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Analysis of Endodontic Errors in Root-Treated Teeth: A Radiographic Study by Dental Students

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A B S T R A C T

Introduction: Endodontic treatment errors (EEs) can lead to complications and require additional follow-up care. This study aimed to investigate the prevalence of root canal treatment errors among dental students, identifying error types based on radiographic criteria, tooth type, location, and technical errors.

Materials & Methods: A cross-sectional study analyzed data from 201 patients who underwent root canal treatment at Ilam University of Medical Sciences between 2021 and 2022. Inclusion criteria were confirmed root disease diagnosis, adherence to standard treatment protocol, availability of radiographs, and complete patient files. The protocol included rubber dam isolation, radiographic length determination, manual file canal preparation, irrigation, obturation with the lateral compression method, and temporary restoration. Two endodontists evaluated filling length, density, convergence, and technical errors such as floor perforation, broken instruments, transportation, ledge formation, and access cavity gouging.

Results: The study included 89 male (44.3%) and 112 female (55.7%) dental students with a mean age of 25.36 years. Among the 201 patients (28.9% male, 71.1% female; mean age 35.24 years), 71.6% had fillings of appropriate length, 12.14% short, and 15.9% long. Appropriate density was observed in 67.6%, and convergence in 86.1%. Technical errors included ledge formation (8.5%), floor perforation (1%), access cavity gouging (1.5%), and broken instruments (0.5%). A significant relationship was found between density and tooth type ($p < 0.002$) and convergence and tooth type ($p < 0.009$).

Conclusion: Proper filling, convergence, and density were more frequent in anterior teeth. Maxillary teeth had higher rates of proper filling compared to mandibular teeth. The overall rate of treatment errors was low, likely due to professor supervision.

Keywords: Frailty, Geriatric, Anxiety, Syndrome, Hospital

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Introduction

Endodontic treatment is a crucial aspect of dental practice, involving the removal of the pulp, mechanical and chemical cleaning, and filling of the root canal system. The quality of each step significantly impacts the success of treatment and the prevention of periapical inflammation (1). Endodontic treatment errors (EEs) can occur during any stage of the procedure and can compromise the long-term prognosis of the treated tooth (2). This study aimed to investigate the prevalence of root canal treatment errors among dental students, with the goal of identifying areas for improvement in training and ultimately reducing the incidence of errors in future practice.

The rate of EEs can vary depending on various factors, including the skill and experience of the dentist, the complexity of the case, and individual patient factors. However, studies have shown that the overall success rate of root canal treatments is high, with a success rate ranging from 85% to over 97%. This means that the majority of root canal treatments are successful in treating dental issues and preserving teeth (3). EEs may include instrument fracture, inadequate cleaning or sealing of canals, missed canals, and post-treatment infections. The occurrence of such errors is relatively low but can vary depending on several factors (4).

The evaluation of EEs involves a combination of clinical examination, radiographic assessment, and patient symptoms. The dentist will perform a thorough examination of the treated tooth and surrounding tissues to assess for signs of complications or errors. They will look for symptoms such as pain, swelling, tenderness, or discharge (5). X-rays or other imaging techniques may be used to evaluate the quality of the root canal treatment and detect any potential errors. This can include assessing the shape and length of the root canals, looking for signs of instrument fractures or perforations, and evaluating the overall quality of filling material placement. Also, patients' reported symptoms are an important factor in evaluating any potential errors in root canal treatment. If there is persistent pain or discomfort following treatment or if signs of infection recur, it may indicate that there are unresolved issues related to the initial procedure (6).

Dental students are still in the learning phase and may not have had extensive practical experience with root canal treatments. Inexperience can contribute to errors such as improper cleaning and shaping of the canals, inadequate obturation, or missed canals. Additionally, dental students may struggle with proper handpiece control, instrument manipulation within the narrow confines of the root canal system, or achieving adequate working lengths and apical patency. Previous studies have reported that dental students frequently made radiographic errors during root canal treatment, such as inadequate instrumentation or obturation, leading to suboptimal outcomes (7, 8). Other studies identified factors contributing to these errors, including lack of experience, knowledge gaps, and time constraints (9). This study investigated the prevalence of root canal treatment errors among dental students and identified types of errors by radiographic criteria according to tooth type, location, and technical errors.

Materials and methods

A cross-sectional study was conducted on data obtained from dental files. The statistical population included all patients referred for root canal treatment over two years, from 2021 to 2022, at Ilam University of Medical Sciences. The study included 201 patients who underwent root canal treatment during this period.

Inclusion criteria were a definite diagnosis of root disease by a dental specialist, adherence to the standard treatment protocol, availability of radiographs (initial, during treatment, and final), and complete and legible files. Exclusion criteria included cases with severe tooth curvature, cases completed by mentors, and cases with incomplete records.

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In this study, the standard treatment was defined as isolation with a rubber dam, determination of functional length using radiography with a half-cut technique, canal preparation with a manual file using the Passive Step Back technique, irrigation with normal saline, and obturation with the lateral compression method (10).

In all participants, dental errors including filling length, density, and convergence, as well as technical errors such as floor perforation, broken instruments, transportation, ledge formation, and gouging, were evaluated by an endodontist and recorded for each patient separately. The study was approved by the ethics committee of Ilam University of Medical Sciences under the reference number IR.MEDILAM.REC.1399.255.

Data Collection

Two endodontists evaluated the quality of the work using a magnifier (x2) and a 30x35 negatoscope, assessing the following:

• Filling Length: Appropriate, short, or long

• Density: Appropriate or inappropriate

• Convergence: Appropriate or inappropriate

• Technical Errors: Floor perforation, broken instrument, transportation, lodgments, and access hole gouging

Statistical analysis

Descriptive statistics (mean, standard deviation, frequency, and relative frequency) were used to analyze the data. Chi-square and T-tests were used to assess relationships between variables.

Results

In this study, the overall Mean ±SD age of dental students was 25.36 ± 2.44, comprising 24 (42.9%) men and 32 (57.1%) women, among 201 patients who underwent root canal treatment. The patients had a Mean ±SD age of 35.24 ± 11.56, including 58 (28.9%) men and 143 (71.1%) women.

Among all patients who received root canal treatment, 71.6% had fillings of appropriate length. Additionally, 12.14% of the fillings were short, and 15.9% were longer than the standard. Regarding density, 67.6% of cases had appropriate density, while 32.4% had inappropriate density.

There was no significant relationship found between density ($P < 0.15$), convergence ($P < 0.12$), and filling length ($P = 0.3$) across different dental arch types (Table 1).

Table 1. Comparison of Errors by Dental Arch Type (Maxilla and Mandible).

Errors		Tooth location		P-value
		Maxilla	Mandible	
Filling length	Appropriate	87 (74.4)	57 (67.9)	0.3
	Long	19 (16.2)	13 (15.5)	
	Short	11 (9.4)	14 (16.7)	
Density	Appropriate	83 (70.9)	53 (63.1)	0.15
	Inappropriate	34 (29.1)	31 (36.9)	
Approximation	Appropriate	104 (88.9)	69 (82.1)	0.12
	Inappropriate	13 (11.1)	15 (17.9)	

The suitable filling length was observed in 74.4% of maxillary teeth, which was higher than the 67.9% observed in mandibular teeth. Similarly, appropriate filling density was found in 70.9% of maxillary teeth, compared to 63.1% in mandibular teeth. For filling approximation, 88.9% of maxillary teeth showed

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appropriate approximation, whereas in mandibular teeth, this figure was slightly lower at 82.1% (Figure 1).

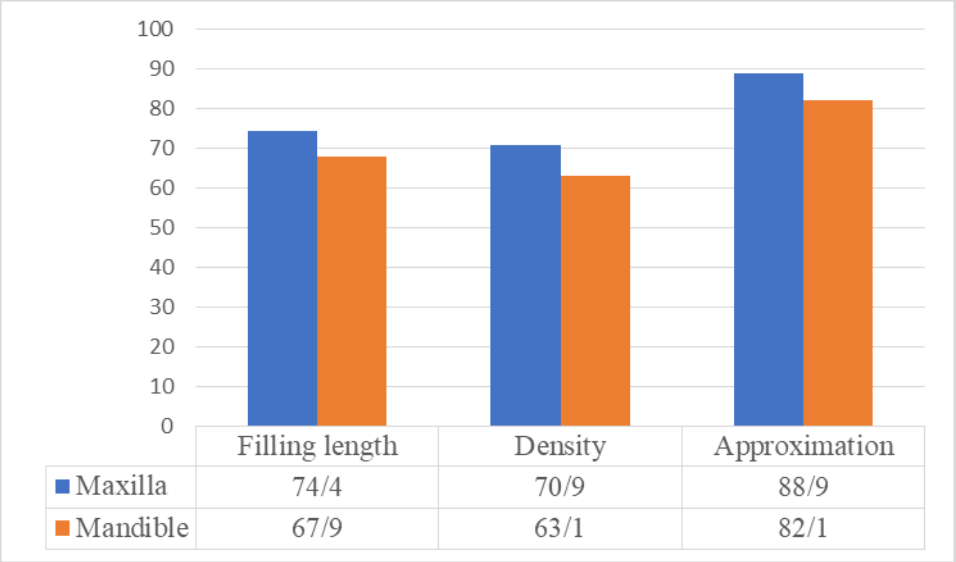


Figure 1. Comparison of Filling Length, Density, and Suitable Approximation by Tooth Location.

The most significant error in filling length occurred in molar teeth 18 (18.6%) and premolar teeth 6 (8.3%). For inappropriate density, the highest error was observed in molar teeth, accounting for 43 cases (44.3%). In terms of inappropriate approximation, molar teeth showed the highest error with 21 cases (21.6%).

There was no significant relationship found between filling length and tooth type (P=0.08). However, significant relationships were identified between density and tooth type (P<0.002), as well as between approximation and tooth type (P<0.009) (Table 2).

Table 2. Comparison of Errors by Tooth Type (Anterior, Premolar, Molar).

Errors		Tooth type			P-value
		Anterior	Premolar	Molar	
Filling length	Appropriate	26 (81.3)	56 (77.8)	62 (63.9)	0.08
	filling	5 (15.6)	10 (13.9)	17 (17.5)	
	length	1 (3.1)	6 (8.3)	18 (18.6)	
Density	Appropriate	26 (81.3)	56 (77.8)	54 (55.7)	0.002
	Inappropriate	6 (18.7)	16 (22.2)	43 (44.3)	
Approximation	Appropriate	30 (93.8)	61 (93.1)	76 (78.4)	0.009
	Inappropriate	2 (6.3)	5 (6.9)	21 (21.6)	

The highest rates of suitable filling length, density, and appropriate approximation were reported for anterior teeth, with percentages of 81.3%, 81.3%, and 93.8%, respectively (Figure 2).

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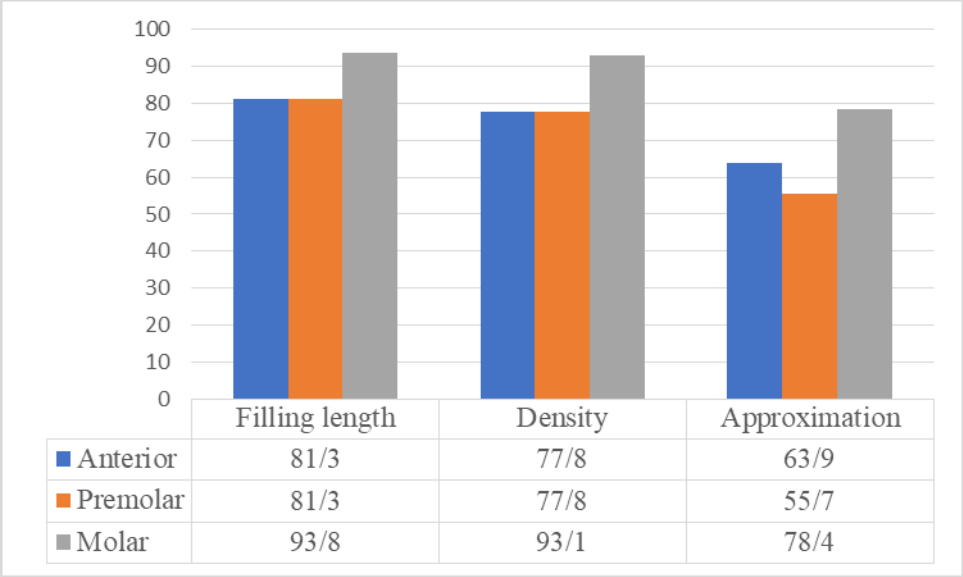


Figure 2. Comparison of Filling Length, Density, and Suitable Approximation by Tooth Type (Anterior, Premolar, Molar).

In total, among all patients, the incidence of technical errors included lodge in 8.5% of cases, floor perforation in 1%, access hole gouging in 1.5%, and broken instrument in 0.5% of cases.

No significant relationship was found between these technical errors and tooth location (Maxilla vs. Mandible) (Table 3).

Table 3. Determination of Technical Errors by Tooth Location.

Technical errors	Tooth location		P-value
	Maxilla	Mandible	
Floor perforation	1 (0.9)	1 (1.2)	0.66
Broken device	0	1 (1.2)	0.41
Transportation	7 (5.9)	3 (3.6)	0.33
Lodge	7 (5.9)	10 (11.9)	0.11
Gauging	3 (2.6)	0	0.19

According to tooth location, among dental technical errors, lodge errors were more frequent in the mandible (10 cases) compared to the maxilla (7 cases). Transportation errors followed, with other errors being less frequent (Figure 3).

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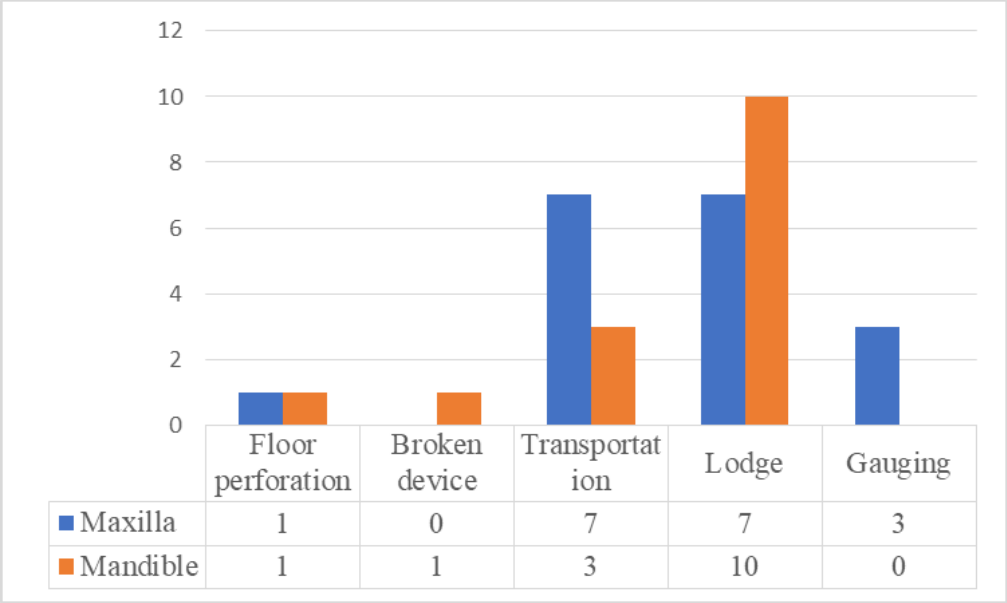


Figure 3. Determination of Technical Errors by Tooth Location.

Technical errors by tooth type are shown in Table 4. Floor perforation was reported more frequently in molar teeth (2.1%). Broken instrument incidences were higher in premolar teeth (2.8%). Transportation errors were more common in anterior teeth (12.5%). Lodge errors were reported most frequently in molar teeth (14.4%). Access hole gouging occurred more often in anterior teeth (6.3%).

Significant relationships were observed between lodge errors (P=0.01) and gouging of the access cavity (P=0.04) with the type of tooth (Table 4).

Table 4. Determination of Technical Errors by Tooth Type.

Technical errors	Tooth type			P-value
	Anterior	Premolar	Molar	
Floor perforation	0	0	2 (2.1)	0.33
Broken device	0	1 (1.4)	0	0.4
Transportation	4 (12.5)	2 (2.8)	4 (4.1)	0.09
Lodge	1 (3.1)	2 (2.8)	14 (14.4)	0.01
Gauging	2 (6.3)	0	1(2.1)	0.04

The dental technical errors, categorized by tooth type, are illustrated in Graph 4. The most prevalent error observed was related to lodgement, surpassing other technical errors. Additionally, the molar region of the tooth exhibited the highest frequency of errors (Figure 4).

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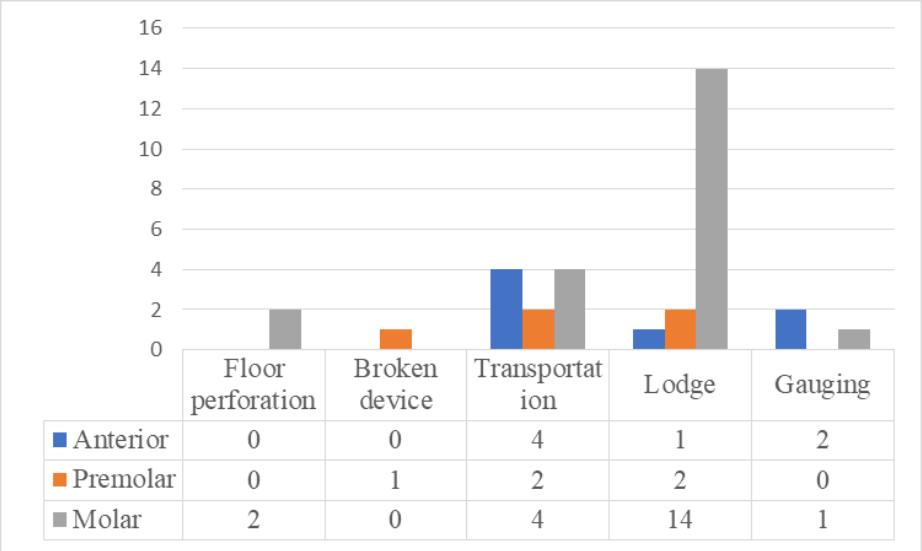


Figure 4. Determination of Technical Errors by Tooth Type.

Discussion

This cross-sectional study aimed to investigate the prevalence of root canal treatment errors among dental students, identifying error types by radiographic criteria based on tooth type, location, and technical errors. In our study, 71.6% of cases exhibited appropriate filling, 15.9% showed overfilling, 12.4% had underfilling, and 32.3% had fillings with inappropriate density. Comparatively, Saatchi et al. (2018) reported 54% appropriate fillings, 11% overfilling, 8.3% underfilling, and 34.6% inappropriate density (4). Eskandarloo et al. (2017) found generally inadequate filling quality (11), while Yavari et al. (12) noted 5.6% overfilling, 2.04% underfilling, and 1.9% root perforations.

In our study, 8.5% of errors were related to ledge formation, and 0.5% involved equipment breakage, a detail not mentioned in prior studies. Chakravarthy et al. (2013) reported 61.35% acceptable fillings and identified technical errors such as ledges (8.5%), floor perforations (1%), access cavity gouging (1.5%), and equipment breakage (0.5%) among examined cases (13).

Filling length showed no significant association with tooth type (P=0.08), but a significant relationship was found between filling density and tooth type (P<0.002). There was no significant relationship observed between these technical errors and jaw arch position. However, ledge formation (P=0.01) and access cavity gouging (P=0.04) were significantly associated with tooth type.

Regarding anterior teeth, appropriate length, density, and convergence (<50%) were associated with successful treatment outcomes. Rafeek et al. (14) found 63% suitable filling lengths and 10.9% overall acceptable fillings in terms of length, density, and convergence. Similarly, Ozgur Er et al. (2006) reported 69% appropriate filling lengths and only 33% acceptable in terms of these criteria (15). Khabaz et al. (2010) reported a 55% rate of acceptable filling lengths (16).

Souza et al. (2019) evaluated the quality of root canal treatments performed by undergraduate dental students, focusing on factors like missed canals, apical transportation, and obturation quality. They concluded that the technical quality of root canal therapy by undergraduate students was suboptimal, suggesting a thorough revision of endodontic training courses at both pre-clinical and clinical levels (17).

Several articles examining root canal treatment errors by dental students provide insights into various aspects of these errors and contribute to

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understanding how educational interventions can enhance their clinical skills in endodontics (8, 9, 18).

The findings underscore the importance of comprehensive training and supervision for dental students in endodontics. The relatively lower overall error rate in this study, compared to others, may be attributed to professor supervision. However, specific areas of concern were identified, such as issues with filling density and convergence, especially in posterior teeth.

The higher prevalence of lodgement errors noted in this study is particularly concerning. Such errors can stem from factors like improper instrument selection, insufficient lubrication, excessive force, or the presence of calcified canals. Further research is warranted to explore the specific factors contributing to lodgement errors among dental students.

Conclusion

The results indicated that anterior teeth exhibited better rates of proper filling, convergence, and density compared to other tooth types. Additionally, proper filling was more frequently reported in maxillary teeth than in mandibular teeth. The overall incidence of treatment errors was notably lower compared to other studies, largely attributed to the supervision provided by professors. This underscores the critical role of supervision in influencing the quality of work performed by students.

Suggestions

The findings of this study highlight the critical need for educational strategies aimed at reducing root canal treatment errors among dental students. These strategies should encompass the following elements:

1. Hands-on Experience: Incorporate practical, hands-on training to familiarize students with various clinical scenarios and procedures.

2. Simulation Exercises: Provide simulation exercises that simulate real-world challenges to enhance students' decision-making and technical skills.

3. Detailed Instruction: Offer comprehensive instruction on proper techniques, instrument selection, and strategies for error prevention during root canal procedures.

4. Mentorship and Supervision: Ensure regular mentorship and supervision by experienced endodontists to provide guidance, monitor progress, and offer constructive feedback.

5. Specialized Instrumentation: Train students in the use of specialized instruments tailored for complex cases, such as those involving calcified canals or severe curvature.

6. Continuing Education: Encourage ongoing education for dental students and practitioners to keep them updated on advancements in endodontic techniques and best practices.

By implementing these educational strategies, dental schools can better equip students with the necessary skills and knowledge to perform root canal treatments effectively and safely, ultimately improving patient care outcomes and overall dental practice quality

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Conflict of interest

The authors declared no conflict of interest.

Authors' contributions

MA: Designed the study, conducted the literature review, prepared the manuscript, and oversaw editing. HS: Contributed to study design, data collection, manuscript preparation, and editing. NS: Participated in study design, data collection, manuscript preparation, and editing.

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