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The effect of operator experience on complications in endodontic treatments: A retrospective evaluation

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Purpose: The objective of this study is to investigate the distribution of complications arising during root canal treatments performed by undergraduate and postgraduate students, and to evaluate the impact of experience level on the occurrence of these complications.

Methods: The present retrospective study evaluated endodontic treatments performed by third-, fourth- and fifth-year dental students, as well as postgraduate students at the beginning of their specialty training and those in their first, second, and third years of training. A total of 1180 root canal treatments performed due to apical periodontitis were subjected to analysis. The complications were classified into the following categories: underfilling, overfilling, inadequate shaping, ledge formation, presence of fractured instruments, apical transportation, and perforation. The collected data were then subjected to analysis using IBM SPSS version 29, and differences between the groups were assessed through the implementation of the Chi-square test ($p<0.05$).

Results: A total of 1180 cases were examined, and the most prevalent complications were identified as underfilling (16.9%), overfilling (10.8%), and inadequate shaping (10.4%). A statistically significant discrepancy was identified in the distribution of complications among undergraduate and postgraduate students ($p<0.001$). Underfilling (22.8% vs. 10.9%), inadequate shaping (14.8% vs. 5.9%), and ledge formation (5.5% vs. 0.7%) were more frequently observed in undergraduate students, whereas the incidence of overfilling was higher among postgraduate students (12.9% vs. 8.7%, $p=0.018$).

Conclusion: The present study demonstrates that the level of experience significantly affects the incidence of complications in root canal treatment. Specifically, complications such as underfilling, inadequate shaping, and ledge formation were more frequently encountered in undergraduate students, whereas postgraduate students exhibited higher rates of overfilling. The present findings underscore the imperative for more comprehensive instruction in endodontic techniques.

Keywords: Endodontic complication; operator experience; postgraduate education; root canal treatment.

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Introduction

Nonsurgical root canal treatment (RCT) is a critical component of comprehensive dental care services (1,2). The primary objective of this procedure is the prevention or management of apical periodontitis through the effective cleaning, disinfection, and hermetic obturation of the root canal system (3,4). A multitude of studies have previously documented success rates that have exceeded 90% for nonsurgical RCTs that have been performed under optimal conditions (5,6). However, it has been documented that these rates decrease to approximately 40–65% when procedures are performed by less experienced practitioners (7,8). This finding emphasizes the substantial impact of clinical experience and expertise level on treatment outcomes.

RCT outcomes can be evaluated through clinical, radiographic, and histological methods (9). Notably, the technical quality of root canal obturations—predominantly evaluated through radiographic analysis—has been consistently identified in the literature as a pivotal determinant of endodontic treatment success and prognosis (10–13). A variety of procedural errors have the potential to compromise the technical success of root canal fillings (RCFs). These include termination of the filling more than 2 mm short of the radiographic apex (underfilling), extrusion of gutta-percha or sealer into the periapical tissues (overfilling), and the absence of continuous tapering from the coronal portion to the apical terminus of the canal (inadequate shaping) (14–16). An erroneous determination of the working length (WL) has the potential to exert a substantial influence on the efficacy of treatment outcomes. It has been documented that in teeth diagnosed with apical periodontitis, a 1-millimeter discrepancy in WL has been shown to result in an increased failure rate of 14% (17). Moreover, in instances of overfilling, the efficacy of treatment has been documented to decline to 75% (17,18). In addition to procedural errors, complications such as apical transportation, ledge formation, perforation, and the presence of fractured instruments within the canal are also recognized as causes of failure in RCT (5,19).

According to the curriculum guidelines established by the European Society of Endodontology (ESE), undergraduate students are obligated to attain the necessary competencies to achieve optimal outcomes in RCT during their educational training (20). Consequently, it is expected that dental undergraduate students will acquire sufficient experience in interpreting diagnostic information and performing the treatment of permanent teeth without complications. However, a review of the extant literature reveals that the success rates of root canal treatments performed by undergraduate students range from 33% to 70% (21,22). A substantial body of research has examined the correlation between treatment quality and the frequency of procedural errors, with a particular focus on molar teeth. These studies have indicated that molar teeth pose a greater challenge for both undergraduate students and general practitioners (23). In cases involving anatomical complexity or complicated conditions, intervention by endodontic specialists is necessary.

According to the core document and consensus report of the ESE regarding postgraduate education, an endodontic specialist must possess advanced knowledge, technical skills, and evidence-based clinical experience in the diagnosis and treatment of diseases of the pulp and periapical tissues (24). This report recommends that postgraduate specialty training should last a minimum of three years, during which residents are advised to perform comprehensive endodontic treatment on approximately sixty patients per year. It is emphasized that the gradual increase in case complexity throughout the training period enables residents to attain the competence necessary to successfully manage increasingly complicated endodontic cases. Despite the extensive evaluation of the quality of RCTs performed by undergraduate students, endodontists, and general practitioners in the literature, there is a paucity of sufficient data assessing the technical quality of treatments performed by students currently undergoing postgraduate specialty training. The evaluation of the technical quality of RCFs is considered a twofold process. Firstly, it serves as a means of assessing the success of RCT. Secondly, it is an important method for evaluating the effectiveness of endodontic education and practice. This highlights a gap in existing literature (25). Therefore, the objective of this study is to examine the types of complications and procedural errors that occur in RCTs performed by undergraduate and postgraduate students. Furthermore, the study seeks to ascertain the correlation between these complications and procedural errors with the type of tooth treated. This study is based on three hypotheses. First, underfilling is expected to be the most common procedural error. Second, procedures carried out by postgraduate students are anticipated to result in fewer complications and errors. Third, complications are expected to occur more frequently in molar teeth than in other tooth types.

Materials and Methods

This retrospective study was conducted in accordance with the ethical standards of the 2024 Declaration of Helsinki and was approved by the Non-Interventional Research Ethics Committee of the Faculty of Health Sciences of Marmara University (Date: 27/03/2025, No: 2025/057). The radiographic data evaluated in this study were obtained

from the archives of the Department of Endodontics at Marmara University. The cases included in the study were those with the diagnostic code of "gangrene or periapical lesion" and for which RCT was completed between September 1, 2024, and January 20, 2025, at the Faculty of Dentistry, Marmara University. Conversely, cases for which obturation approval had not been obtained, cases with incomplete radiographic data, and cases treated outside the specified dates were excluded from the study. The calculation of a minimum sample size was not performed; instead, to avoid selection bias, we included all periapical radiographs that had been fully archived within the specified date range. A post-hoc power analysis was then conducted in Python (v3.12) with the statsmodels package (v0.15) using a two-proportion z-test (NormalIndPower). This analysis, based on the largest clinically relevant difference observed (incomplete filling: 22.8% vs 10.9%; Cohen h=0.32), demonstrated that our total sample (n=1,180; n_1=600, n_2=580) provides >99% power at α=0.05. Accordingly, the study is more than sufficiently powered to detect complication-rate differences of this magnitude between undergraduate and postgraduate operators.

A total of 1180 periapical radiographs that met the inclusion criteria were examined by two experienced endodontists, each with five years of clinical experience. The categorization of complications and procedural errors was conducted with a focus on the specific tooth involved and the operator's level of expertise. In instances where consensus could not be achieved, a third specialist was consulted to facilitate agreement. During the radiographic evaluation, an analysis was conducted of the technical quality of the RCFs and the frequency of procedural errors.

Statistical Analysis

The data obtained in the study were analyzed using IBM SPSS version 29, a software program that facilitates data analysis through its suite of statistical functions. The descriptive data were presented as frequencies and percentages. The distribution of teeth presenting complications, as well as the types of complications according to the experience levels of undergraduate and postgraduate students, was examined using Chi-square tests. In all analyses, the Type I error rate was set at 5%.

Results

In this study, a total of 1180 RCTs were evaluated, performed by third-, fourth- and fifth-year undergraduate students, as well as by postgraduate students at various stages of their training. The stages of training included early stage (0–6 months), first year (6–12 months), second year (12–24 months), third year (24–36 months), and fourth year (>36 months). The study corresponded to 29, 240, 331, 36, 130, 125, 170, and 119 cases, respectively. The distribution of teeth examined is as follows: 23.6% were mandibular molars, 21.0% were maxillary anterior teeth, 16.9% were maxillary premolars, 15.1% were maxillary molars, 14.5% were mandibular premolars, and 8.9% were mandibular anterior teeth (Table 1).

The most prevalent procedural errors observed across all teeth were underfilling (16.9%), overfilling (10.8%), and inadequate shaping (10.4%), respectively. Upon analysis of the distribution of teeth evaluated according to level of experience, a statistically significant difference was identified between undergraduate and postgraduate students (Chi-square test, p<0.001). The prevalence of errors observed in maxillary anterior and maxillary molar teeth was found to be higher among postgraduate students compared to undergraduate students (24.0% vs. 18.0% for maxillary anterior teeth; 19.1% vs. 11.2% for maxillary molars). Conversely, errors were less frequent in mandibular anterior (5.5% vs. 12.2%) and mandibular premolar teeth (11.4% vs. 17.5%). When the distribution of complications was evaluated according to experience level, it was observed

Table 1. Distribution of descriptive data

Experience (n=1180)	Number (%)
3rd Grade	29 (2.5)
4th Grade	240 (20.3)
5th Grade	331 (28.1)
Resident (0)	36 (3.1)
Resident (1)	130 (11.0)
Resident (2)	125 (10.6)
Resident (3)	170 (14.4)
Resident (4)	119 (10.1)
Complications	**Number (%*)**
Incomplete Filling	200 (16.9)
Overfilling	127 (10.8)
Inadequate Shaping	123 (10.4)
Ledge	37 (3.1)
Broken File	27 (2.3)
Transportation	23 (1.9)
Perforation	6 (0.5)
Tooth Type	**Number (%)**
Mandibular Molar	278 (23.6)
Maxillary Premolar	200 (16.9)
Maxillary Anterior	248 (21.0)
Maxillary Molar	178 (15.1)
Mandibular Premolar	171 (14.5)
Mandibular Anterior	105 (8.9)

* Only the distribution of affirmative responses is presented.

Table 2. Distribution of complications experienced, and teeth involved according to operators' experience

Tooth Type	Student (%*)	Resident (%*)	p value**
Maxillary Anterior	108 (18.0)	140 (24.1)	**<0.001**
Maxillary Premolar	108 (18.0)	92 (15.9)	
Maxillary Molar	67 (11.2)	111 (19.1)	
Mandibular Anterior	73 (12.2)	32 (5.5)	
Mandibular Premolar	105 (17.5)	66 (11.4)	
Mandibular Molar	139 (23.2)	139 (24.0)	
Complication* **	**Student (%*)**	**Resident (%*)**	**p value**
Incomplete Filling (n=200)	137 (22.8)	63 (10.9)	**<0.001****
Overfilling (n=127)	52 (8.7)	75 (12.9)	**0.018****
Inadequate Shaping (n=123)	89 (14.8)	34 (5.9)	**<0.001****
Ledge (n=37)	33 (5.5)	4 (0.7)	**<0.001*****
Broken File (n=27)	11 (1.8)	16 (2.8)	0333*****
Transportation (n=23)	15 (2.5)	8 (1.4)	0.207*****
Perforation (n=6)	5 (0.8)	1 (0.2)	0.218*****

*Column percentages are presented. ** Pearson's Chi-Square Test. *** For ease of interpretation, only the distribution of affirmative responses is presented. **** Fisher's Exact Test.

Table 3. Distribution of teeth associated with observed complications

Complications	Anterior (n=353) Number (%*)	Premolar (n=371) Number (%*)	Molar (n=456) Number (%*)	p value**
Incomplete Filling (n=200*)	42 (11.9)	73 (19.7)	85 (18.6)	0.006
Overfilling (n=127*)	29 (8.2)	37 (10.0)	61 (13.4)	0.053
Inadequate Shaping (n=123*)	53 (15.0)	42 (11.3)	28 (6.1)	<0.001
Ledge (n=37*)	5 (1.4)	8 (2.2)	24 (5.3)	0.003
Broken File (n=27*)	1 (0.3)	5 (1.3)	21 (4.6)	<0.001
Transportation (n=23*)	4 (1.1)	10 (2.7)	9 (2.0)	0.315
Perforation (n=6*)	1 (0.3)	1 (0.3)	4 (0.9)	0.368

* Only the distribution of the affirmative responses is presented. ** Pearson's Chi-Square Test.

that undergraduate students exhibited higher rates of underfilling, inadequate shaping, and ledge formation, whereas postgraduate students exhibited a higher frequency of overfilling (Table 2).

Regardless of operator experience, an evaluation of the complications encountered in different teeth revealed that inadequate shaping was significantly more prevalent in anterior teeth compared to molar and premolar teeth ($p<0.001$). The prevalence of underfilling, ledge formation, and fractured instrument complications was found to be significantly higher in molar teeth ($p=0.003$ and $p<0.001$, respectively). No statistically significant differences were identified among the groups with respec4t to overfilling, apical transportation, and perforation ($p>0.05$) (Table 3).

Discussion

The current study was conducted with the objective of analyzing the types of complications and procedural errors that occurred in RCTs performed by undergraduate and postgraduate students. The study found that the most frequently treated teeth were mandibular molars (23.6%) and maxillary anterior teeth (21.0%). This finding is consistent with the reports of several studies (26–28). Mandibular molars demonstrate a higher propensity for early caries development and the necessity for RCT due to their accelerated eruption and morphology, which fosters plaque retention. Conversely, maxillary anterior teeth exhibit heightened vulnerability to pulp diseases resulting from trauma and are consequently among the teeth most frequently subjected to RCT. A comprehensive analysis

of RCTs revealed that underfilling emerged as the most prevalent complication, followed by overfilling and inadequate shaping. This finding aligns with the literature to date on the subject (29,30). The first hypothesis of the study was thus confirmed.

When the types of complications were analyzed according to the level of experience, it was observed that undergraduate students encountered complications such as underfilling, inadequate shaping, and ledge formation more frequently compared to postgraduate students ($p<0.001$; $p<0.001$; $p<0.001$, respectively). These complications have been attributed to multiple factors, including inadequate determination of WL, suboptimal obturation techniques, the use of non-flexible files, the presence of highly curved and narrow canals (particularly in molars), and insufficient irrigation after each instrumentation step (31,32). In addition to the inadequate clinical experience of undergraduate students, their reliance on manual instrumentation may further explain the higher incidence of ledge formation, inadequate shaping, and underfilling observed in this group. However, it is acknowledged that certain academic institutions employ rotary file systems in their undergraduate clinical practices. Studies conducted in France and Spain have reported that undergraduate students perform root canal treatments using rotary file systems in all educational institutions (33,34). The early integration of rotary systems into the curriculum is emphasized to enable students to perform safer and more successful treatments in a shorter period of time (35). In the study by Matoug-Elwerfelli et al. (36), it was demonstrated that the utilization of rotary file systems led to a reduction in procedural errors by approximately 40% in comparison with conventional hand instruments. A notable decline was observed, particularly with regard to ledge formation, perforations, and filling errors. In a similar study, De Oliveira et al. (37) reported that novice students could achieve satisfactory outcomes when using rotary systems. Conversely, the integration of rotary NiTi files within the scope of endodontic education necessitates a distinct learning curve. Research has demonstrated that experienced clinicians exhibit a reduced incidence of technical errors when compared to inexperienced operators when utilizing these systems (38).

From the students' perspective, evaluations indicate that rotary systems are generally well received. Students have reported that these systems offer several advantages, including time savings and a less physically demanding working environment (39). However, certain studies have also observed that a paucity of practical experience may result in students exhibiting diminished confidence when operating rotary systems in comparison to hand instruments (40). A study conducted in Brazil reported that the utilization of rotary systems contributed positively to clinical skills. However, the study emphasized that this association could not be directly associated with overall treatment success (41). This finding indicates that while the integration of technological equipment into education offers significant advantages, clinical outcomes are influenced by multifactorial elements.

The findings of this study indicated that postgraduate students demonstrated a significant higher frequency of overfilling in comparison with undergraduate students. This discrepancy may be ascribed to the observation that postgraduate students exhibited a higher frequency of treatment on maxillary anterior teeth, which are predisposed to open apices due to traumatic injuries. Another potential explanation for this phenomenon is the increased use of rotary instruments by postgraduate students. At the commencement of their specialty training, students may encounter difficulties in maintaining WL due to challenges in following the plastic stopper on rotary files. A similar body of research has indicated that the overfilling rate tends to rise among less experienced operators when using rotary systems in comparison with hand files (29,33). Considering these findings, the second hypothesis of our study was partially supported. Although underfilling, inadequate shaping, and ledge formation were more frequently encountered by undergraduate students, overfilling was observed more often among postgraduate students. No statistically significant difference was found between the two groups regarding apical transportation or perforation. When the types of complications were analyzed according to the level of experience, it was observed that undergraduate students encountered complications such as underfilling, inadequate shaping, and ledge formation more frequently compared to postgraduate students ($p<0.001$; $p<0.001$; $p<0.001$, respectively). These complications have been attributed to multiple factors, including inadequate determination of WL, suboptimal obturation techniques, the use of non-flexible files, the presence of highly curved and narrow canals (particularly in molars), and insufficient irrigation after each instrumentation step (31,32). In addition to the inadequate clinical experience of undergraduate students, their reliance on manual instrumentation may further explain the higher incidence of ledge formation, inadequate shaping, and underfilling observed in this group.

The present study ascertained that the nature and frequency of complications exhibited variability according to the postgraduate year of training. As postgraduate students approached the completion of their specialty education, the incidence of inadequate shaping and underfilling pro-

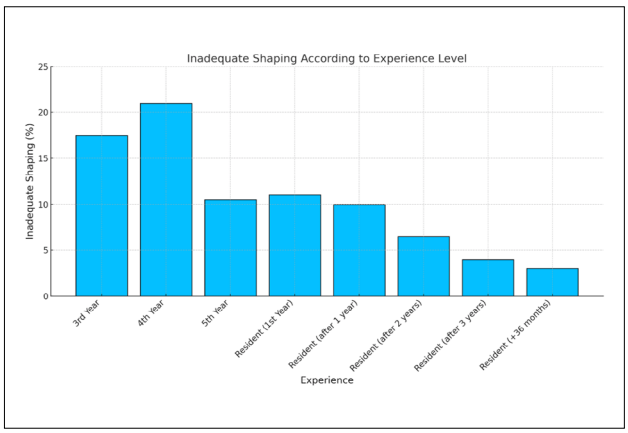

Fig. 1. Distribution of the percentage of inadequate shaping according to experience.

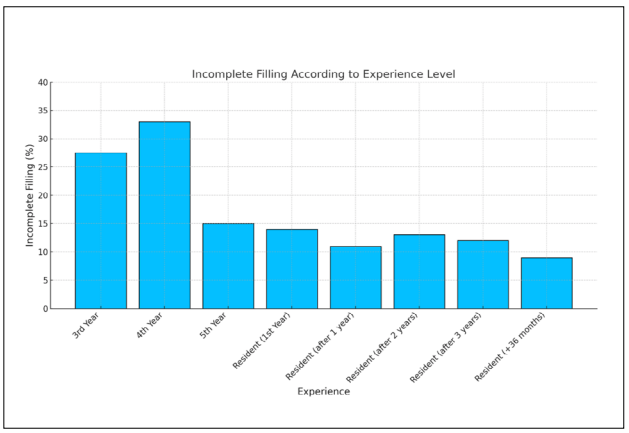

Fig. 2. Distribution of the percentage of incomplete filling according to experience.

gressively decreased (Figs. 1 & 2). A higher frequency of complications was observed among fourth-year students compared to third- and fifth-year students. This finding aligns with the extant literature (34). This phenomenon can be attributed, at least in part, to the observation that fourth-year students manage a greater number of patients than third-year students but possess less clinical experience than fifth-year students. Conversely, as no other studies have evaluated complication rates according to the level of postgraduate education, direct comparisons with existing data in literature are not possible.

When complications were evaluated according to tooth type, irrespective of operator experience, it was determined that underfilling, ledge formation, and the presence of fractured instruments were more frequently encountered in molar teeth compared to other tooth groups. A substantial body of research has been conducted on the subject, and the results of these studies support the observation that endodontic procedural errors are more commonly observed in molar teeth (23,35–38). This pattern may be due to the complex root and root canal anatomy of molar teeth, which predisposes them to such errors. Conversely, inadequate shaping was observed more frequently in anterior teeth, a finding that stands in contrast to the prevalence of other types of complications. This finding may be attributed to the anatomical characteristics of anterior teeth, which are known to exhibit wider and straighter canals. In such cases, the operator may prematurely conclude that sufficient shaping has been achieved, resulting in inadequate canal preparation. Considering these findings, the third hypothesis of the study was partially accepted. In the current study, no statistically significant association was identified between tooth type and the occurrence of perforation or apical transportation. This result is inconsistent with the findings reported in the previous research (36,38). In a retrospective study conducted by Matoug-Elwerfelli et al. (36), procedural errors were analyzed according to tooth type. The study found that both perforation and apical transportation occurred significantly more frequently in molar teeth. This discrepancy may be attributed to the reduced sample size and the exclusive use of stainless-steel hand instruments in the earlier study.

The present study aims to elucidate the impact of clinical experience on the occurrence of complications by comparing complication rates in root canal treatments performed by dental students and postgraduate students. The findings of the study indicated a decline in complication rates with an increase in experience. However, a higher prevalence of specific complications, such as overfilling, was observed among postgraduate students. These findings suggest that postgraduate education plays a critical role in the development of endodontic skills and that clinical experience is particularly effective in preventing common complications such as underfilling and inadequate shaping. A notable limitation of this study is that the assessment of root canal treatment success was based solely on two-dimensional evaluations using periapical radiographs and was conducted retrospectively. A notable limitation of the study is its restriction to a single center, which may limit the generalizability of the findings to institutions offering undergraduate and postgraduate dental education. Additionally, the evaluation of the treatments was limited to the technical quality at the conclusion of the interventions, with no subsequent follow-up assessments conducted. Consequently, a direct correlation between technical quality and clinical success cannot be established. The necessity for long-term and prospective studies in this area is evident.

Conclusion

In consideration of the study's limitations, it was ascertained that the extent of clinical experience exerts a substantial influence on the quality of endodontic treatment. The increased incidence of complications —such as underfilling, inadequate shaping, and ledge formation— observed among undergraduate students indicates that limited clinical exposure may predispose less experienced operators to procedural errors. In light of these findings, it is imperative to enhance the diversity of clinical cases and technical knowledge provided during endodontic education, and to establish structured and progressive clinical training programs for students. Furthermore, future prospective studies focusing not solely on technical success but also on long-term post-treatment clinical outcomes would make substantial contributions to the extant literature.

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

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