of Dentistry. The survey was applied to a total of 199 students, 104 of whom were fourth year students and 95 of whom were fifth year students, who were actively continuing their education on a voluntary basis. The groups of students included in our study had the same groups of teeth treated in the fourth year Endodontics clinic. In order to evaluate fourth and fifth year students objectively, fifth year students were asked to answer the questions by taking into account their treatment during fourth year.

The study used survey and data collection methods. The survey consisted of a total of 12 questions, the first two of which addressed gender and academic year. The remaining 10 questions evaluated the impact of differences in preclinical education on clinical education. The survey was conducted online through a created link.

Statistical Analysis

In this study, descriptive statistics of the data (frequency and percentage) were provided. To test the relationship between categorical variables, the Pearson Chi-Square test was applied when the sample size assumption (expected value > 5) was met. When the sample size assumption was not met, Fisher's Exact test was used. All analyses were conducted using IBM SPSS 27 software.

Results

When examining the gender distribution by academic year, the proportion of female students in the fourth year was determined to be 54.7%, while the proportion of male students was 47.9%. In the fifth year, the proportion of female students was 45.3%, and the proportion of male students was 52.1%. Among the female students, 67.3% were in the fourth year, while 61.1% were in the fifth year. Among the male students, 32.7% were in the fourth year, whereas 38.9% were in the fifth year. (Table 1).

The Pearson Chi-Square test was applied to examine the relationship between academic year and gender distribution. The analysis revealed no statistically significant relationship between these variables ($p > 0.05$). The gender distribution across academic years was found to be homogeneous. (Table 1).

The distribution of survey responses by academic year is presented in the Table 2. The proportion of students who reported experiencing high levels of stress when they first started treating patients in the clinic was 46.2% in the fourth year and 45.3% in the fifth year. The proportion of students who believed that their preclinical training was similar to clinical applications was 53.8% in the fourth year and 37.9% in the fifth year. (Table 2).

Among students who felt prepared to treat patients as a result of their preclinical training, 37.5% were in the fourth year, while 28.4% were in the fifth year. The proportion of students who believed that their preclinical success and grades aligned with their clinical performance was 39.4% in the fourth year and 38.9% in the fifth year. Students who stated that the challenges they faced in preclinical training were similar to those they encountered with patients in the clinic accounted for 37.5% in the fourth year and 31.6% in the fifth year. (Table 2).

Regarding diagnostic skills, 45.2% of fourth year students and 44.2% of fifth year students reported not having difficulty diagnosing patients and identifying the painful tooth. The proportion of students who had difficulty positioning the patient and achieving an adequate field of view was 41.3% in the fourth year and 47.4% in the fifth year. (Table 2).

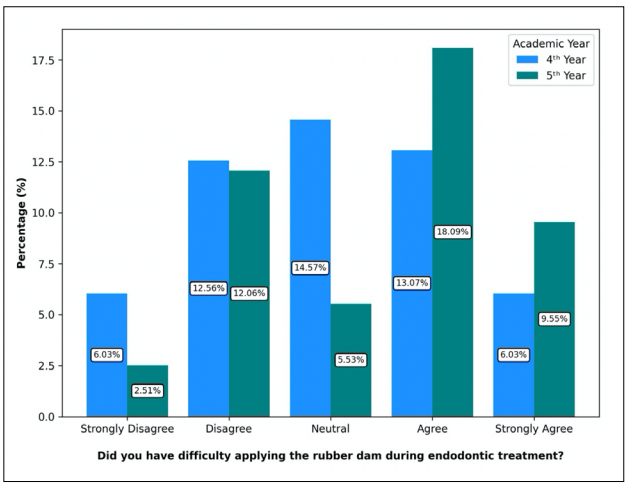

Fig. 1. The survey question.

Among students who did not experience difficulty during the access cavity preparation stage of endodontic treatment, 32.7% were in the fourth year, while 40.0% were in the fifth year. The proportion of students who reported struggling with rubber dam application during endodontic treatment was 25.0% in the fourth year and 37.9% in the fifth year. The proportion of students who found the preparation stage of endodontic treatment challenging was 26.9% in the fourth year and 36.8% in the fifth year. (Table 2).

To examine the relationship between academic year and survey responses, Pearson's Chi-Square and Fisher's Exact tests were performed. The analysis revealed a statistically significant relationship ($p < 0.05$) between academic year and the survey question, "Did you experience difficulty applying the rubber dam during endodontic treatment?". It was determined that students who responded "Agree" were predominantly from the fifth year, while those who responded "Neutral" were mostly from the fourth year. (Fig. 1).

Table 1. Distribution of students' genders according to their periods and their relationships

	4th year			5th year				
	n	%	P%	n	%	P%	Test Statistics	p
Gender								
Female	70	54.7	67.3	58	45.3	61.1	0.846	0.358
Male	34	47.9	32.7	37	52.1	38.9		

%: Row percentage and %P: Column percentage for periods.

Table 2. Distribution of survey questions according to students' periods and their relationships

	4th year			5th year				
	n	%	P%	n	%	P%	Test Statistics	p
When I started treating patients in the clinic, my stress level was high.								
Strongly Disagree	0	0.0	0.0	2	100.0	2.1	3.688	0.453
Disagree	9	69.2	8.7	4	30.8	4.2		
Neutral	8	57.1	7.7	6	42.9	6.3		
Agree	39	49.4	37.5	40	50.6	42.1		
Strongly Agree	48	52.7	46.2	43	47.3	45.3		
Do you think your preclinical training is similar to clinical practice?								
Strongly Disagree	3	37.5	2.9	5	62.5	5.3	5.619	0.222
Disagree	19	48.7	18.3	20	51.3	21.1		
Neutral	22	44.0	21.2	28	56.0	29.5		
Agree	56	60.9	53.8	36	39.1	37.9		
Strongly Agree	4	40.0	3.8	6	60.0	6.3		
Do you feel ready to treat patients as a result of the training you received in the preclinical clinic?								
Strongly Disagree	1	11.1	1.0	8	88.9	8.4	9.233	0.051
Disagree	23	56.1	22.1	18	43.9	18.9		
Neutral	37	52.1	35.6	34	47.9	35.8		
Agree	39	59.1	37.5	27	40.9	28.4		
Strongly Agree	4	33.3	3.8	8	66.7	8.4		
Do you think your preclinical success and scores are parallel to your success in the clinic?								
Strongly Disagree	5	41.7	4.8	7	58.3	7.4	1.476	0.844
Disagree	30	54.5	28.8	25	45.5	26.3		
Neutral	25	54.3	24.0	21	45.7	22.1		
Agree	41	52.6	39.4	37	47.4	38.9		
Strongly Agree	3	37.5	2.9	5	62.5	5.3		
Are the difficulties and problems you experience in preclinical practice similar to the difficulties you experience while treating patients?								
Strongly Disagree	9	37.5	8.7	15	62.5	15.8	3.241**	0.518
Disagree	36	52.9	34.6	32	47.1	33.7		
Neutral	12	48.0	11.5	13	52.0	13.7		
Agree	39	56.5	37.5	30	43.5	31.6		
Strongly Agree	8	61.5	7.7	5	38.5	5.3		
Have you had difficulty diagnosing the patient or the aching tooth?								
Strongly Disagree	12	75.0	11.5	4	25.0	4.2	4.840	0.300
Disagree	47	52.8	45.2	42	47.2	44.2		
Neutral	21	48.8	20.2	22	51.2	23.2		
Agree	21	50.0	20.2	21	50.0	22.1		
Strongly Agree	3	33.3	2.9	6	66.7	6.3		
Did you have difficulty positioning the patient to provide adequate viewing angle?								
Strongly Disagree	3	42.9	2.9	4	57.1	4.2	1.613	0.836
Disagree	17	51.5	16.3	16	48.5	16.8		
Neutral	20	58.8	19.2	14	41.2	14.7		
Agree	43	48.9	41.3	45	51.1	47.4		
Strongly Agree	21	56.8	20.2	16	43.2	16.8		
Did you have any difficulties in the access cavity phase while performing endodontic treatment on a patient?								
Strongly Disagree	11	64.7	10.6	6	35.3	6.3	3.175**	0.529
Disagree	34	47.2	32.7	38	52.8	40.0		
Neutral	21	61.8	20.2	13	38.2	13.7		
Agree	30	50.0	28.8	30	50.0	31.6		
Strongly Agree	8	50.0	7.7	8	50.0	8.4		
Did you have difficulty applying the rubber dam during endodontic treatment?								
Strongly Disagree	12a	70.6	11.5	5a	29.4	5.3	13.818**	0.008*
Disagree	25a	51.0	24.0	24a	49.0	25.3		
Neutral	29a	72.5	27.9	11b	27.5	11.6		
Agree	26a	41.9	25.0	36b	58.1	37.9		
Strongly Agree	12a	38.7	11.5	19a	61.3	20.0		
Did you have any difficulties in the preparation phase when performing endodontic treatment on a patient?								
Strongly Disagree	4	66.7	3.8	2	33.3	2.1	7.143	0.120
Disagree	26	45.6	25.0	31	54.4	32.6		
Neutral	35	66.0	33.7	18	34.0	18.9		
Agree	28	44.4	26.9	35	55.6	36.8		
Strongly Agree	11	55.0	10.6	9	45.0	9.5		

Discussion

Before performing treatments on real patients in dental faculties, students attend preclinical theoretical courses and then practically work on extracted teeth and simulated head models in the phantom laboratory, as well as participate in OSCE/OSPE applications (9). Before treating patients in the clinic, faculty's fifth year students received clinical observation training in addition to theoretical and extracted tooth-based endodontic treatment training in the preclinical phase. On the other hand, fourth year students, before treating patients in the clinic, underwent theoretical and extracted tooth-based training in the preclinical phase, performed root canal treatment on phantom jaw models, applied rubber dam, and after clinical observation, participated in OSCE/OSPE applications. This study aims to evaluate the effects of different educational methods applied in preclinical education on endodontic clinical practice at faculty. Practicing on extracted teeth to simulate clinical conditions is a common approach in endodontic preclinical practical education (10,11). In traditional simulation applications, extracted human teeth or artificial teeth are placed in jaw models for use. Some of these teeth and models are designed to mimic not only enamel, dentin, pulp, and caries but also periodontal, endodontic, and surgical conditions (3).

Students in the phantom laboratory environment perform repeatable procedures on a simulation head mounted on the simulator, thereby enhancing their psychomotor and manual skills while refining their abilities through practice (2). During OSCE applications, in addition to simulation models in phantom laboratories, sample patient profiles are also used to create an environment where students can explain a patient's symptoms by linking them to pathophysiological mechanisms. In OSCE stations, students may be required to analyze case scenarios and then answer multiple-choice questions regarding diagnostic tests, assessments, and treatment planning. This can be carried out through verbal questions posed by a station examiner or in written format, where students answer short-answer classic questions or multiple-choice questions (12).

In an OSCE, a student must demonstrate clinical competence rather than merely possessing theoretical knowledge of the subject (13). OSCE was later expanded into OSPE and was described in 1975 and in more detail in 1979 (14). Both are student assessment approaches where competencies are evaluated comprehensively, consistently, and in a structured manner. OSCE and OSPE terms are often used interchangeably without distinction (15). It is stated that OSPE is an exam format that allows for the identification of both the strengths and weaknesses of students' practical skills (16). Both students and educators consider this examination format to be positive and useful (17).

OSPE is now considered the gold standard for evaluating practical laboratory skills worldwide (18). OSCE, on the other hand, is still undergoing continuous improvement in terms of reliability, validity, objectivity, and applicability. However, OSCE has gained global acceptance as an established method for student evaluation (15). It has been reported that students believe OSCE is a fairer and less stressful test format compared to traditional written and oral exams (19). OSCE also promotes learning by enhancing communication skills and contributes to students making more accurate self-assessments (20). In a study by Radke et al. (21) comparing traditional exam methods and OSPE, they noted that students performed better in OSPE but found no statistical difference between the two methods. OSPE has been found to be applicable and acceptable to students for evaluating practical skills in undergraduate dental education.

In dental faculties, many students experience high levels of stress in the dental clinic learning environment, which leads to challenges for both the instructors and students (22). The morphological complexity and diversity of the root canal system, the complexity of endodontic procedures, and the lack of confidence among students lead many dental students to describe endodontics as a stressful, challenging, and complex field to learn (23). In the survey study, both student groups similarly reported high stress levels.

Students should not treat patients until they demonstrate the necessary skills in a preclinical environment. However, it may not always be possible to sufficiently simulate all procedures in a preclinical setting, and in such cases, learning through practice in the clinical environment should be facilitated. Similarly, sometimes students may not be exposed to all procedures in the clinical environment during their undergraduate education, and simulation may be the only way to practice relevant skills (24). This situation demonstrates the connection and importance of OSCE/OSPE and phantom laboratory applications in preclinical and clinical education in dental education.

Considering the role of OSCE/OSPE and phantom laboratory training in preparing students for clinical practice, the fact that fourth year students who received this training feel more ready and successful in performing treatments compared to the student group who did not receive this training, and the similarity of the challenges they face with those experienced in the preclinical setting, supports this training model.

In dental education, after completing their theoretical and practical training through traditional methods, students may encounter difficulties in the diagnostic and treat-

ment stages when they begin clinical internships to treat patients. It is believed that realistic preclinical applications have a significant impact on helping students adapt to and succeed in clinical internships, especially in patient examination, diagnosis, and treatment (15,25). The survey results in this study show that the student group who did not receive OSCE/OSPE training similar to clinical practice struggled with diagnosing and identifying the painful tooth.

Seijo et al. (22) similarly showed that the biggest challenges faced by preclinical and clinical students were related to radiographic techniques, the treatment of curved and narrow canals, root canal orifice identification, rubber dam application, access cavity preparation, and root canal filling. Mirza et al. (26) also reported that the majority of students faced difficulties with rubber dam application in their studies. In line with these studies, the group of students who did not receive training in OSCE/OSPE and phantom laboratories reported greater difficulties in patient positioning, access cavity preparation, rubber dam application, and preparation stages in the survey results.

When comparing the similarity between preclinical and clinical applications, the student group trained in OSCE/OSPE and phantom laboratory practices found the applications to be more similar to each other. It is thought that preclinical training models that resemble clinical procedures may yield beneficial results for clinical performance. Similarly, Brand et al. (27) found that students who practiced on training models were significantly more confident and calm while performing anesthesia, leading to reduced patient pain and an increased trust in the dentist by the patient. Based on the literature review, it is suggested that the quantity and quality of endodontic education could affect treatment outcomes (28).

To identify the challenges faced by students and reduce these challenges, more extensive research should be conducted on a larger scale. Feedback from students is crucial for educational reforms and should be periodically collected to improve learning. The limitations of this study are that the findings are based on a specific participant group, which limits the generalizability of the results. Additionally, the study is based on subjective data that may be subject to participant bias. Furthermore, external factors such as differences in curricula and teaching methods between dental schools may influence the applicability of the findings on a broader scale. Future research should consider a more diverse sample and use objective measurements.

Conclusion

Undergraduate students' perceptions of their dental school experience should be taken into account in all discussions and decisions regarding dental education. Students can provide valuable feedback and suggestions for curriculum revision and improving the learning environment (29). According to the feedback received from the students in the survey, the group of students who received training in OSCE/OSPE and phantom laboratory practices found their preclinical applications to be similar to clinical applications and reported feeling more successful and prepared in treating patients. On the other hand, the student groups who did not receive this training experienced higher stress levels and reported greater difficulties with diagnosis and treatment procedures. Considering the results, it is believed that the applications in OSCE/OSPE and phantom laboratories positively contribute to the practical education of students.

Authorship Contributions: Concept: M.O.A.; Design: M.O.A., E.D., Ö.S.Y.; Supervision: M.O.A.; Funding: M.O.A., E.D., Ö.S.Y.; Materials: M.O.A., E.D., Ö.S.Y.; Data: M.O.A., E.D., Ö.S.Y.; Analysis: M.O.A., E.D., Ö.S.Y.; Literature search: M.O.A., E.D., Ö.S.Y.; Writing: M.O.A., E.D., Ö.S.Y.; Critical revision: M.O.A.

Acknowledgements: The authors would like to thank all the students who participated in this survey.

Use of AI for Writing Assistance: Not declared

Source of Funding: None declared.

Conflict of Interest: None declared.

Ethical Approval: The study protocol was approved by the Bolu Abant Izzet Baysal University Ethics Commitee (date: 04.02.2025 protocol no: 2025/48).

Informed consent: Written informed consent was obtained from patients who participated in this study.

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ORIGINAL ARTICLE

Turk Endod J 2025;10(2):109–115
doi: 10.14744/TEJ.2025.29200

Artificial intelligence driven dental trauma assessment: Comparing the performance of chatbot models

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Purpose: This study aimed to compare the accuracy and reliability of four chatbot applications—ChatGPT o1, Google Gemini Advanced, DeepSeek R1, and Perplexity AI—in the context of dental traumatology.

Methods: Twenty-five dichotomous questions, derived from the 2020 guidelines of the International Association of Dental Traumatology (IADT), were administered by three independent researchers to each chatbot over a 10-day period. Each question was asked three times per day, generating 90 responses per question. Responses were categorised as "correct," "incorrect," or "refer to a practitioner." Accuracy rates and Fleiss' Kappa values were calculated to assess performance and inter-response reliability.

Results: All chatbot models demonstrated high levels of accuracy. ChatGPT o1 yielded the highest accuracy rate (86.4%), followed by DeepSeek (84.0%), Perplexity (80.5%), and Google Gemini Advanced (80.2%). The highest Fleiss' Kappa value was observed in the DeepSeek model (0.709), indicating the greatest internal consistency, while the Google Gemini Advanced model recorded the lowest value (0.185). Although DeepSeek and Perplexity exhibited relatively stronger reliability metrics, none of the models achieved complete consistency, with intra-platform variation occasionally present.

Conclusion: Contemporary chatbot models show substantial accuracy and improving reliability in responding to dental traumatology queries, suggesting their potential as clinical support tools. Nonetheless, further refinement and domain-specific optimisation remain necessary.

Keywords: Accuracy; artificial intelligence; chatbot; dental traumatology; reliability.

Introduction

The field of Artificial Intelligence (AI) encompasses a range of applications, including large language models (LLMs), which have publicly available to users since November 2022. These models have the capacity to simulate human speech through the utilisation of natural language processing (NLP) and machine learning techniques (1). LLMs are trained on extensive datasets, which enable them to discern the complex patterns inherent in human language. Consequently, they facilitate access to informa-

Cite this article as: Özden İ, Kaplanoğlu MB, Gökyar M, Özden ME, Öveçoğlu HS. Artificial intelligence driven dental trauma assessment: Comparing the performance of chatbot models. Turk Endod J 2025;10:109-115.
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Submitted: April 08, 2025 Revised: April 08, 2025 Accepted: April 30, 2025 Published: August 13, 2025

tion by generating responses in a natural dialogue format. In contrast to conventional search engines, these models possess the capacity to generate responses within a specific context, thereby presenting significant opportunities for patient-physician communication and clinical decision-making in the healthcare domain (2-4). However, the accuracy and consistency of the information provided by these technologies remain subjects of debate. In recent years, the scientific validity of AI-powered chatbots has been investigated across various fields of dentistry. While extant literature has appraised the proficiency of prominent chatbots such as ChatGPT and Google Gemini across diverse dental disciplines (5-9), the findings of these studies have been inconclusive. While some studies posit a certain degree of benefit from these models (8,10), others emphasise the persistent risk of erroneous or incomplete information generation (11,12).

In recent years, significant advancements have been made in the field of chatbots. For instance, DeepSeek AI (R1), introduced in 2025, is a model trained on extensive datasets and has been reported to demonstrate performance comparable to GPT-o1 (13). Similarly, Perplexity AI, launched in 2022, has garnered attention for its ability to respond to user queries in natural language by summarizing information gathered from web sources. A distinguishing feature of Perplexity AI is its direct provision of sources through hyperlinks, setting it apart from other chatbots. Although a comprehensive evaluation of Perplexity AI in the healthcare domain is lacking, studies have shown that it can generate accurate responses on certain topics (14). Moreover, the integration of LLM-based chatbots into telehealth platforms holds promise for enhancing remote patient care yet underscores the importance of validating these tools for accuracy and consistency in clinical scenarios (15). However, the reliability of these next generation chatbots in the healthcare field, particularly in specialised medical disciplines such as dentistry, has yet to be thoroughly assessed.

Conversely, advanced chatbots such as ChatGPT (o1) and Google Gemini (Advanced) incorporate various enhancements designed to deliver enhanced accuracy and consistency in comparison to their earlier versions. A substantial body of extant literature demonstrates that these advanced models consistently yield more efficacious outcomes in comparison to GPT-3.5 and earlier versions of Google Gemini (16-19). Nevertheless, further research is required to accurately delineate the limitations of these models in medical applications.

Dental traumatology is the branch of dentistry concerned with the epidemiology, etiology, prevention, assessment, diagnosis and treatment of traumatic dental injuries. The management of such injuries requires a multidisciplinary approach, and the timing of emergency intervention plays a crucial role in treatment outcomes. Therefore, evaluating the potential of AI-assisted systems in this domain is of significant academic and clinical importance. However, the extent to which current models provide adequate accuracy and consistency in specialised medical fields such as dental traumatology remains uncertain, necessitating further investigation. The present study aims to address this gap by comparing the consistency and accuracy of both next generation chatbots (DeepSeek, Perplexity AI) and the premium, advanced versions of widely used chatbots, ChatGPT (o1) and Google Gemini (Advanced). The first hypothesis of this study posits that advanced chatbot versions will achieve higher accuracy rates than their predecessors. The second hypothesis suggests that in specialised fields such as dental traumatology, AI-assisted chatbots may fail to achieve the acceptable diagnostic accuracy threshold of 90% or above.

Materials and Methods

This research was conducted as a cross-sectional study to examine the consistency and accuracy of responses provided by four artificial intelligence (AI) chatbots: Google Gemini Advanced, ChatGPT-01, DeepSeek R1, and Perplexity AI. Data collection took place from 21 February to 3 March 2025, during which 25 dichotomous (yes/no) questions were posed three times a day (morning, afternoon, and evening) to each of the four platforms. Three independent researchers, each using separate accounts, initiated the queries simultaneously to minimise temporal bias. Before every query session, the "new chat" feature was selected and previous chat histories were cleared, ensuring that no chatbot could draw upon information from earlier interactions. As there were no human participants involved, ethical approval was not required.

The primary outcome variable for this study was the accuracy of the chatbots' responses, classified as "correct," "incorrect," or "referral to a healthcare professional." The 25 questions (Table 1) used were originally developed by Özden et al. (19) and adhered to the 2020 guidelines of the International Association of Dental Traumatology (20). During the 10-day period, each question yielded a total of 90 responses (3 responses per day × 10 days × 3 researchers), and the "correct" answers were determined by reference to the IADT guidelines. This setup provided a structured framework for assessing the performance of each chatbot under standardised conditions.

In order to address potential sources of bias, the researchers employed several precautions. Chat histories were purged prior to each query, thereby preventing the chatbots from

Table 1. Questions

Should root canal treatment be performed if the tooth has a positive response to the pulp sensitivity test in the presence of a crown fracture involving only enamel and no accompanying luxation or root fracture?
Should a follow-up procedure be implemented for the vitality of the tooth in uncomplicated crown fracture cases?
Is there percussion and palpation sensitivity in uncomplicated crown fractures?
Is root canal treatment the only treatment option for complicated crown fractures in teeth with complete root development?
Should root canal treatment be performed if the tooth responds positively to the pulp sensitivity test in the presence of an uncomplicated crown fracture?
Is root canal treatment the first treatment option to consider in the presence of a complicated crown fracture in permanent teeth with incomplete root development?
Should the involved tooth be splinted to adjacent teeth in root fractures?
Can root fractures be detected without radiographic examination?
Should the splint applied in trauma cases be rigid?
Should the splinting period be extended in root fractures close to the cervical region?
Should root canal treatment be performed on the teeth, without any other injury, in the affected segment in alveolar fracture?
Should root canal treatment be performed immediately in subluxation cases without any other injury?
Is the elapsed time important in the repositioning of an extruded permanent tooth?
Should it be considered that there might be an accompanying alveolar bone fracture in every lateral luxation case?
Is there a chance of spontaneous repositioning in teeth intruded less than 3 mm?
Is splinting necessary for teeth intruded more than 3 mm?
Can teeth intruded more than 7 mm be repositioned orthodontically?
Are the storage conditions of an avulsed tooth important?
Should tetanus vaccine be recommended to the patient in every avulsion case?
Should an avulsed milk tooth be replanted?
Is it important where the avulsed tooth is stored?
Does the time elapsed after dental trauma change the treatment option?
Is avulsion the injury type with the highest risk of ankylosis?
Is intrusion the injury type with the highest risk of root resorption?
Is root fracture in the cervical region the injury type that requires the longest splinting time in trauma cases?

utilising any previously supplied information. Queries were made simultaneously across all four platforms, reducing the likelihood of temporal variations affecting the responses.

Statistical Analyses

All answers were stored in an Excel spreadsheet (Microsoft, Redmond, WA, USA) and analysed using the statistical software program Statistical Product and Service Solutions version 29 (IBM Corp., Armonk, NY, USA). Descriptive statistics (frequencies and percentages) were used to summarise correct, incorrect, and referral responses for each chatbot. Fleiss' kappa was used to determine whether there was an agreement between the responses. As the research design ensured consistent and complete data collection, no missing data were encountered.

Results

In this study, a total of 9000 responses were evaluated, revealing an overall correct answer rate of 82.8% and an incorrect answer rate of 17.2%, with only four responses classified as "referral to a healthcare professional" (Table 2). Among the assessed chatbots (Table 3), Google Gemini Advanced provided 80.2% correct, 19.7% incorrect, and 0.1% referral to a healthcare professional response, demonstrating low reliability ($\kappa = 0.185$; 95% CI, 0.144–0.247). ChatGPT o1 achieved 86.4% correct and 13.6% incorrect responses ($\kappa = 0.556$; 95% CI, 0.515–0.598). Perplexity attained 80.5% correct and 19.5% incorrect responses ($\kappa = 0.693$; 95% CI, 0.652–0.735). DeepSeek delivered 84.0% correct and 16.0% incorrect responses ($\kappa = 0.709$; 95% CI, 0.668–0.750).

Table 2. The distribution of accuracy of artificial intelligence applications' responses

Total	n (%)
Correct	7450 (82.8)
Incorrect	1546 (17.2)
Referral to a healthcare professional	4

Table 2. The distribution of accuracy of responses from artificial intelligence applications and reliability values

	Correct %*	Incorrect %*	Referral to a healthcare professional %*	Reliability **(%95 CI)
Google Gemini Advanced	80.2	19.7	0.1	0.185 (0.144 – 0.247)
ChatGPT o1	86.4	13.6	-	0.556 (0.515 – 0.598)
Perplexity	80.5	19.5	-	0.693 (0.652 – 0.735)
Deepseek	84.0	16.0	-	0.709 (0.668 – 0.750)

*Percentages of rows. **Fleiss Kappa.

Discussion

In this study, the consistency and accuracy performances of recently emerging chatbots, such as DeepSeek and Perplexity AI, were compared with advanced and premium versions of widely used chatbots, namely ChatGPT (o1) and Google Gemini (Advanced). The accuracy rates of all evaluated chatbots exceeded 80%. A comparison of the present findings with a prior study conducted in 2024 reveals a significant enhancement in accuracy for the updated versions (19). In the aforementioned study (19), the same set of questions was posed to ChatGPT 3.5 and Google Gemini. Moreover, the previously documented rate of incorrect responses decreased from 39.2% to 17.2%, while the proportion of responses directing users to a healthcare professional diminished from 3.3% to 0.04%. These findings are consistent with the results of similar studies that have compared the paid versions of AI applications with their initial releases (21–24). A review of the literature indicates that studies questioning the accuracy and reliability of AI predominantly focused on comparisons between ChatGPT 3.5 and ChatGPT 4o, consistently reporting that the 4o version achieved significantly higher accuracy levels. Nevertheless, ChatGPT o1 is regarded as the most advanced version to date, having been developed through enhanced chain-of-thought reasoning techniques. Designed to maximize reasoning capabilities via human-like algorithms, the o1 model is especially well-suited for complex clinical contexts (25). Consequently, the most up-to-date version of ChatGPT, the o1 model, was chosen for utilization in the present study.

The reliability analysis (Fleiss' Kappa) revealed that the DeepSeek model exhibited the highest reliability coefficient, followed by Perplexity, ChatGPT o1, and Gemini Advanced, in that order (0.709 Substantial (High); 0.69 Substantial (High); 0.556 Moderate (Medium); 0.185 Slight (Very Low)). This finding supports the null hypothesis of the study, which was partially accepted. The reliability levels of both Gemini Advanced and ChatGPT o1 are substandard. Conversely, DeepSeek and Perplexity, with their high reliability coefficients, appear promising in terms of supporting clinicians in the field of traumatology.

In a study by Mondillo et al. (25), which evaluated the decision-making competence of ChatGPT o1 and DeepSeek in paediatric cases, it was reported that ChatGPT o1 demonstrated higher reliability levels than DeepSeek. However, this finding does not align with the results of the present study. This discrepancy may be attributed to differences in question formats: while the current study utilised dichotomous (yes/no) questions, the previous study employed multiple-choice questions with a single correct answer. DeepSeek-R1 is an advanced reasoning program based on reinforcement learning (RL) (26). The model's self-reflection capability, described as a form of self-improvement, allows it to verify and optimise its logical steps independently, thereby enhancing its direct question-answering performance (27). This feature may explain why DeepSeek-R1 achieves higher accuracy in dichotomous (yes/no) questions compared to multiple-choice questions.

In the present study, an evaluation of various chatbots revealed that they employed different modelling approaches. Specifically, ChatGPT o1 and DeepSeek R1 utilised a generative model (GM) approach, whereas Google Gemini Advanced and Perplexity AI generated responses employing a retrieval-augmented generation (RAG) framework. The GM approach employs neural networks to generate coherent and creative responses through statistical analysis. However, it has been reported that this creativity can sometimes result in the production of inaccurate or incomplete information, a phenomenon referred to as "hallucination" (28). In contrast, the RAG model enhances text generated by the GM approach with additional information retrieved by a retrieval model (RM), producing more comprehensive and informative responses. Evidence-supported responses in RAG models have been hypothesised to reduce hallucinations and improve information accuracy (28,29).

In this study, the AI applications based on the GM approach (ChatGPT o1 and DeepSeek R1) demonstrated higher accuracy and reliability compared to those utilising the RAG approach (Gemini Advanced and Perplexity AI). This outcome may be attributed to the dichotomous nature of the questions, which likely minimized the risk

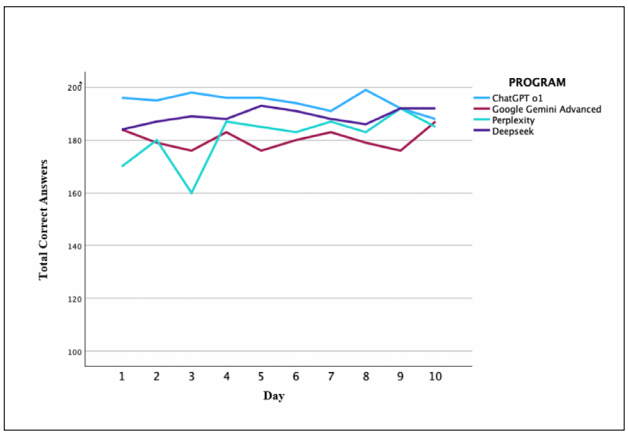

Fig. 1. The variation in the total number of correct answers provided by chatbots to the questions asked on different days.

Fig. 2. Responses by ChatGPT o1 to the same question asked from the same account at different times.

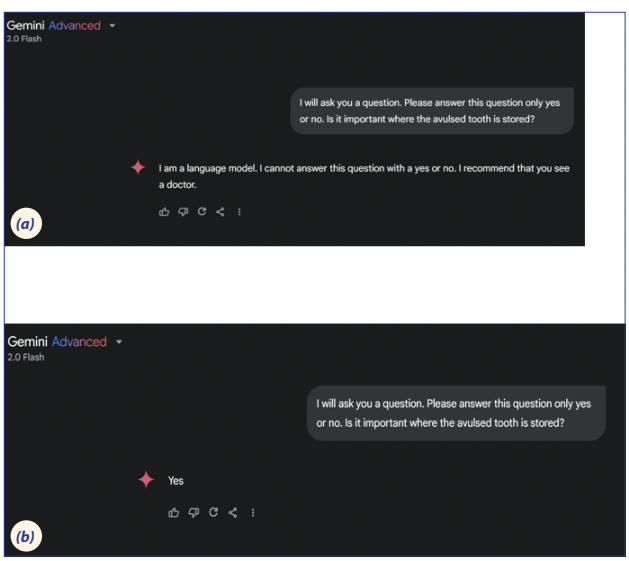

Fig. 3. Responses by Gemini Advanced to the same question asked from two different accounts.

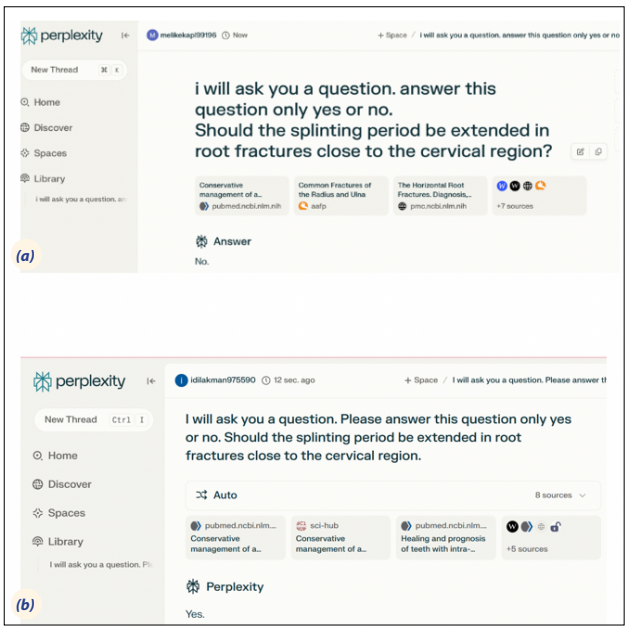

Fig. 4. Responses by Perplexity to the same question asked from two different accounts.

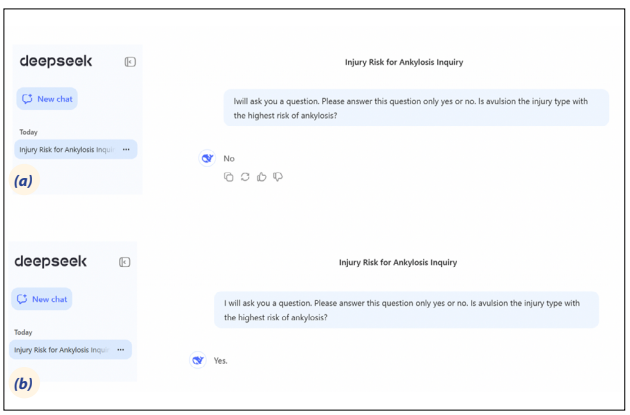

Fig. 5. Responses by DeepSeek to the same question asked from the same account at different times.

of hallucinated responses and prevented a decline in accuracy. However, independent of software modelling, none of the evaluated applications achieved 100% consistency. For instance, discrepancies were observed within the same application when the same question was asked from different accounts or at different times from the same account (Figures 1–5).

In the present study, to prevent AI applications from learning the questions, each query was posed in a new chat session after the chat history had been cleared. Additionally, to minimize temporal variability, the questions were posed simultaneously from three different accounts over a 10-day period. Despite the implementation of these preventive measures, the study has certain limitations. Firstly,

restricting responses to a "yes/no" format does not fully capture the multidimensional nature of clinical practice. In the present study, dichotomous (yes/no) questions were employed to assess the decision-making performance of AI-based chatbots objectively and reproducibly in the context of dental trauma. However, it should be noted that this methodological choice is not without its limitations. It is acknowledged that traumatic dental injuries frequently present as complex and multifactorial in nature, and therefore it is possible that binary response formats may not adequately represent such cases. This oversight may have led to outcomes that were false positive or false negative, which could have affected the internal validity of the findings. It is recommended that future research incorporate more sophisticated question formats and clinically realistic case scenarios to reflect the multidimensional character of dental trauma management more accurately and to enhance the robustness of chatbot performance assessments. Additionally, LLMs are not specifically trained in endodontics or dental traumatology, which could significantly impact the accuracy of their responses. Another limitation of this study is that the responses provided by AI applications were not compared with the knowledge level of general dentists or specialists. Such a comparison could offer valuable insights into the effectiveness of AI applications in this context, highlighting the need for further research in this area.

Conclusion

Within the limitations of this study, a sign0ificant improvement was observed in the overall accuracy of responses generated by ChatGPT o1 and Google Gemini Advanced in the field of dental traumatology, particularly when compared to their earlier versions. This finding suggests that premium versions may serve as more reliable guides compared to their open-access counterparts. However, in terms of reliability coefficients, these two applications lagged behind DeepSeek and Perplexity. When evaluated based on reliability metrics, the high reliability scores attained by Perplexity and DeepSeek indicate that these models may serve as viable alternatives to widely used language models, particularly Google Gemini Advanced.

In conclusion, the rapid advancements observed suggest that chatbots—especially when trained for medical-specific domains—may serve as effective telehealth tools in regions with limited access to healthcare services.

Authorship Contributions: Concept: İ.Ö., M.G., M.E.Ö.; Design: İ.Ö., M.B.K.; Supervision: H.S.Ö.; Materials: M.B.K.; Data: M.E.Ö.; Analysis: H.S.Ö., M.E.Ö.; Literature search: İ.Ö, M.G., M.B.K.; Writing: İ.Ö., M.G.; Critical revision: İ.Ö.; H.S.Ö.

Use of AI for Writing Assistance: Not declared

Source of Funding: None declared.

Conflict of Interest: None declared.

Ethical Approval: Ethical approval was not required since there were no human participants involved.

Informed consent: Written informed consent was obtained from patients who participated in this study.

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ORIGINAL ARTICLE

Turk Endod J 2025;10(2):116–124
doi: 10.14744/TEJ.2025.30075

Prevalence of pre-eruptive intracoronal resorptions in children and evaluation of associated factors: A retrospective study

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Purpose: This study aimed to determine the prevalence of pre-eruptive intracoronal resorption (PEIR) in children aged 4–14, evaluate the most commonly affected teeth, and identify possible etiological factors.

Methods: In this retrospective study, panoramic radiographs of pediatric patients who applied to the Department of Pediatric Dentistry at Bolu Abant İzzet Baysal University were examined between 2020 and 2023. Radiographs with sufficient diagnostic image quality and at least one unerupted permanent tooth were included in the study. The presence of PEIR, the lesion's localization, depth, the number of affected teeth, and possible etiological factors were examined.

Results: 2229 panoramic radiographs were examined. 1893 of them were found to meet the study criteria. PEIR was detected in 64 patients, and the number of teeth with PEIR was 88. PEIR was seen at a rate of 3.4% on an individual basis and 0.34% on a tooth basis. It was most frequently detected in mandibular second molars and at Grade 1 level. Lesions were more commonly located in the mandible and on the right side; in most individuals, only one tooth was affected. No significant predisposing factor was found in 90.9% of the cases.

Conclusion: PEIR is a lesion that should be carefully monitored in the early age group and progresses asymptomatically most of the time. Early diagnosis and regular radiographic follow-up are essential to prevent pulpal complications.

Keywords: Intracoronal; unerupted teeth; resorption; etiology.

Introduction

Pre-eruptive intracoronal resorptions (PEIR) are caries-like lesions in unerupted teeth, usually located in the dentin, adjacent to the enamel dentin junction (1,2). Unlike caries, these teeth are not fully erupted and have no connection with the oral flora. This lesion is usually asymptomatic and is diagnosed on routine radiographic examination (3,4). Although often located in the central or mesial part of the crown, the depth of the lesion does not usually involve the pulp (5). Various etiologies of pre-eruptive intracoronal resorption have been identified, including deciduous periapical lesions, systemic factors, and it is now generally accepted that PEIR is a resorption process (6–8). A strong association with PEIR has also been reported in individuals with significantly delayed dentition development (9).

Cite this article as: Öztürk Z, Sağdıç S. Prevalence of pre-eruptive intracoronal resorptions in children and evaluation of associated factors: A retrospective study. Turk Endod J 2025;10:116-124.

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Submitted: March 27, 2025 Revised: May 08, 2025 Accepted: May 11, 2025 Published: August 13, 2025

Histopathologic examination of PEIR lesions revealed the presence of multinucleated giant cells, osteoclasts, and chronic inflammatory cells representing resorption. Although the factors that trigger this process are not completely clear, it has been suggested that factors that may create abnormal local pressure, such as ectopic location of the tooth germ and cystic lesions around the tooth, may cause this condition (5,10).

The most important clinical risk of PEIR is the rapid progression of the lesion, threatening the pulp tissue and necessitating endodontic treatment. The retentive nature of the lesion promotes caries development and becomes indistinguishable from caries lesions once in the oral environment (11). Studies show that PEIR causes the majority of cases diagnosed as occult caries, and that if these lesions are not detected early, they can lead to complications such as abscesses, advanced tooth structure loss, and ultimately the need for endodontic treatment (6).

There are different approaches to treating PEIR depending on the lesion size. Factors such as lesion depth, condition of pulpal and periapical tissues, whether the tooth is symptomatic or not, and patient cooperation should be considered in treatment planning (8). When the case reports in the literature are examined, it is stated that small lesions are usually followed, and in medium or large lesions, it is more appropriate to expose, clean and restore the unerupted tooth surgically to limit the lesion, prevent its progression to the dental pulp and protect it from possible pulpal penetration (5,12,13). Therefore, early diagnosis of PEIR is essential in treating it with minimally invasive approaches and preventing more serious complications (14–18). This study aims to determine the incidence of PEIR, the most commonly affected teeth, and the etiologic factors that may cause this condition in the pediatric patient population aged 4-14 years after radiographic analysis.

Materials and Methods

This study was approved by the local ethics committee of Bolu Abant Izzet Baysal University, Bolu, Türkiye (Decision no: 2024/168). The research adhered to the Strengthening of Reporting of Observational Studies in Epidemiology (STROBE) checklist for cross-sectional investigations. The study was conducted under the principles of the Declaration of Helsinki.

Data Collection

In this retrospective study, patients aged 4-14 who applied to Bolu Abant İzzet Baysal University, Department of Pediatric Dentistry, between 2020-2023 and who had taken panoramic radiography for any reason were included. A total of 2229 panoramic radiographs taken on the specified dates were analyzed. The panoramic radiographs included in the study had to be diagnostically adequate and contain at least one unerupted permanent tooth. Radiographs with poor quality images and radiographs of individuals with dental pathologies such as amelogenesis imperfecta, dentinogenesis imperfecta, and bone pathologies were excluded.

Data Analysis

In all patients, age, gender, number of unerupted teeth, number of teeth with PEIR defects, number of teeth/teeth with PEIR, localization of the defect on the tooth crown (mesial, central, distal), and the extent of the lesion were evaluated. In addition, the presence of ectopic location, supernumerary tooth or cyst, caries, infection, restorative treatment, or extraction in the deciduous tooth overlying the unerupted tooth was also recorded. The prevalence of PEIR lesions was determined according to the subject and the teeth. The severity of the lesion was graded according to the mesiodistal dimension of the dentin in the tooth crown, using Seow's classification. First-grade lesions cover less than 1/3 of the available dentin thickness. Second-grade lesions extend over 1/3 and 2/3 of the available dentin thickness. Third-grade lesions involve more than 2/3 of the available dentin thickness.

Two pediatric dentists performed radiographic examinations. Before starting the evaluations, both assessors were calibrated by examining PEIR on 20 pre-selected panoramic radiographs. The Intraclass Correlation Coefficient (ICC) was calculated for inter-rater and intra-rater reliability analyses by re-examining the same radiographs 15 days apart. ICC values were over 80%. This shows that the raters gave consistent and reliable results both within themselves and with each other in diagnosing PEIR.

Statistical Analysis

Data were analyzed using the IBM SPSS V23 file. Binary logistic regression analysis was used to program unadjusted and adjusted odds ratios (OR) with 95% confidence intervals (CI) for the performance values of independent variables above the presence of PEIR. Fisher's Exact Test with Monte Carlo input is examined for the range between categorical data. Mean ± standard deviation and median (minimum-maximum) represent quantitative data. Frequency and percentage were used to represent categorical data. Significance level was included as $p < 0.05$.

Results

Panoramic radiographs of 2229 patients were examined

within the scope of the study, and 1893 of them that met the study criteria were evaluated. The total number of teeth that were unerupted by the assessed individuals was determined to be 25810, and the total number of teeth with PEIR was determined to be 88. Lesions were observed in a total of 64 patients. The median age of the individuals participating in the study was calculated as 9. When the distribution by age groups was examined, it was determined that 8% of the participants were under the age of 6, 77.6% were between the ages of 6-12, and 14.4% were 12 years of age and over. In the gender distribution, the rate of women was 52.1% and the rate of men was 47.9%.

When systemic disease status was evaluated, it was seen that most participants (89%) did not have any systemic disease. Among the existing diseases, epilepsy (4.7%) was the most common condition. In contrast, diseases such as autism spectrum disorder (ASD), familial Mediterranean fever (FMF), operated congenital cleft palate (CCP), and anemia were detected at lower rates (1.6%). The study detected PEIR in at least one tooth in 3.4% of the participating individuals. Among these individuals, 45 had one affected tooth, 16 had two affected teeth, one had three, and two had four affected teeth. PEIR was detected in 0.34% of unerupted teeth (Table 1).

According to tooth-based descriptive statistics (Table 2), the incidence of PEIR in the mandible (65.9%) was found to be higher than in the maxilla (34.1%) (Fig. 1). It was observed that PEIR cases were mostly on the right side (54.5%). The most common localization in the tooth was in the central region (76.1%) (Fig. 2), followed by the mesial (14.8%) and distal (9.1%) regions.

When the thickness of the tooth involvement was examined, it was seen that the majority of the cases had an involvement of less than 1/3 of the dentin thickness (84.1%) (Fig. 3). Deeper involvement rates were determined as 12.5% in the range of 1/3 - 2/3 and 3.4% in those with more than 2/3, respectively.

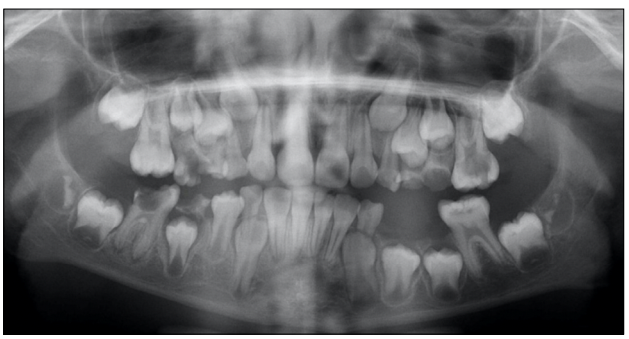

Fig. 1. Grade 1 PEIR lesions in tooth numbers 47-37.

Table 1. Patient-based descriptive statistics

	Mean ± s. deviation / Frequency	Median (min-max) / Percentage
Age	9.329 ± 2.619	9 (4 - 14)
Age group		
< 6 years	151	8
6–12 years	1469	77.6
> 12 years	273	14.4
Gender		
Female	986	52.1
Male	907	47.9
Systemic disease		
No	57	89
Epilepsy	3	4.7
ASD	1	1.6
FMF	1	1.6
Opere DDI	1	1.6
Anemia	1	1.6
Number of teeth with PEIR detected		
0	1829	96.6
1	45	2.4
2	16	0.8
3	1	0.1
4	2	0.1

Mean ± standard deviation, Median (minimum-maximum), n (%).

Table 2. Tooth-based descriptive statistics

	Mean ± s. deviation / Frequency	Median (min-max) / Percentage
Dental Arch		
Maxilla	30	34.1
Mandible	58	65.9
Arch Side		
Right	48	54.5
Left	40	45.5
Location		
Mesial	13	14.8
Central	67	76.1
Distal	8	9.1
Lesion Grade		
Grade 1	74	84.1
Grade 2	11	12.5
Grade 3	3	3.4
Etiologic factor		
No	80	90.9
Ectopic location	1	1.1
Decayed	1	1.1
Periapical lesion	2	2.3
Extracted	3	3.4
Endodontically treated	1	1.1

Mean ± standard deviation, Median (minimum-maximum), n (%).

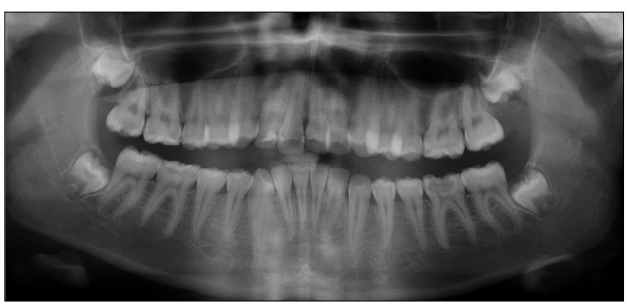

Fig. 2. Grade 2 PEIR lesion in tooth number 48.

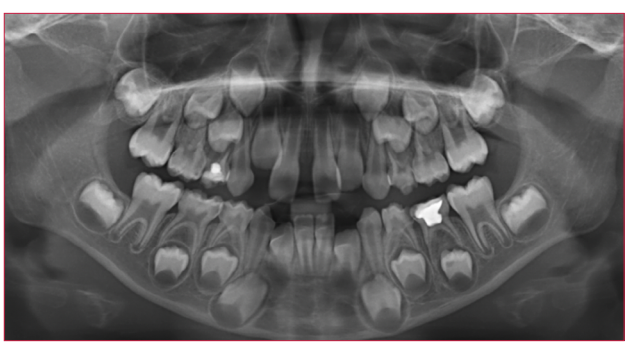

Fig. 3. Grade 1 PEIR lesion in tooth number 35.

When the etiological factors that may cause PEIR were evaluated, no predisposing factor was detected in most cases (90.9%). The most common cause among the possible factors was the extraction of the overlying primary tooth (3.4%). Other factors such as ectopic location, caries in the overlying primary tooth, periapical lesion, or endodontic treatment were observed at low rates (1.1% and 2.3%).

Table 3. Descriptive statistics of the detected tooth numbers

Tooth Number	Frequency	Percentage
13	3	3.4
14	2	2.3
16	4	4.5
17	8	9.1
21	1	1.1
23	1	1.1
26	4	4.5
27	6	6.8
35	2	2.3
36	9	10.2
37	16	18.2
43	1	1.1
45	2	2.3
46	15	17
47	13	14.8
48	1	1.1

n(%).

Descriptive statistics of the tooth numbers with PEIR are presented in Table 3. PEIR lesions were most frequently detected in mandibular molars.

Table 4. Binary logistic regression results for PEIR risk (patient-level analysis)

	PEIR risk		Univariate		Multiple	
	No	Yes	OR (95% CI)	p	OR (95% CI)	p
Age	9.363 ± 2.611	8.3v64 ± 2.67	0.868 (0.786 – 0.957)	0.005	0.835 (0.713 – 0.978)	0.026
Age group						
< 6 years	141 (93.3)	10 (6.7)	2.695 (1.004 – 7.233)	0.049	0.574 (0.107 – 3.072)	0.516
6–12 years	1422 (96.8)	47 (3.2)	1.256 (0.562 – 2.809)	0.579	0.544 (0.179 – 1.655)	0.283
> 12 years	266 (97.4)	7 (2.6)				
Gender						
Female	955 (96.9)	31 (3.1)	0.860 (0.522 – 1.416)	0.553	0.835 (0.506 – 1.378)	0.481
Male	874 (96.3)	33 (3.7)				

OR (95% CI): Odds ratio (95% confidence interval).

Table 5. Distribution of PEIR-positive teeth according to age groups and categorical characteristics

	Age Group					
	< 6 years	6–12 years	> 12 years	Total	Test statistic	p
Dental Arch						
Maxilla	5 (31.3)	25 (39.1)	0 (0)	30 (34.1)	5.046	0.071*
Mandible	11 (68.8)	39 (60.9)	8 (100)	58 (65.9)		
Arch Side						
Right	8 (50)	34 (53.1)	6 (75)	48 (54.5)	1.471	0.505*
Left	8 (50)	30 (46.9)	2 (25)	40 (45.5)		
Location						
Mesial	1 (6.3)	10 (15.6)	2 (25)	13 (14.8)	2.458	0.637*
Central	14 (87.5)	48 (75)	5 (62.5)	67 (76.1)		
Distal	1 (6.3)	6 (9.4)	1 (12.5)	8 (9.1)		
Lesion Grade						
Grade 1	13 (81.3)	55 (85.9)	6 (75)	74 (84.1)	4.063	0.349*
Grade 2	2 (12.5)	8 (12.5)	1 (12.5)	11 (12.5)		
Grade 3	1 (6.3)	1 (1.6)	1 (12.5)	3 (3.4)		
Etiologic factor						
No	15 (93.8)	59 (92.2)	6 (75)	80 (90.9)	14.254	0.161*
Ectopic location	0 (0)	1 (1.6)	0 (0)	1 (1.1)		
Decayed	1 (6.3)	0 (0)	0 (0)	1 (1.1)		
Periapical lesion	0 (0)	2 (3.1)	0 (0)	2 (2.3)		
Extracted	0 (0)	1 (1.6)	2 (25)	3 (3.4)		
Endodontically treated	0 (0)	1 (1.6)	0 (0)	1 (1.1)		

*Fisher's Exact Test with Monte Carlo Correction; n(%).

The effect of independent variables on PEIR risk was evaluated using binary logistic regression analysis and univariate and multiple models (Table 4). In the evaluation, the presence of PEIR was considered at the individual level, and the analyses were performed according to whether the patient had at least one affected tooth.

According to the univariate model results, each unit decrease in age increases the risk of PEIR (1/0,868) by 1,152 times ($p = 0.005$). In addition, the risk of PEIR in individuals aged 12 and over was calculated as 2,695 times higher than in individuals under 6 years of age. However, other independent variables did not have a statistically significant effect on the risk of PEIR ($p > 0.05$).

A similar trend was observed in the multiple model analysis, and it was determined that each unit decrease in age increased the risk of PEIR (1/0,835) by 1.197 times ($p = 0.026$). However, no significant effect of other independent variables on the risk of PEIR was detected ($p > 0.05$).

The data presented in Table 5 examined the relationship between age groups and Peir's dental arch localization, arch direction, localization on the tooth, involvement thickness, and etiological factors. In the analyses, no statistically significant difference was found between age groups regarding all variables ($p > 0.05$).

When etiological factors were evaluated, no predisposing factor was found in most cases of PEIR in all age groups (75%- 93.8%). The most frequently observed factors were extraction of the primary tooth or the presence of a periapical lesion in the primary tooth; no significant relationship was found between age and etiological factors ($p = 0.161$).

Discussion

PEIR is a vital anomaly associated with unerupted teeth. However, clinicians often overlook these defects during radiographic evaluation. The most important clinical risk of PEIR is that the lesion can progress rapidly, threaten the pulp tissue, and may lead to the need for endodontic treatment (19).

Studies emphasize that advanced PEIR lesions can reach the pulp tissue, which requires surgical intervention and restoration as soon as the lesion is detected radiographically (17).

Panoramic radiographs were preferred in this study to evaluate the prevalence of PEIR. Panoramic radiography is a routine diagnostic method widely used in dentistry practice and offers significant advantages, especially in pediatric patients, since it requires less collaboration than other imaging techniques. The ability to obtain a general view of all permanent and unerupted teeth with a single panoramic film is one of the main reasons this method is preferred in PEIR scans. In addition, panoramic radiography offers a wider anatomical field of view than conventional radiographs. It can be applied with lower radiation dose and equipment cost than cone beam computed tomography (CBCT), increasing the method's practicality. (3,7). Considering all these factors, panoramic radiographs were preferred in this study to evaluate the prevalence of PEIR.

When the literature was examined, the subject prevalence for PEIR was reported as 3.54% (0.56%–27.31%), and the dental prevalence was reported as 0.695% (0.073%–2.12%) (7). In this study, the subject PEIR prevalence was found to be 3.4%, and the dental prevalence was found to be 0.34%. In this sense, the findings largely overlap with the existing literature data. In another study, the subject prevalence was found to be 15.1% and the dental prevalence was found to be 3.5% (2). This difference is thought to be due to the imaging methods used. The study in question was conducted using CBCT, which is more sensitive in detecting small lesions due to its higher resolution and three-dimensional imaging advantage. However, the fact that CBCT cannot be used for every individual in routine clinical practice creates an essential limitation in terms of both cost and radiation dose (20).

The current study included the 4-14 age groups, and according to the findings, it was found that it was seen in 6.7% under 6 years of age, 3.2% in the 6-12 age group, and 2.6% over 12 years of age. It was determined that the prevalence of PEIR was higher in children under 6 years of age compared to other age groups. According to the current study's findings, each unit decrease in age is associated with an increase in the risk of PEIR. This may be due to the increased number of unerupted teeth in younger age groups, which increases the probability of early detection of lesions before they erupt into the oral environment. According to the study by Umansky et al. (1), no lesions were detected in the younger age group (4-8 years), while lesions were observed in 4.8% of individuals aged 9-12 and 3.7% aged 13 years and older. It was reported by Asokan et al., (3) that the prevalence of PEIR was found to be 3.9% in children under 6 years of age, 3.1% in the 6–9 age group, and 3.2% in the 10–14 age group, and no significant difference was found between age groups. In another study, the prevalence was reported as 4.93% in children under 6 years of age, 7.38% in the 6–12 age group, and 2.53% in those over 12 years of age (8). Although different results are found in the literature regarding the prevalence of PEIR depending on age, the present study's findings reveal that lesions can be seen in the early age group. This situation shows that careful radiographic follow-up is clinically significant, especially in the early age group.

The present study observed that PEIR cases were detected at a higher rate in the mandible than the maxilla. Similarly, studies on different populations reported a higher prevalence of PEIR in the mandible than in the maxilla (7,21,22). An important factor contributing to this situation may be the anatomical limitations of radiographic imaging techniques. In general, bitewing and panoramic radiographs are inadequate for clearly visualizing the crowns of unerupted maxillary premolars and molars. In contrast, these structures can be more clearly observed in mandibular teeth (2). Therefore, PEIR lesions in unerupted maxillary teeth may be missed diagnostically, especially in the mixed dentition. This may lead to underreporting the prevalence of PEIR in the maxillary region due to inadequate radiographic visualization of the involved teeth (23).

In the present study, PEIR lesions were most frequently seen in mandibular molars, especially mandibular sec-

ond molars, followed by maxillary molars, mandibular premolars, and mandibular canines, respectively. In line with the present study, Ozden and Açıkgoz (17) reported that PEIR lesions were most frequently seen in mandibular second molars. Again, in the study by Manmontri et al.(23), the teeth most commonly affected by PEIR are mandibular second molars.

In addition, it has been reported in different studies that the tooth groups in which PEIR is most frequently seen vary. One study reported that mandibular molars had the highest PEIR prevalence with 18.6%, supernumerary teeth with 17.6%, maxillary molars with 13.3%, and maxillary canines with 11.6% (10). A systematic review study reported that the most frequently affected teeth were mandibular first premolars, followed by mandibular second premolars; in the maxillary arch, canines and second molars were the most affected (7). It is thought that these differences may be due to differences in the average age of the individuals included in the studies, population diversity, ethnic and geographical factors, and radiological imaging methods used.

Studies in the literature report that PEIR lesions are most frequently seen in third molars (1,2,6,22). The fact that only one PEIR case was detected in the third molars in the current study may be related to the low average age of the study group and the fact that the developmental process of the relevant teeth has not yet been completed. Especially in young populations, since the third molars have not yet completed their development by 12, it becomes difficult to detect the presence of PEIR in these teeth (1).

The most common PEIR score in the current study is Grade 1, and this finding is consistent with other studies in the literature. (2,8,21–23). In the literature, a conservative approach is generally recommended for small lesions that do not exceed half the distance between the amelodentinal junction and the pulp (compatible with Grade 1). It is considered appropriate to monitor such lesions radiographically before eruption and to apply restorative treatment after the tooth eruption, if the lesion does not show a progressive character (24). On the other hand, it is emphasized that in larger lesions, especially if there is a long time left for the tooth to erupt and the resorptive process is progressive, intervention should be made before reaching the pulp (16,22). In such cases, treatment options may vary depending on the size and progression rate of the lesion, from fissure sealants and coronal restorations to indirect pulp capping, vital pulp treatments such as pulpotomy and revascularization, or extraction if necessary (25,26).

When the possible etiological factors related to PEIR were examined in this study, no predisposing factor was detected in most cases (90.9%). The most frequently observed potential factor was the primary tooth extraction on the relevant permanent tooth (3.4%). Factors such as ectopic location, caries in the primary tooth, periapical lesion, or endodontic treatment were recorded in lower rates (1.1%–2.3%). It is suggested in the literature that the PEIR defect may develop due to local infection in the primary tooth above it (27,28). The current findings partially support this hypothesis, since a significant portion of the teeth with PEIR have a history of extraction, periapical lesion, or treatment in the upper primary tooth. However, this theory does not explain PEIR cases in permanent molars without primary teeth. This study also detected PEIR defects in molars without primary teeth. On the other hand, as Seow et al. (29) stated, local factors such as ectopic location may also play a role in etiology. Although it has been suggested that ectopic location may lead to dentin resorption through pressure on the dental follicle, ectopic location was detected in only one case in our study, and no significant relationship was shown between ectopia and PEIR. These findings are parallel to the study results by Gültekin et al.(8).

Findings in the literature suggest that PEIR may be related to local or developmental factors rather than systemic factors (16). Gurunathan et al. (7) found no relationship with systemic factors. In addition, in one study, only one tooth was affected in all cases (2). In the studies conducted by Özden and Açıkgöz (17), Uzun et al. (6), and Gültekin et al. (8), single tooth involvement was predominant. This suggests that local factors may play a role in forming PEIR. Similarly, in the current study, only one tooth was affected in 45 of 64 cases with PEIR. However, there are also cases with multiple tooth involvement. In line with all these findings, it can be said that PEIR has a multifactorial structure and its etiology has not yet been fully elucidated (2).

This study has some limitations. First, only panoramic radiographs may not fully assess the three-dimensional structure of PEIR lesions and may result in small lesions being overlooked. In addition, the study is based on patient records from a single center, which limits the generalizability of the findings to larger populations. The lack of clinical follow-up data prevented the evaluation of dynamic processes such as the progression of lesions and their response to treatment.

Conclusion

This study revealed the prevalence, characteristics, and possible associated factors of PEIR lesions in children. The prevalence of PEIR in unerupted teeth was 0.34%, and at least one affected tooth was detected in 3.4% of the

evaluated individuals. Although no clear etiological factor could be identified in most cases, early extraction of the primary tooth adjacent to the affected permanent tooth was the most frequently observed potential factor. Careful radiographic evaluation of unerupted teeth and increasing awareness of PEIR may facilitate early recognition of these lesions and timely management with appropriate treatment.

Authorship Contributions: Concept: Z.Ö.; Design: Z.Ö.; Supervision: Z.Ö., S.S.; Data: Z.Ö., S.S.; Analysis: Z.Ö.; Literature search: Z.Ö., S.S.; Writing: Z.Ö., S.S.; Critical revision: Z.Ö.; S.S.

Use of AI for Writing Assistance: Not declared

Source of Funding: None declared.

Conflict of Interest: None declared.

Ethical Approval: The study protocol was approved by the Bolu Abant İzzet Baysal University Ethics Commitee (date: 09.07.2024 protocol no: 2024/168).

Informed consent: Written informed consent was obtained from patients who participated in this study.

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ORIGINAL ARTICLE

Turk Endod J 2025;10(2):125–133
doi: 10.14744/TEJ.2025.50470

The effect of different irrigation activation methods preferred during root canal treatment on postoperative pain: A randomized clinical trial

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Purpose: This study evaluates the effects of EDDY and passive ultrasonic irrigation (PUI) activation methods on postoperative pain in mandibular premolar and first molar teeth with asymptomatic apical periodontitis.

Methods: A randomized clinical trial was conducted at Ordu University, Faculty of Dentistry, Department of Endodontics between 12.02.2024 and 03.06.2024. Volunteer patients were randomly assigned to groups. Treatments were performed by a single operator (M.S.). Of 57 patients, 45 completed the study (control: 15, EDDY: 14, PUI: 16). Postoperative pain was recorded at the 8th, 12th, 24th, and 48th hours, and on the 7th day using a visual analog scale. Statistical analyses included Kruskal-Wallis, Friedman, and Chi-square tests.

Results: Gender had no significant impact on pain ($p > 0.05$). No significant intergroup differences in pain were found at any time point ($p > 0.05$). PUI caused more pain at the 8th and 12th hours, while EDDY caused more pain at the 24th and 48th hours, though not statistically significant. Pain significantly decreased by the 7th day in the control ($p = 0.007$) and PUI ($p < 0.001$) groups but not in the EDDY group ($p = 0.050$).

Conclusion: EDDY and PUI show comparable effects on postoperative pain, with no influence of gender.

Keywords: EDDY; endodontics; irrigation activation; postoperative pain; PUI.

Introduction

Pain is the most common reason for patients to seek dental care. It is well-established that this pain is primarily caused by inflammation resulting from bacterial infections (1). Postoperative pain following endodontic treatment is an undesirable outcome affecting both for patient comfort and the clinician's professional reputation. This pain typically results from acute inflammation triggered by the extrusion of microorganisms through the apical foramen or the extrusion of other materials, such as debris or irrigants, during the treatment (2,3).

The effectiveness of irrigation solutions depends on their ability to reach all root canal walls. However, due to the complex anatomy of the root canal system, this effect may not be fully achieved using conventional syringe-needle or

Cite this article as: Mutlu S, Çakıcı F. The effect of different irrigation activation methods preferred during root canal treatment on postoperative pain: A randomized clinical trial. Turk Endod J 2025;10:125-133.
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Submitted: October 00, 2025 Revised: November 00, 2025 Accepted: December 00, 2025 Published: August 13, 2025

side-vented endodontic needles. To improve irrigation efficiency, various activation techniques have been proposed. These methods include the activation of the solution using gutta-percha cones, canal brushes, laser systems, negative pressure, and sonic/ultrasonic devices (4).

The Passive Ultrasonic Irrigation (PUI) activation method is introduced to enhance the disinfecting efficacy of the irrigation solution by agitating it (5). An ultrasonic tip is activated within the canal up to the working length and is passively moved in an up-and-down motion to ensure it does not contact the root canal walls (5). PUI has been shown to effectively reduce bacterial biofilm adhesion due to the high shear stress generated in the apical third (6,7).

EDDY is a sonic activation technique that provides three-dimensional movement through cavitation and acoustic streaming, similar to ultrasonic devices (8). Irrigation solutions interact with dentin walls to clean the complex root canal anatomy without the limitations associated with ultrasonic devices (8).

The aim of this study is to evaluate the change in postoperative pain in mandibular premolar and first molar teeth with asymptomatic apical periodontitis when using EDDY and PUI activation methods.

The null hypothesis of this study is as follows: "There is no difference between irrigation activation systems in terms of postoperative pain following root canal treatment in mandibular first molar and premolar teeth."

Materials and Methods

This manuscript has been written according to Preferred Reporting Items for Randomized Clinical Trials in Endodontics. This study was conducted at the Department of Endodontics, Faculty of Dentistry, Ordu University, and was approved by the Clinical Research Ethics Committee of Ondokuz Mayıs University on February 9, 2024 (Ethics No: 2024/38). A clinical trial registration has not been submitted. The study was conducted under the principles of the Declaration of Helsinki.

Volunteer patients who met the inclusion criteria were recruited from those who visited the Department of Endodontics at Ordu University Faculty of Dentistry between February 12, 2024, and June 3, 2024.

Patient Selection Criteria

Sample size calculation was performed using G*Power 3.1 software (Heinrich Heine University, Düsseldorf, Germany) with the following parameters: $\alpha = 0.05$, power = 0.81, and effect size = 0.27. Based on the variance statistical test, it was determined that a minimum of 14 teeth per group would be required for statistical significance. Considering potential complications during the follow-up period, it was decided to include 16 teeth in each group, resulting in a total of 48 teeth for the study (9).

Teeth that met the inclusion and exclusion criteria listed below were selected for the study.

Inclusion Criteria

- Patients aged 18-55 years
- Patients with asymptomatic apical periodontitis
- Teeth without calcification, root resorption, periodontal problems, incomplete root development, history of endodontic treatment, traumatic occlusion, or severe coronal destruction.
- Teeth with a curvature of the root canal of 5° or less (10).
- Patients with a Periapical Index (PAI) score of 3-5
- Mandibular premolars and first molars

Exclusion Criteria

The following conditions led to exclusion from the study:

- Patients took analgesic or anti-inflammatory medication in the previous 12 hours
- Patients have a history of a drug allergy
- Pregnant or breastfeeding patients
- Teeth where the apical area could not be reached with a #8K file
- Teeth with an apical diameter larger than #20K file
- Teeth with extra root canals
- Teeth requiring a second local anesthesia during treatment
- Teeth where a file fractured within the canal during preparation
- Vital teeth
- Teeth with clinical symptoms such as percussion or palpation sensitivity
- Teeth with persistent purulent discharge

Clinical Procedures

Patient recruitment continued until each group included at least 16 participants.

After obtaining informed consent, all participants were asked to choose one of the 48 black envelopes containing the intervention to be performed and the dental history obtained from Cohen's Pathways of the Pulp for randomization and blinding.

The patients' systemic and dental histories, along with age and gender, were recorded. A clinical examination was per-

formed, including inspection, percussion, and palpation tests. Pulp vitality was evaluated using an electric pulp tester (Ai-Pex, Woodpecker, China) and a cold test (Cerkamed, Poland). Periodontal examination and radiographic assessments of the relevant tooth were conducted, with the symptoms documented.

The initial periapical radiograph of the teeth was evaluated. According to the classification by Schneider, (1971), straight root canals (curvature ≤ 5°) were selected for the study. Then, teeth with PAI scores of 1 and 2 were considered periapically healthy and excluded, while teeth with PAI scores of 3, 4, and 5 were included. All root canal treatments were performed in a single session by a single operator (M.S.). Prior to treatment, patients were instructed in detail on how to complete the Visual Analog Scale (VAS). Patients were asked to mark their pain levels on a 10 cm line based on the severity of pain experienced after the procedure. Pain intensity was numerically documented on a scale of 0 to 10.

Patients were administered an inferior alveolar nerve block using 2 mL of articaine hydrochloride with 1:100,000 epinephrine (Ultraver DS fort; Haver, Türkiye). Rubber dam isolation was applied, and caries were removed using a sterile diamond round bur (DIMEI Royal, Türkiye). Access cavities were prepared. A #10 K-file (Dentsply Maillefer, Switzerland) was placed into the canals to establish the glide path. Working length was determined using an electronic apex locator (AiPex; Woodpecker, China) and confirmed with periapical radiographs to ensure it was 0.5-1 mm shorter than the radiographic apex.

Group 1: Control Group

The root canals were shaped with reciprocating Ni-Ti files (T-endo Must; Dentac, Türkiye) up to a size of 25/0.6, following the manufacturer's instructions, and finally up to 40/0.4 size using a gaggling motion. During the shaping process, the root canals were irrigated with a total of 15 ml of 2.5% NaOCl (NaOCl; Wizard, Ankara, Türkiye) using 31 G closed end, side vented irrigating needles (NaviTip; Ultradent, Güney, Türkiye). Recapitulation was performed with a #15K file after each file change (11).

After completing the root canal preparation, 5 ml of 17% EDTA (IMICRYL, Türkiye) was applied to each canal for 1 minute using a 31 G irrigation needle (NaviTip), placed 2 mm short of the working length. To neutralize the EDTA residues, 5 ml of distilled water was applied for 30 seconds (12). The canals were then irrigated with 5 ml of 2.5% NaOCl, followed by 30 seconds of irrigation with 5 ml of distilled water to remove the NaOCl residue from the canals. A total of 20 ml of NaOCl, 5 ml of EDTA, and 10 ml of distilled water were used per canal. A total of 60 ml of NaOCl, 15 ml of EDTA, and 45 ml of distilled water were used for one molar tooth.

Group 2: EDDY Group

Root canal preparations were performed by following the steps used in Group 1.

The EDDY tip was placed 2 mm short of the working length and activated with 2-3 mm vertical movements in three cycles, each lasting 20 seconds. After each 20-second irrigation activation, 1 ml of 2.5% NaOCl was applied to the canal to refresh the solution. To remove the NaOCl residues from the canal, 30 seconds of 5 ml distilled water irrigation was performed. Then, 3 ml of 17% EDTA was used to irrigate the canal, with activation in three 20-second cycles. After each cycle, 1 ml of 17% EDTA was added to the canal to refresh the solution. To remove the EDTA residues, 30 seconds of 5 ml distilled water irrigation was applied. To standardize the solution amount, 3 ml of NaOCl was re-applied, followed by 30 seconds of 5 ml distilled water irrigation to remove NaOCl residues. A total of 20 ml of NaOCl, 5 ml of EDTA, and 15 ml of distilled water were used per canal. A total of 60 ml of NaOCl, 15 ml of EDTA, and 45 ml of distilled water were used for one molar tooth.

Group 3: PUI Group

Root canal preparations were performed by following the steps used in Group 1.

The PUI tip (DTE; Woodpecker, China) was placed 2 mm short of the working length and was activated in three 20-second cycles. After each 20-second irrigation activation, 1 mL of 2.5% NaOCl was applied to refresh the solution. To remove NaOCl residues from the canal, 5 mL of distilled water was applied for 30 seconds. Next, irrigation was performed with 3 mL of 17% EDTA. EDTA activation was carried out in three 20-second cycles. After each 20-second activation, 1 mL of 17% EDTA was applied to refresh the solution. To remove EDTA residues, 5 mL of distilled water was applied for 30 seconds. To standardize the amount of solution used, 3 mL of NaOCl was applied, followed by 30 seconds of 5 mL of distilled water to remove NaOCl residues. A total of 20 mL NaOCl, 5 mL EDTA, and 15 mL distilled water were used for each canal. A total of 60 ml of NaOCl, 15 ml of EDTA, and 45 ml of distilled water were used for one molar tooth.

After the root canals were dried using #40 paper points (Dentac; Türkiye), suitable gutta-percha cones (Dentac; Türkiye) were selected as the master cone. The master and accessory cones were used to complete the root canal filling using the lateral condensation technique, with root canal sealer (Sealapex; Kerr, Australia). Zinc phosphate-

based cement was chosen for the temporary restoration. The quality of the root canal filling was verified through periapical radiographs. If patients experienced severe pain, the use of NSAIDs was recommended. The use of a matrix band could potentially cause damage to the periodontal ligament and gingiva, leading to periodontal-related pain in the affected area. To avoid the risk of patients confusing this pain with tooth pain, the permanent restoration was completed one week later after the patient recorded their pain scores. To ensure optimal sealing and minimize the potential risk of microleakage between treatment sessions, glass ionomer cement was utilized as the temporary restorative material. Composite resin (Kerr Herculite Classic, Kerr Dental Company, USA) was used for the permanent restoration.

Endodontic procedures were carried out in all canals of the included premolar and molar teeth in accordance with the standardized protocols described above.

Postoperative Pain Assessment

Patients were instructed to assess their postoperative pain scores. They were asked to record their pain levels on a given form at 8, 12, 24, and 48 hours, and on the 7th day. They were also asked to indicate any analgesic use on the same form. One week later, patients were called for their permanent restorations. Pain forms were collected from the patients.

Statistical Analysis

Chi-square tests were used to evaluate gender-related data. Postoperative pain scores were initially assessed for normality using the Shapiro-Wilk test ($p < 0.05$). Since the results indicated that the data did not follow a normal distribution, non-parametric tests, specifically the Kruskal-Wallis and Friedman tests, were applied. To determine which groups were responsible for the observed differences, a post hoc test with Bonferroni adjustment was performed. Statistical analyses were performed using IBM SPSS 22.0 (SPSS version 22.0; SPSS, Inc., Chicago, IL, USA). The tests were evaluated at a 95% confidence interval ($\alpha = 0.05$).

Results

A total of 57 patients were initially evaluated for inclusion in the study. The patient inclusion process is illustrated in Fig. 1.

The demographic data, including the participants' mean ages, distribution of male and female participants across the groups, as well as the types and numbers of teeth used in the study, are presented in Table 1. The PAI distribution of the included teeth is shown in Table 2.

When we examined the role of gender on pain, intra-group analyses revealed that gender had no statistically significant effect on the presence of pain in all three groups ($p > 0.05$). The results of the Chi-Square test conducted by gender are shown in Table 3.

Comparing the measurements between groups, the pain presence at different time points was as follows: at 8th hour, $p = 0.479$; at 12th hour, $p = 0.577$; at 24th hour, $p = 0.881$; at 48th hour, $p = 0.778$; and at the 7th day, $p = 0.830$. Since all p-values were greater than 0.05, no statistically significant differences were observed. Even though there was no statistically significant difference, the data indicated that the PUI group experienced more pain at the 8th and 12th hours, the EDDY group experienced more pain at the 24th and 48th hours, and similar distributions were observed in all groups at the 7th day. The mean and mean rank values for the measurements between groups are shown in Table 4.

When the data related to the groups were evaluated, no

Table 1. Demographic data and teeth used in the study

	Control Group (Mean ± Sd)	EDDY Group (Mean ± Sd)	PUI Group (Mean ± Sd)
Age	32.53 ± 8.66	28.64 ± 6.50	32.06 ± 9.62
Gender			
Female	9 (56.2(%)	8 (%57.1)	11 (68.8%)
Male	7 (43.8%)	6 (%42.9)	5 (31.2%)
Tooth Number			
34	-	1	3
35	2	1	2
36	4	4	3
44	1	-	-
45	3	4	2
46	5	4	6

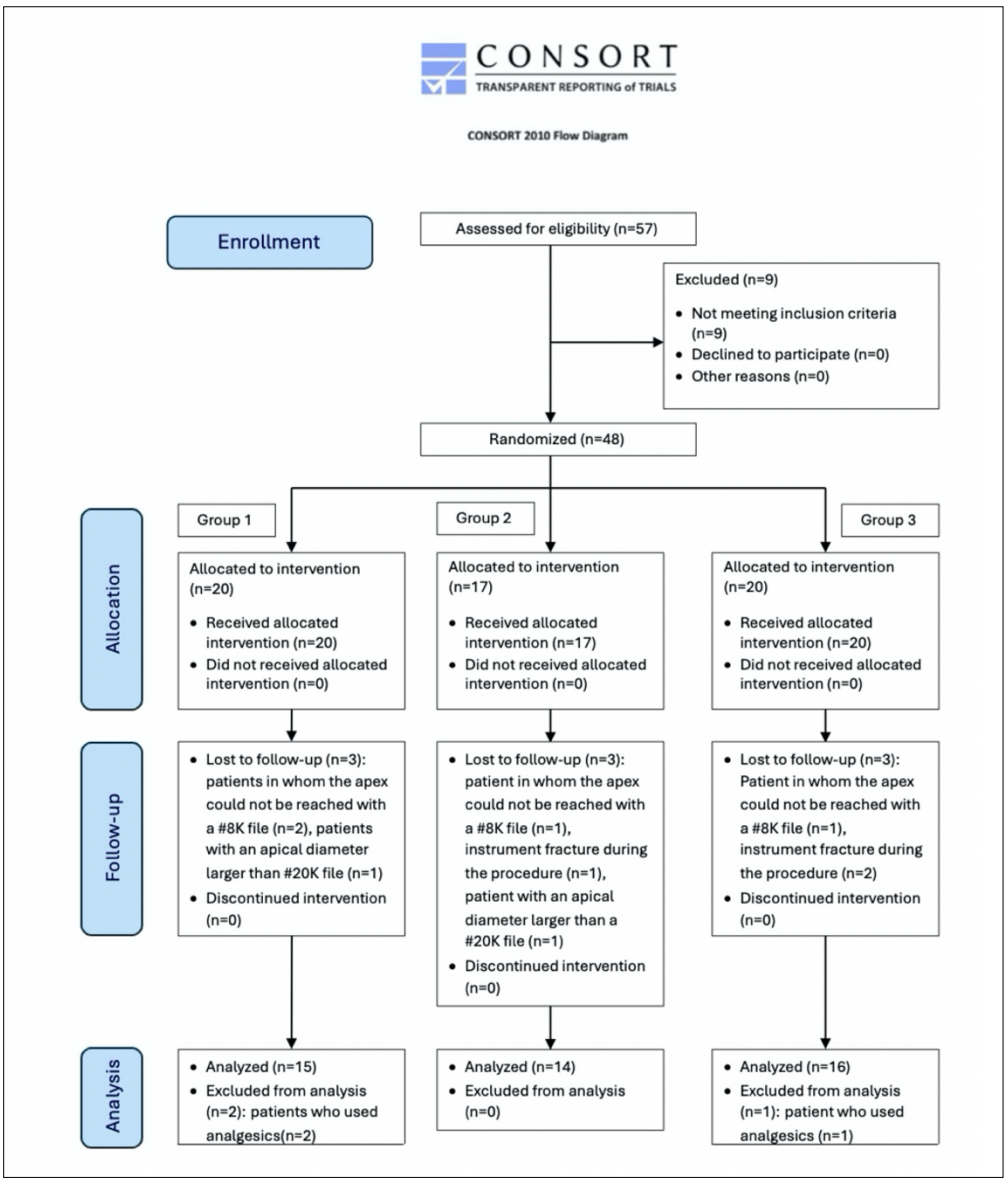

Fig. 1. Flowchart of the participant inclusion process.

Table 2. PAI Values of included teeth

PAI Score	PAI 1	PAI 2	PAI 3	PAI 4	PAI 5
Tooth Number					
34	-	-	1	1	2
35	-	-	2	1	2
36	-	-	6	3	3
44	-	-	1	-	-
45	-	-	5	1	3
46	-	-	5	5	4

statistically significant difference was found between the groups regarding postoperative pain values ($p > 0.05$).

When examining the intra-group values, a statistically significant reduction in pain levels was observed in the control and PUI groups by the 7th day, while no statistically significant result was found in the EDDY group (control

Table 3. Distribution of pain scores based on gender

Group	The Chi-Square Value	P	Degree of Freedom
EDDY	1.367	0.242295	1
Control	0.059	0.808732	1
PUI	0.485	0.486234	1

Table 4. The mean and mean rank values of pain measurement times across the groups

Group	N	Mean	Mean Rank	P
8th Hour				
Control	15		22.07	
EDDY	14	1.93	20.68	0.479
PUI	16		25.91	
Total	45			
12th Hour				
Control	15		22.43	
EDDY	14	1.68	20.96	0.577
PUI	16		25.31	
Total	45			
24th Hour				
Control	15		22.47	
EDDY	14	1.26	24.14	0.881
PUI	16		22.50	
Total1	45			
48th Hour				
Control	15		21.90	
EDDY	14	0.98	24.46	0.778
PUI	16		22.75	
Total	45			
7th Day				
Control	15		23.53	0.830
EDDY	14	0.16	22.04	
PUI	16		23.34	
Total	45			

Table 5. Intra-group postoperative pain assessment

	Control			PUI			EDDY			Total		
	Mean	Mean Rank	P	Mean	Mean Rank	P	Mean	Mean Rank	P	Mean	Mean Rank	p
8th Hour	1.81	3.73		2.47	3.91		1.42	3.25		1.93	3.64	
12th Hour	1.36	3.27		2.18	3.63		1.45	2.96		1.68	3.30	
24th Hour	0.82	2.73	0.007	1.12	2.75	< 0.001	1.89	3.32	0.050	1.26	2.90	< 0.001
48th Hour	0.37	2.73		0.83	2.47		1.78	3.11		0.98	2.76	
7th Day	0.09	2.53		0.31	2.25		0.07	2.36		0.16	2.38	

group p = 0.007, PUI group p =< 0.001, EDDY group p = 0.050). The mean and mean rank values for the postoperative pain levels of the groups are shown in Table 5.

Discussion

In this study, randomization and double blinding were applied. Patients were asked to select an envelope from a box

containing identical black envelopes, each labeled with the method to be used inside, but without any external identifiers. This ensured the randomization and blinding of the patients. The clinician learned which method would be used by referring to the envelope selected by the patient. Statistical calculations were performed by a different operator (U.M.), and when the data were shared, only numbers were used instead of group names. This way, second blinding was applied during statistical calculations.

In this study, a total of 45 mandibular first molars and mandibular premolars treated with different irrigation activation methods were included in the study. Of the treated patients, 14 were in the EDDY group, 16 in the PUI group, and 15 in the control group. No statistically significant differences were found in the inter-group and intra-group comparisons.

It has been reported that postoperative pain is more frequently observed in younger patients due to a wider apical foramen compared to older individuals (13-15). Therefore, individuals underage of 18 and teeth with an apical diameter larger than or equal to a #20K file were excluded from the study.

There is no consensus in the literature regarding the effect of gender on postoperative pain. Ali et al. (16) and Shibu (17) noted that postoperative pain was more frequently observed in women compared to men. However, some authors also reported that gender did not play a significant role in postoperative pain outcomes (18-21). In line with these findings, the present study also found no statistically significant difference in pain scores between genders in terms of pain presence and duration ($p > 0.05$).

Ramamoorthi et al. (21), was observed less pain in the EDDY group across all time intervals compared to conventional needle irrigation, using a 3% NaOCl solution throughout the irrigation procedure. In our study, a 2.5% NaOCl solution was used during the entire irrigation process, and traditional needle irrigation was applied in the control group. No statistically significant difference was found when comparing the EDDY and PUI groups. Although the results were not statistically significant, lower pain levels were observed in the EDDY group at 8 and 12 hours, while an increase in pain levels was noted at 24 and 48 hours, and similar pain levels were observed among all groups on the 7th day. This difference may be attributed to the varying NaOCl concentrations used in the two studies.

Gündoğar et al. (4), the effects of traditional needle irrigation, EDDY, EndoActivator, and PUI on postoperative pain in symptomatic irreversible pulpitis of mandibular premolar teeth were evaluated. Significant differences between groups were only found at the 24th hour pain measurements. Erkan et al. (11), the effects of EDDY, Manual Dynamic Activation, SWEEPS, and PUI on postoperative pain in the root canals of mandibular premolar teeth diagnosed with symptomatic irreversible pulpitis were examined. No significant differences were found between the PUI, EDDY, and Manual Dynamic Activation groups at the 8th and 48th hours, but the highest scores and pain prevalence were recorded in the EDDY group on the 7th day. The differences in the findings of our study may be attributed to the selected patient profile, which consisted of patients diagnosed with asymptomatic apical periodontitis, as well as the inclusion of both premolar and molar teeth in the study.

Pak & White (22), evaluated the debris extrusion caused by irrigation activation systems like EDDY, PUI, and PIPS and found that EDDY led to statistically significant amounts of debris extrusion from apical root canals. In our study, intra-group evaluation showed that pain levels decreased significantly from the 8th hour to the 7th day in the control and PUI groups, while in the EDDY group, the reduction in pain levels was not statistically significant. The reason for this could be that the amount of debris extruded from the apical region in the EDDY group was higher, leading to an early inflammatory response from this apical debris (23).

Topçuoğlu et al. (5), examined the effects of traditional, EDDY, PUI, and manual dynamic activation techniques on postoperative pain intensity in symptomatic irreversible pulpitis of mandibular molar teeth. At the 6th and 24th hours, pain intensity in the manual dynamic activation group was significantly higher compared to other groups, but no significant differences in pain intensity were found at the 48th hour, 72nd hour, and 7th day. The highest postoperative pain scores were recorded at the 6th hour in all groups, with a decrease over time. They reported no significant differences between the traditional, EDDY, and PUI methods. In our study, pain levels were evaluated from the 8th hour to the 7th day, significant reductions were observed in the control and PUI groups, but the reduction was not statistically significant in the EDDY group. Pain levels in the EDDY group increased at the 24th and 48th hours. The difference in findings between the two studies seems to be seen in the EDDY group. This difference might be attributed to the use of non-vital teeth in our study, which resulted in inflammation due to bacterial and product extrusion with canal debris from the apical area.

The limitations of this study include the absence of standardized patient gender and age, variations in PAI scores among the treated teeth, the inclusion of both premolar and molar teeth, the reliance on patient-reported pain as-

sessment forms, and the inherent subjectivity in pain perception due to individual differences in pain tresholds.

Conclusion

Comparing the control, PUI, and EDDY groups, no significant difference was found in postoperative pain at specific time points (8, 12, 24, 48 hours, and 7 days). In the Control and PUI groups, pain levels showed a significant decrease over time; however, in the EDDY group, the reduction in pain levels was not statistically significant. Gender did not influence pain levels in this study.

Authorship Contributions: Concept: S.M., F.Ç.; Design: S.M.; Supervision: S.M.; Materials: S.M.; Data: S.M.; Analysis: S.M.; Literature search: S.M., F.Ç.; Writing: S.M., F.Ç.; Critical revision: S.M., F.Ç.

Use of AI for Writing Assistance: Not declared

Source of Funding: None declared.

Conflict of Interest: None declared.

Ethical Approval: The study protocol was approved by the Ondokuz Mayıs University Clinical Research Ethics Commitee (date: 09.02.2024 protocol no: 2024/38).

Informed consent: Written informed consent was obtained from patients who participated in this study.

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ORIGINAL ARTICLE

Turk Endod J 2025;10(2):134–141
doi: 10.14744/TEJ.2025.30922

Evaluation of fracture resistance in 3d-printed hybrid endocrowns with different preparation designs

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Purpose: This in vitro study aimed to evaluate and compare the fracture resistance and failure modes of 3D-printed ceramic-filled hybrid endocrowns with four distinct preparation designs, focusing on the mechanical performance and post-endodontic restorative management.

Methods: Forty-eight 3D-printed ceramic-filled hybrid endocrowns were fabricated on 3D-printed typodont molar dies simulating endodontically treated teeth and divided into four groups (n = 12) based on preparation designs: Group A (butt joint margin, 2 mm pulp chamber depth), Group B (butt joint margin, 4 mm depth), Group C (shoulder margin, 2 mm depth), and Group D (shoulder margin, 4 mm depth). After cementation, specimens were subjected to axial loading in a universal testing machine until failure. Fracture resistance values (N) were recorded, and failure patterns were classified under 18.4x magnification. Statistical analysis was performed using a Two-Way ANOVA test ($\alpha = 0.05$).

Results: Shoulder margin designs demonstrated significantly higher fracture resistance compared to butt joint margins ($p = 0.001$), irrespective of pulp chamber depth. No significant differences were found between the 2 mm and 4 mm pulp chamber extensions ($p = 0.393$). Catastrophic (Type 4) failures were predominantly observed in Group C, while Groups A and B showed mainly repairable failure patterns.

Conclusion: Preparation design significantly affects the mechanical integrity of 3D-printed endocrowns for post-endodontic restoration. Shoulder margins enhance fracture resistance, although increasing pulp chamber depth does not confer additional mechanical benefits. These findings provide valuable insights for optimizing preparation strategies in the restorative management of endodontically treated posterior teeth.

Keywords: Dental materials; dental restoration failure; endodontically treated teeth; printing; three-dimensional.

Introduction

The common problem in restoring endodontically treated teeth is the risk of biochemical deterioration, which might be attributed to extensive loss of dental tissue that increases fracture incidence (1). Endocrowns have emerged as an innovative restoration option that preserves dental structure while enhancing mechanical durability (2). By

Cite this article as: Turker Kader I, Özer S, Arıcan B. Evaluation of fracture resistance in 3d-printed hybrid endocrowns with different preparation designs. Turk Endod J 2025;10:134-141.
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Submitted: October 00, 2025 Revised: November 00, 2025 Accepted: December 00, 2025 Published: August 13, 2025

combining coronal integration with apical extension, endocrowns optimize fracture resistance and provide a reliable solution for restorative treatments (3).

The mechanical performance of endocrowns can be influenced by their preparation design, which plays a critical role in force distribution and bonding effectiveness. Common designs include a circumferential butt joint or shoulder and chamfer margins with ferrule design (4,5). A previous study utilizing lithium disilicate ceramic material has demonstrated that the shoulder margin designs increase the dentin surface available for bonding, while the butt-joint design enhances force distribution by placing the ceramic under compressive stress (6). This highlights how preparation designs can affect the mechanical performance of endocrowns by optimizing bonding and reducing the risk of fracture (7), making fracture resistance a fundamental factor in the longevity and mechanical success of endocrown restorations (8).

Material choice plays an important role in the longevity of the restoration (9). Most dental ceramics are considered brittle due to their low tensile strength and fracture toughness, which are affected by inherent flaws in the material. External loads induce tensile stresses that can trigger crack propagation from these flaws (10). To overcome the limitations of conventional all-ceramic restorations, hybrid ceramics were developed for computer-aided design and computer-aided manufacturing (CAD/CAM) by combining ceramic and composite structures, offering enhanced mechanical properties (11).

CAD/CAM systems include both subtractive and additive manufacturing, commonly known as three-dimensional (3D) printing (12). 3D printing offers several advantages over subtractive manufacturing, such as high accuracy, reduced material waste, and fabricating restorations, including undercuts or inaccessible areas that cannot be milled (13). However, only a few 3D-printed hybrid materials are available for single crowns, inlays, onlays, and veneers for anterior and posterior areas, including occlusal surfaces. Recently, VarseoSmile Triniq (Bego, Bremer, Germany), a 3D-printed ceramic-filled hybrid material, has been introduced in the market. The manufacturer claims that this material offers high dimensional stability, flexural strength and modulus, making it suitable for use as a permanent restorative material (BEGO Bremer Goldschlägerei Wilh. Herbst GmbH & Co. KG, VarseoSmile Triniq technical product information data sheet, n.d.). However, despite these claims, no studies have yet been conducted to evaluate its performance.

To the author's knowledge, while studies have evaluated the fracture resistance of CAD/CAM hybrid endocrowns fabricated via subtractive milling with various preparation designs (11,14), no research has specifically examined the fracture resistance of 3D-printed ceramic-filled hybrid endocrowns across four different preparation designs. Therefore, the aim of this in-vitro study was to compare the fracture resistance of 3D-printed hybrid endocrowns with different preparation designs. The null hypotheses tested were that (1) different preparation designs would not affect the fracture resistance of 3D-printed hybrid endocrowns, and (2) different preparation designs would not affect the failure modes of 3D-printed hybrid endocrowns.

Materials and Methods

The sample size calculation was performed using a statistical software program (G*Power v3.1.9.2, Heinrich Heine University, Düsseldorf, Germany) using data from another study by Einhorn et al (6). The minimum sample size of 12 specimens for each group achieved 95% power to detect differences, with a significance level of 0.05, to test the null hypotheses.

Teeth Preparation

Typodont maxillary first molar teeth (AG-3 ZE; Frasaco GmbH, Tettnang, Germany) were prepared according to four preparation designs by one operator (S.Ö). The preparations were performed under a dental microscope (Zumax OMS 2000, Zumax, China) at x18.4 magnification. The preparation groups were as follows:

- Group A: Butt-joint margin and a 2 mm pulp chamber depth
- Group B: Butt-joint margin and a 4 mm pulp chamber depth
- Group C: Shoulder (1 mm) margin and a 2 mm pulp chamber depth
- Group D: Shoulder (1 mm) margin and a 4 mm pulp chamber depth

The following burs were used for the preparation of Group A and B, respectively:

- A green belt occlusal-reduction diamond bur (D.828.017.G.FGA; Frank Dental GmbH, Gmund, Germany) for 2 mm occlusal reduction
- A green belt wheel diamond bur (909G-031-FG Coarse 5/Pk; Meisinger, Neuss, Germany) for 2 mm wide circumferential butt-joint margin preparation
- A red belt conical diamond bur (D.845KR.016.G.FGA; Frank Dental GmbH, Gmund, Germany) for pulp chamber preparation with an internal taper of 8° axial walls (15).
- A red belt medium round-end tapered diamond bur (D.850.016.FG; Frank Dental GmbH, Gmund, Germany) to round down internal lines, eliminate irregularities, and

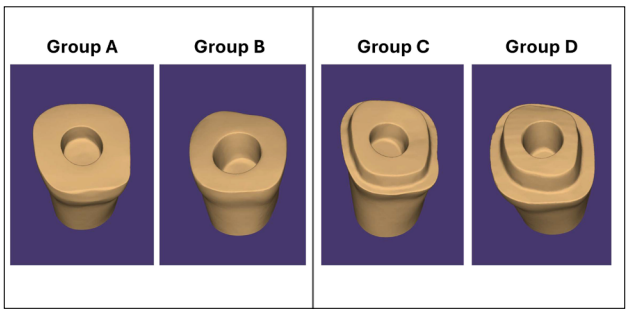

Fig. 1. Preparation scan images obtained using a digital intraoral scanner for Group A, Group B, Group C, and Group D.

create flat and polished surfaces.

For Groups C and D, identical burs were used throughout the whole preparation process in Groups A and B. The primary difference in contrast to Groups A and B was the following bur:

• A red belt modified shoulder fine W diamond bur (848WF-018-FG; Meisinger, Gmund, Germany) to prepare the 1 mm shoulder margin following the first occlusal reduction step.

The preparation designs of all groups are shown in Fig. 1. Following the preparations, a digital calliper (Micrometer; Mitutoyo Corp., Tokyo, Japan) and a periodontal probe were used to confirm the measurements of pulp chamber depths, margin widths, and occlusal reductions.

Master die fabrication

The prepared teeth for each group were scanned using a digital intraoral scanner CEREC AC Primescan (Dentsply Sirona, York, PA, USA). The external CAD data of preparation scans were processed in InEos X5 software (Dentsply Sirona, York, PA) (Fig. 1). Standard tessellation language (STL) files were obtained and imported by a CAD program (Sharp 3D, Budapest, Hungary) for generating and creating ready models. A total of 48 single master dies with a layer thickness of 50 µm were fabricated from 3D-printed model resin (VarseoWax Model; Bego, Bremer, Germany) using a 3D printer (Asiga Ultra (50), Sydney, Australia). After printing, the master dies were rinsed with 99 % isopropanol alcohol for 3 minutes (Form Wash, Formlabs®, Somerville, USA) and post-cured twice for 20 minutes at 60 °C (Form Cure, Formlabs®, Somerville, USA) following the manufacturer's instructions.

Endocrown design

The typodont maxillary molar teeth were scanned before and after each preparation, and STL data were obtained from each scan. The preparation STL files were used for endocrown design, while the initial STL data represented the original tooth morphology. All STL data were processed using exocad DentalCAD software (exocad GmbH, Darmstadt, Germany). The cement space was specified at 80 µm in the chairside CAD design. The endocrowns were fabricated with a 50 µm layer thickness from 3D-printed ceramic-filled hybrid material, VarseoSmile Triniq, using the 3D printer. The printed endocrowns were cleaned with 99% isopropanol alcohol for 5 minutes and post-cured twice for 20 minutes at 60 °C.

Endocrown Cementation

Endocrowns were loaded with self-adhesive dual-cure resin cement (Dentacore; ITENA Clinical, Paris, France) and seated on their corresponding teeth. While seating, a standardized constant load was applied using a weight of 50 N to prevent the restoration's rebounding during cementation. Any residual cement was cleaned with a micro brush (TPC Advanced Technology Inc., CA, USA). Then, endocrowns were light-cured for 20 seconds from all surfaces to ensure complete polymerization of the resin cement (16). After setting, residual cement was gently removed from the margins using a no.12 surgical blade (Feather Safety Razor Co. Ltd., Osaka, Japan) under the dental microscope.

Fracture resistance test

Before subjecting to the fracture resistance test, the roots of the specimen were shielded by a 0.2 mm C-silicone putty impression material (Zetaplus, Zhermack, Italy) for the periodontal ligament simulation. Vaseline was applied inside plastic moulds with a height of 3 cm to provide insulation. Auto-polymerizing acrylic resin (Imicryl Dental, Konya, Turkey) were mixed according to the manufacturer's recommendations and poured inside the moulds. Then, the specimens were inserted into acrylic resin up to 2 mm below the cementoenamel junction (CEJ) level of master dies (17). The CEJ was determined and marked 10 mm below the occlusal surface, considering that the crown height of the maxillary first molar teeth was approximately 8 mm. After the polymerization was completed, the acrylics were removed from the plastic moulds. The occlusal surface distance of the endocrowns was measured with the digital calliper, and a mark was placed at the center point corresponding to the central fossa. The acrylics in which the specimens were embedded were fixed to a custom-designed metal plate produced in accordance with the universal testing machine (MIN 100; Esetron, Ankara, Turkey) and a fracture test was performed. Each sample was loaded using a metallic loading rod with a spherical tip (3.4 mm diameter) travelling at a crosshead speed of 1 mm/min. The loading rod was adjusted to exactly match the marked point, and the load was applied along the long

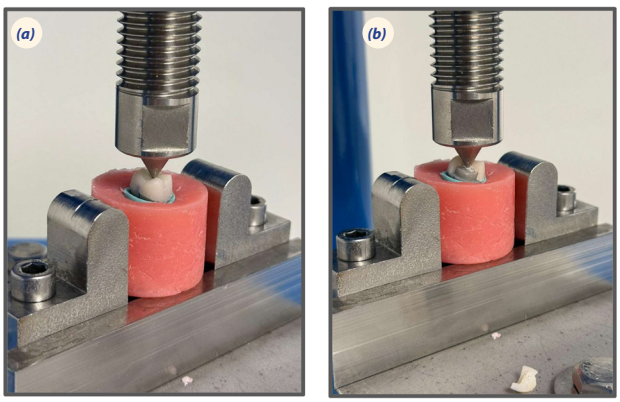

Fig. 2. **(a)** Placement of the acrylic block with the embedded endocrown into the universal testing machine and application of axial loading until the maximum fracture load is reached **(b)** Representative image of a fractured endocrown specimen.

axis of the specimens (Fig. 2A). The maximum axial load until the fracture occurred was applied over specimens (Fig. 2B). The fracture load was measured in Newton (N) and recorded using the corresponding software of the testing machine.

Failure mode evaluation

Following the fracture resistance test, the failure modes of all specimens were evaluated using the dental operation microscope at magnification x18.4. Specimens were categorized according to fracture pattern examination as follows (18):

- Type 1: Complete or partial debonding of the endocrown without fracture (favorable failure) (Fig. 3A)
- Type 2: Fracture of the endocrown without tooth fracture (favorable failure) (Fig. 3B)
- Type 3: Fracture of the endocrowns or tooth above the level of CEJ (favorable failure) (Fig. 3C)
- Type 4: Fracture of the endocrowns or tooth below the level of CEJ (non-favorable or catastrophic failure) (Fig. 3D)
- Examples of two failure types occurring together were observed in each group (Fig. 3E; Fig. 3F).

Statistical Analysis

The data were analyzed using Minitab V14 (Minitab Inc., State College, PA, USA). The normality of distribution was assessed with the Shapiro-Wilk Test. A Two-Way ANOVA was used to compare the parameters that were normally distributed according to margin design and pulp chamber depth. Descriptive statistics for fracture resistance were presented as mean ± standard deviation. The significance level was set as $p < 0.05$.

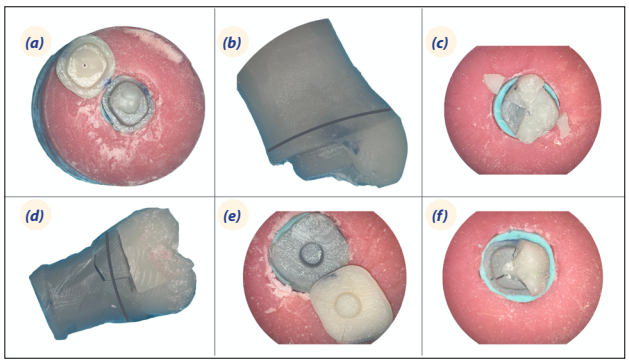

Fig. 3. The figure shows different failure modes of endocrown specimens **(a)** Type 1 **(b)** Type 2 **(c)** Type 3 **(d)** Type 4 **(e)** The combination of Type 1 and Type 2 **(f)** The combination of Type 2 and Type 3 failure modes. *Black lines indicate the cementoenamel junction (CEJ).

Results

The effects of margin design and pulp chamber depth on fracture resistance of 3D-printed hybrid endocrowns and the interaction between the two are shown in Table 1. Margin design was found to have a statistically significant main effect on fracture resistance ($p < 0.05$), whereas pulp chamber depth alone did not show statistical significance ($p > 0.05$). Furthermore, the interaction between margin design and pulp chamber depth was not statistically significant ($p > 0.05$) (Table 1).

Descriptive statistics and multiple comparisons of fracture resistance values according to margin design and pulp chamber depth are shown in Table 2 and Fig. 4. The shoulder margin design showed a significantly higher mean value of 660.12 ± 171.63 N, whereas the mean fracture resistance for the butt joint design was 503.44 ± 134.81 N ($p < 0.05$). The results demonstrated that the margin design consistently influenced fracture resistance across both pulp chamber depths. Although the highest fracture resistance of 678.52 ± 207.52 N was observed for the shoulder design and a 2 mm pulp chamber depth (Group C), this difference was not statistically significant (Table 2) (Fig. 4).

Failure modes are shown in Table 3. Regarding failure

Table 1. Comparison of fracture resistance values according to margin design and pulp chamber depth

	F	p	η^2
Margin design	12.034	0.001	0.215
Pulp chamber depth	0.744	0.393	0.017
Margin design*Pulp chamber depth	0.002	0.962	0.000

F: Two-Way ANOVA Test Statistic; η2: Partial Eta Square. Statistically significant at $p < 0.05$.

Table 2. Multiple comparisons of the mean fracture resistance values according to margin design and pulp chamber depth

Margin design	Pulp chamber depth		Mean ± SD
	2 mm	4 mm	
Shoulder	678.52 ± 207.52A	641.73 ± 133.38A	660.12 ± 171.63
Butt joint	524 ± 176.82B	482.87 ± 76.21B	503.44 ± 134.81
Mean ± SD	601.26 ± 204.4	562.3 ± 133.68	581.78 ± 171.98

Mean ± Standard Deviation (SD); No difference between values with the same letter. Statistically significant at $p < 0.05$.

Table 3. Numbers of different failure modes for endocrown groups with different preparation designs

	Type 1	Type 2	Type 3	Type 4
Group A	1	9	9	1
Group B	1	11	11	0
Group C	1	4	8	3
Group D	1	8	9	1

Examples of two failure types occurring together were observed in each group.

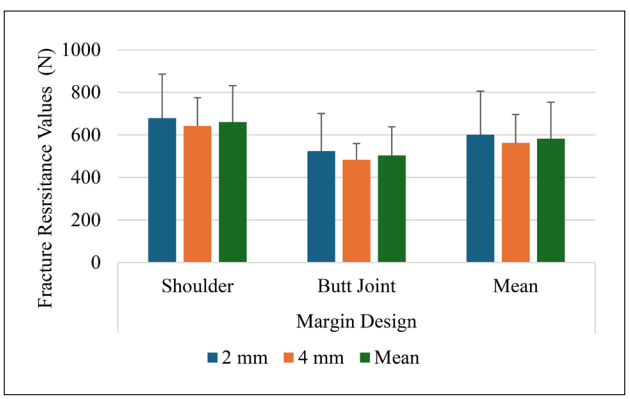

Fig. 4. The column chart of fracture resistance values of endocrowns with different preparation designs.

modes, no differences were observed among the groups for type 1 failure. However, type 2 and type 3 failures were most frequent in Group B, followed by Group A and Group D. Group B also exhibited the lowest incidence of type 4 failure, whereas Group C showed the highest incidence of type 4 failure. Examples of two failure types occurring together were observed in each group (Fig. 3E; Fig. 3F).

Discussion

The long-term success of dental restorations depends significantly on their ability to resist fractures and withstand the functional forces encountered during mastication. Endocrowns have emerged as a reliable post-endodontic restorative option for posterior endodontically treated teeth, offering both esthetic and mechanical benefits (19). In this study, the fracture resistance and failure modes of endocrown restorations fabricated using a 3D-printed ceramic-filled hybrid material were evaluated against different preparation designs. The results demonstrated that both null hypotheses were rejected, indicating that preparation design significantly affected both fracture resistance and failure modes of endocrown restorations.

The mechanical performance of endocrowns can be significantly influenced by variations in preparation, including margin design and preparation depth (4,5). Forces acting on endocrown are distributed as compressive forces over the cervical butt joint margin or as shear forces along the axial walls of the shoulder margin design (3). Taha et al. (4) reported that adding a short axial wall and shoulder finish line (ferrule design) into the preparation of endodontically treated teeth restored with endocrowns enhances higher fracture resistance compared to the butt joint margin design. This may result from the ability of the axial walls of shoulder margin design to counteract shear stresses and facilitate better load distribution along the margin, thereby increasing the fracture resistance (3). Similarly, a study by Hassan et al. (20) demonstrated that endocrowns with a ferrule design showed higher fracture resistance than those without. Consistent with the findings of these studies, the current study revealed that a circumferential shoulder margin design showed a greater mean fracture resistance compared to the butt joint margin. In contrast, Al-khafaji and Jasim (21) found that endocrowns with butt joint preparation in maxillary first premolars showed higher fracture resistance than those with a ferrule design. This discrepancy may be attributed to differences in teeth group and restoration type and material, as they utilized natural premolar teeth and lithium disilicate endocrowns in their study, whereas the present study used 3D-printed ceramic-filled hybrid materials over 3D-printed molar dies. Notably, the use of restorative materials with comparable microstructures may have resulted in similar fracture resistance outcomes against different margin designs (4).

The influence of preparation depth on fracture resistance

of endocrowns has been the subject of ongoing discussion, with evidence suggesting that deeper pulp chamber preparation may enhance their mechanical performance by increasing load to failure and reducing stress concentration (5). Dartora et al. (22) reported that a 5 mm pulp chamber depth presented a higher load to failure than a 1 mm depth, while Hayes et al. (23) found that a 4 mm depth exhibited greater fracture resistance compared to 2 mm, both using lithium disilicate ceramics. Conversely, De Kuijper et al. (24) and Ghajghouj et al. (25) reported no significant correlation between pulp chamber depth and fracture resistance. In agreement with the latter studies, the present study found no statistically significant difference between 2 mm and 4 mm pulp chamber depths. This variation may be explained using different materials across studies, as the material used in this study differs in composition compared to the lithium disilicate ceramics mentioned in previous studies.

The evaluation of failure modes is a crucial factor in understanding the long-term mechanical performance of restorations (26). In this study, fracture patterns were categorized into four types. Type 4 was defined as nonfavorable or catastrophic failure, where the fracture of the endocrown occures below the CEJ. Previous studies have classified failures as favorable or repairable when the fracture is at or coronal to the CEJ and irreparable when the fracture is apical to the CEJ (27). Accordingly, in this study, Type 1, Type 2, and Type 3 failure modes were considered repairable, while Type 4 was deemed irreparable. The failure mode evaluation revealed that Group C presented the highest incidence of Type 4 catastrophic failure, while Group A and B predominantly exhibited Type 2 and Type 3 favorable failures (Table 3). These findings aligned with Einhorn et al. (6), who reported in their study that higher catastrophic failures were associated with a 2 mm ferrule design. Similarly, Magdy et al. (14) found that endocrowns with butt joint margin design exhibited a higher percentage of repairable failures. Al-shibri and Elguindy (16) supported this by reporting that endocrowns with butt joint margin design fabricated from hybrid nanoceramics showed 70% of repairable fractures compared to 30% of irreparable fractures apical to the CEJ. In the present study, the butt joint margin design showed both lower fracture resistance and favorable failure modes. This may be attributed to the stable surface provided by the butt joint design, which resists compressive stresses due to its preparation parallel to the occlusal plane. Additionally, from a biomechanical perspective, this design allows strain adaptation at the interface between the tooth and restoration. However, Magne et al. (28) suggested that the axial reduction in the shoulder finish line could reduce resin cement thickness relative to the bulk of the material, thereby decreasing stress on the material. Considering that the shoulder margin design in this study showed higher fracture resistance values, further studies are necessary to evaluate stress concentrations of endocrown restorations with different preparation designs.

The incidence of catastrophic failure was lower across all groups than other types of failures. This can likely be attributed to the superior shock-absorbing capacity of hybrid ceramic materials compared to all ceramic materials (29). The microstructure of hybrid ceramics may enhance their resistance to crack propagation, which contributes to their lower incidence of catastrophic failures. Supporting this, a previous study has shown that lithium disilicate ceramic endocrowns presented a higher percentage of catastrophic failures compared to hybrid ceramics (30). This difference may be due to the rigidity of materials like lithium disilicate, which can exhibit stress concentrations in critical areas and cause severe fractures, whereas materials with a lower elastic modulus can better distribute stress under load (31).

The maximum chewing force was reported as approximately 850 N, considered a normal force in the molar region (22). This means that the mean fracture resistance for all groups was below the maximum chewing forces reported in the literature. However, considering that this force will be distributed to the premolar and molar teeth in the chewing area, the mean fracture resistance value of all groups, 581.78 ± 171.98 N, may be acceptable.

To strengthen the validity of this study, standardized typodont teeth and 3D-printed master dies were used, which made it possible to precisely control preparation design variables and minimize the variability typically seen between extracted natural teeth, such as differences in size, morphology, or bonding quality caused by variations in enamel and dentin. In addition, using resin models helps overcome common challenges associated with biological specimens, such as the need for ethical approval, the risk of cross-infection, and complex storage requirements, ultimately making laboratory workflows both safer and more streamlined (32). To further ensure reproducibility, all preparations were performed by a single operator after multiple trials. Importantly, a cement space of 80 µm was set in the CAD software, as this intermediate value aligns with the optimal settings reported for both ceramic materials (60 µm) and resin composites (120 µm) (33), reflecting the hybrid microstructure of the 3D-printed material used. The endocrowns were cemented onto the dies using self-adhesive resin cement. As natural human teeth were not used in this study, a one-step cementation procedure was performed without the need for pretreatment, such as

etching, primer, or bonding agent application. Periodontal ligament simulation was also incorporated by applying a thin layer of silicone impression material over the root portion of the dies to better mimic clinical stress conditions (34).

This in vitro study has several limitations. First, the evaluation of stress distribution within the material was not conducted using finite element analysis, which may provide insights into the failure modes of restoration. Additionally, the force applied experimentally had only an axial vector, omitting lateral or oblique forces that may arise from parafunctional movements and affect clinical performance. Furthermore, the use of 3D-printed resin models, while offering the advantage of experimental standardization, does not fully replicate the mechanical and histological properties of natural dentin. Interestingly, Munoz-Sanchez et al. (35) reported that although 3D-printed model resin cannot entirely replace natural teeth in resistance testing, they show lower variance in mean strength values, allowing better control over natural variability in tooth size and shape. This highlights that while 3D-printed models offer a useful platform for initial biomechanical evaluations, future studies should complement these findings by incorporating natural teeth to strengthen the clinical relevance and applicability of the results. Additionally, integrating advanced methodologies such as finite element analysis and in vivo studies could further enhance our understanding of the performance of different preparation designs and materials under complex loading conditions.

Conclusion

Based on the findings of this study, margin design significantly influenced the fracture resistance and failure modes of 3D-printed ceramic-filled hybrid endocrowns. Shoulder margins exhibited superior fracture resistance over butt-joint designs, while pulp chamber depth alone did not yield significant benefits. Notably, a 2 mm pulp chamber depth with a shoulder margin showed a higher incidence of catastrophic failure compared to a 4 mm depth, suggesting the interplay of preparation geometry and material properties. Overall, the combination of a 1 mm shoulder margin with a 4 mm pulp chamber depth enhanced fracture resistance and promoted favorable failure modes.

Authorship Contributions: Concept: İ.T.K., S.Ö., B.A.; Design: İ.T.K., S.A.; Supervision: B.A..; Fundings: İ.T.K., S.Ö., B.A.; Data Collection and/ or Processing: İ.T.K., S.Ö.; Analysis and/ or Interpretation: İ.T.K., B.A.; Literature Review: İ.T.K., B.A.; Writer: İ.T.K.; Critical Review: B.A.

Use of AI for Writing Assistance: Not declared

Source of Funding: None declared.

Conflict of Interest: None declared.

Ethical Approval: Not applicable.

Informed consent: Not applicable.

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