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Original Article

Evaluation of the outcomes of endodontic treatment applications performed by undergraduate students during dental education

Edanur Maraş [a]

[a] Department of Endodontics, Faculty of Dentistry, Recep Tayyip Erdogan University, Rize, Turkey

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CORRESPONDENCE

Edanur Maraş
Department of Endodontics, Faculty of Dentistry, Recep Tayyip Erdogan University, Rize, Turkey
E-mail: edanurmaras53@gmail.com

CLINICAL SIGNIFICANCE

To improve the quality of endodontic treatment, it is crucial to place a strong emphasis on the enhancement of endodontic education during undergraduate dental training. This can be achieved through the integration of hands-on clinical experiences.

ABSTRACT

Objectives: Assessing the outcomes of endodontic treatments performed by undergraduate students is important for providing better treatments and improving the education. This study aimed to assess the radiographic outcomes of endodontic treatments performed by undergraduate students over a follow-up period of 24-52 months.

Materials and Methods: Endodontic treatments performed by undergraduate students between January 2020 and May 2021 were retrospectively evaluated. Patients who underwent root canal treatment and had at least 2 years of follow-up radiography after the initial treatment were included. The presence of lesions was recorded, and subsequent treatment procedures performed on the same tooth were also documented. The Jamovi program was used for statistical analysis.

Results: Out of 464 teeth, 104 (22.4%) were included in the study. The average time interval for patients returning for follow-up visits at the dental faculty was 35±6.79 months. Mandibular molar teeth were the most frequently treated, while mandibular anterior teeth received the least treatment. A significant decrease in PAI scores was observed for teeth treated by fourth-year students ($p<0.05$), while no significant difference was found for teeth treated by fifth-year students ($p>0.05$). Tooth extraction was the most common secondary procedure performed (12%).

Conclusion: Academic term, tooth group, and presence of crowns were identified as influential prognostic factors for endodontic treatment outcomes. Fourth-year students tend to have higher success rates than fifth-year students. This may be due to the fact that the dental cases treated in fourth year are usually less complex, mainly involving anterior and premolar teeth.

1. Introduction

If the pulp tissue sustains irreversible damage, it is necessary to undergo endodontic treatment to restore the normal physiology and chewing functions of the tooth.[1] The primary aim of endodontic treatment is to achieve satisfactory coronal restoration with proper debridement, shaping of the root canal system, and final obturation.[2] Despite the complex structure of the root canal system, research has shown that the endodontic treatment success rate ranges between 85% and 95% if the infection is confined to the pulp chamber.[1] However, there is still a chance of treatment failure due to persistent infection or recontamination of the root canal system.

Several studies have explored the various factors that affect the success of non-surgical root canal treatments. A prior research has pointed out that the periapical status is a crucial preoperative factor that significantly impacts the outcome.[3] However, other factors such as the patient's age, gender, tooth type, the occurrence of procedural errors during the treatment, follow-up period, quality of coronal restoration, and the clinician's skill also play a crucial role in determining the treatment outcome.[4-6]

After examining literature on the subject, it has been observed that root canal treatments carried out by professionals with specialized training have a higher success rate compared to those performed by undergraduate students.[7,8] Although guidelines have been put in place to improve the outcomes of endodontic treatments, studies evaluating the results of non-surgical root canal treatments by undergraduate students show success rates ranging from 61% to 81%.[9,10]

The results of endodontic treatments are one of the evaluation criteria for students to improve their quality of endodontic undergraduate education. Although the outcomes of canal treatments conducted by undergraduate students have been reported in various studies within the literature, the limitations in assessment periods, the criteria used for success assessment, sample sizes, and variables such as tooth- or root-based evaluations impact these results in different ways.[5,9,11] This study aimed to report the relationship between the results of endodontic treatment outcomes applied by undergraduate students during their educational process and various parameters such as patient's age, gender, the tooth type receiving treatment, the presence of crown, and the academic term of the student in follow-ups of 24-52 months.

2. Materials and Methods

A retrospective study was conducted in line with the ethical guidelines established by the Declaration of Helsinki principles. To guarantee compliance with these principles and ethical standards, the study received ethical approval from Recep Tayyip Erdogan University, the local Ethics Committee (Approval no: 2023/198).

2.1. Sample size calculation

To calculate effect size, G Power 3.1 software from Kiel University in Germany was utilized. By analyzing the Periapical Index (PAI) scores obtained from a study evaluating the periapical conditions of endodontically treated teeth conducted by Peker, et al. [12], a sample size of 70 participants was determined to be appropriate, with a type 1 error of 0.05 and a power of 99%.

2.2. Calibration procedure

A randomly selected 10% of the periapical status from patient records treated by students was reviewed by two experts on separate times to assess the consistency between and within

observers utilizing Kappa Statistical Analysis. The instructors did not know which students belonged to which observer.

2.3. Study design

This study retrospectively evaluated the outcomes of endodontic treatments conducted by undergraduate students in their 4th and 5th years at the Department of Endodontics, Recep Tayyip Erdogan University Faculty of Dentistry, from 2020 to 2021. The study focused on radiographic outcomes, and data such as the patient's age, gender, existing systemic diseases, the tooth type receiving treatment, and the academic term of the student performing the treatment were obtained from the university's patient information system. The teeth were divided into six groups, including anterior, premolars, and molars for both maxilla and mandibula.

If the system had no record of the patient from the time of their root canal treatment until May 2023, it was marked as "no further entries made into the system." If there was a record, we checked whether any procedures, such as extraction, retreatment, crown, apical surgery, or restoration renewal, had been performed on the treated tooth, and recorded the information accordingly. If no procedure had been carried out on a tooth that was previously treated by students, and if a new panoramic radiograph was taken, the relevant tooth was included in the radiographic evaluation.

The study included patients who did not have any underlying health conditions that could complicate their treatment, with immature permanent teeth that had high-quality diagnostic imaging available for follow-up for at least 24-52 months, and who underwent non-surgical root canal treatment, which was performed by 4th and 5th year dental students under clinical supervision. Patients under 18 years old, teeth with external/internal resorption, root fractures, intraosseous pathology, or image artifacts that prevented evaluation were excluded from the study.

2.4. Endodontic treatment protocol

All endodontic treatments were performed by undergraduate dental students under the supervision of experienced endodontic clinical staff, following the same treatment protocol. After evaluating each patient's medical and dental history, a diagnosis was made for the tooth following clinical and radiographic examinations. After obtaining informed consent from each patient, local anesthesia was administered when deemed necessary. Following cavity preparation, straight-line access was established. Using an electronic apex locator and radiography, working length was determined using #10 to #15 K-type files. The root canals were enlarged using stainless steel hand files until a #25 master apical file size was achieved. Subsequently, ProTaper Universal files (PTU; Dentsply Maillefer, Ballaigues, Switzerland) were used to shape the root canals at the working length. In cases of retreatment, ProTaper Retreatment files (Dentsply Maillefer, Ballaigues, Switzerland) were used along with a solvent if necessary, to remove gutta-percha and sealer from the canal. During shaping, root canals were irrigated using 2 ml of 2.5% sodium hypochlorite (NaOCl) between each file. In cases of teeth with apical periodontitis, if the tooth was asymptomatic and the canals were dry before the procedure, the treatment was performed in a single session. Otherwise, calcium hydroxide was used as an intracanal medicament. Two weeks later, when the teeth exhibited normal clinical signs and symptoms, root canals were irrigated with 5 mL of 17% ethylenediaminetetraacetic acid (EDTA) (Saver, Prime Dental, Maharashtra, India), 2 mL of 0.9% isotonic sodium chloride (Polifarma, Tekirdağ, Turkey), and 5 mL of 2.5% NaOCl (Microvem AF, Istanbul, Turkey).The canals were filled using the cold lateral condensation technique with gutta-percha and resin-based root canal sealer. Finally, the teeth were permanently restored either with direct composite resin or with indirect restorations.

2.5. Radiographic assessment

Two endodontists with five years of experience independently reviewed all digital images. The evaluation was conducted by a Consultant Endodontist on a voluntary basis. To ensure objectivity, the observers examined panoramic radiographs twice at a two-week interval separately. The results were compared, and a final consensus was reached. In case of discrepancies, radiographs were re-evaluated until a consensus was reached between the observers. If no consensus could be reached, the relevant data was excluded from the study.

At the same power settings (66 kVp, 8 mA, and 16.6 s exposure time), panoramic images obtained from the Planmeca Promax 2D S2 device (Planmeca, Helsinki, Finland) were evaluated. The images were positioned with the Frankfurt horizontal plane parallel to the ground and aligned with the sagittal plane with the vertical plane of the digital panoramic device. The preoperative and postoperative periapical status of the treated teeth was radiographically evaluated using the PAI as suggested by Ørstavik, et al. [13] In multi-rooted teeth with the presence of multiple apical lesions, the root with the worst PAI score among all roots was used to represent the score of the respective tooth.[14] PAI is based on the usage of reference radiographs with confirmed histological diagnoses and consists of five categories as follows [13]:

PAI 1: Normal periapical structure;
PAI 2: Small changes in bone structure;
PAI 3: Changes in bone structure along with some mineral loss;
PAI 4: Periodontitis with well-defined radiolucent areas;
PAI 5: Severe periodontitis with features of exacerbation.

2.6. Statistical analysis

For the statistical analysis, Jamovi Software (Version: 2.3.26) was utilized. A descriptive analysis was carried out, and the normality was tested using the Anderson-Darling test. As the distribution was non-normal, Wilcoxon Signed-Rank, Mann-Whitney U, and Kruskal Wallis analyses were conducted. The significance level was set at $p<0.05$.

3. Results

The inter-reliability analysis showed a good level of standardization among the observers, with a kappa value of 0.82 for PAI scores. In the intra-reliability analysis, 10% of the cases were duplicated, and the agreement percentage for PAI scores was 79%.

There were 84 patients, with 33% males (n=30) and 64% (n=54) females. The average age of the patients was 42 years old (Table 1). Out of the 464 treated teeth, 104 were followed up. Of those, 45% were followed for 36 months or more, and the remaining 55% were followed for less than 36 months. The most commonly treated teeth were mandibular molars (35%) while the least treated were mandibular anterior teeth (5.8%). 79% of procedures were root canal treatments, and 21% were retreatments. Most teeth (66%) did not require additional procedures, but the most common secondary procedure was extraction (14%). The study included teeth treated by both fourth and fifth-grade students equally (Table 2).

No significant differences were observed in post-treatment PAI scores in relation to follow-up duration, gender, and age range ($p>0.05$). However, significant differences in post-treatment PAI

Table 1. The frequencies of involved patients in the study

Characteristic	Patient N = 84
Gender	
Male	28 (33%)
Female	56 (67%)
Age	42 (25, 49)

[1] n (%), Median (IQR)

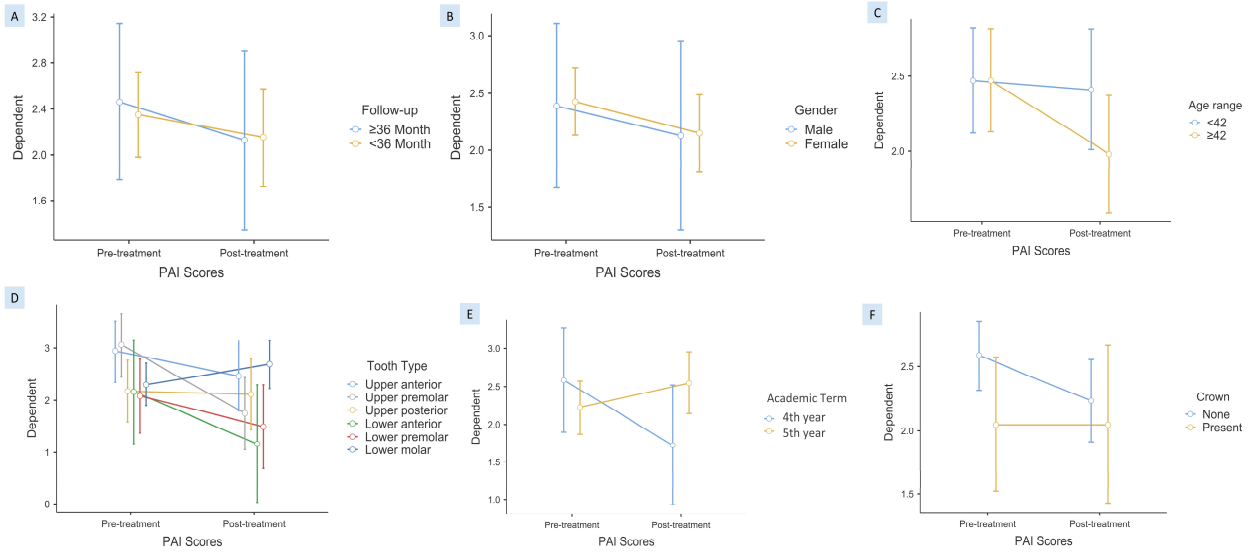

Fig. 1. The plots that show the pre and post PAI Scores according to (A) follow-up period, (B) gender, (C) age range, (D) tooth type, (E) academic term, and (F) the presence of crown.

scores were detected among tooth types ($p<0.05$), with mandibular molars and maxillary anterior teeth exhibiting higher post-treatment score. Additionally, the pre-treatment PAI scores of teeth treated by fourth-year students were significantly higher compared to those treated by fifth-year students ($p<0.05$). After treatment, the PAI scores of teeth treated by fifth-year students were significantly higher than those treated by fourth-year students ($p<0.05$) (Table 3).

There were no significant differences in pre-treatment and post-treatment PAI values concerning before and after the 36-month follow-up ($p>0.05$) (Fig. 1A). Among females, the pre-treatment PAI score was significantly higher than the post-treatment PAI score ($p<0.05$), while no significant difference was observed among males ($p>0.05$) (Fig. 1B). For age, individuals aged 42 and above displayed a significantly higher pre-treatment PAI score than the post-treatment PAI score ($p<0.05$), whereas no significant difference was found for those under 42 years ($p>0.05$) (Fig. 1C). The PAI score for maxillary premolar teeth significantly decreased ($p<0.05$), but no significant change was observed for other teeth ($p>0.05$) (Fig. 1D). Furthermore, the PAI score significantly decreased for teeth treated by fourth-grade students ($p<0.05$), but no significant difference was noted for teeth treated by fifth-grade students ($p>0.05$) (Fig. 1E). While it was observed that the PAI score decreased significantly in the crowned teeth ($p<0.05$), there was no significant difference in the non-crowned teeth ($p>0.05$) (Fig. 1F) (Table 3).

Table 2. The frequencies of involved teeth in the study

Characteristic	Teeth N = 104
Followup	
≥36	47 (45%)
<36	57 (55%)
Tooth type	
Upper anterior	17 (16%)
Upper premolar	16 (15%)
Upper posterior	17 (16%)
Lower anterior	6 (5.8%)
Lower premolar	12 (12%)
Lower molar	36 (35%)
Treatment	
Root Canal Treatment	82 (79%)
Retreatment	22 (21%)
Secondary operation	
Extraction	15 (14%)
Replacement	8 (7.7%)
Resection	2 (1.9%)
Retreatment	10 (9.6%)
None	69 (66%)
Student's grade	
4th grade	52 (50%)
5th grade	52 (50%)

[1] n (%), Median (IQR)

4. Discussion

One of the evaluation criteria for endodontic treatments performed by undergraduate students is the outcomes of these treatments.[9] In Turkey, there are few studies that focus on the long-term evaluation of endodontic treatment outcomes performed by dental students, and these studies often emphasize the impact of root canal filling quality on success.[9,12] Therefore, the purpose of this study was to assess the outcomes of non-surgical endodontic treatments completed by undergraduate students. Additionally, the study aimed to clarify the potential effects of various parameters such as age, gender, tooth type, academic term (fourth and fifth year), and periapical status on the success of

Table 3. The relationship between various factor and PAI scores

Factors	Pre-treatment PAI scores	Post-treatment PAI scores	p-value
Follow-up			
≥36	2 (1-5)	2 (1-5)	0.071[1]
<36	2 (1-5)	1 (0-5)	0.504[1]
p-value	0.253[2]	0.188[2]	
Gender			
Male	2 (1-5)	2 (0-5)	0.935[1]
Female	2 (1-5)	1 (1-5)	**0.013**[1]
p-value	0.962[2]	0.294[2]	
Age range			
<42	2 (1-5)	2 (0-5)	0.771[1]
≥42	2 (1-5)	1 (1-5)	**0.036**[1]
p-value	0.973[2]	0.163[2]	
Tooth type			
Upper anterior	3 (1-5)	2 (1-5)	0.125[1]
Upper premolar	3 (1-4)	1 (1-4)	**0.002**[1]
Upper molar	2 (1-5)	1 (1-5)	0.959[1]
Lower anterior	2 (1-3)	1 (1-2)	0.095[1]
Lower premolar	2 (1-4)	1 (1-4)	0.168[1]
Lower molar	2 (1-5)	3 (0-5)	0.235[1]
p-value	0.104[3]	**0.036**[3]	
Academic term			
4th year	2.5 (1-5)	1 (1-5)	**<0.001**[1]
5th year	2 (1-5)	2 (0-5)	0.289[1]
p-value	**0.049**[2]	**0.034**[2]	
Crown			
None	2 (1-5)	1.5 (0-5)	0.053[1]
Present	2 (1-5)	1 (1-5)	**0.038**[1]
p-value	0.062[2]	**0.048**[2]	

[1] Wilcoxon Signed-Rank test, [2] Mann-Whitney-U test, [3] Kruskal-Wallis test

endodontically treated teeth.

In many epidemiological studies, panoramic radiographs have been found to be sufficient for detecting periapical pathologies, and statistically significant differences have not been reported between panoramic and periapical radiographs.[15,16] Ahlqwist et al.[17] reported a sensitivity of 76-96% for panoramic radiographs in assessing periapical pathologies. In this study, the periapical status of endodontically treated teeth was evaluated using digital panoramic radiographs. The objective of assessing the outcome of endodontic treatment is not just to analyze a single image but to compare potential changes in periapical status between two images of the same tooth taken at different times.[18]

The PAI developed by Ørstavik, et al.[13] is the most commonly cited method in many epidemiological and clinical studies that assess the outcomes of endodontic treatment. It is based on comparing the radiographic image of periapical changes with histological analyses' results. PAI demonstrates excellent accuracy, sensitivity, validity, and repeatability among researchers.[12,18] Therefore, in the current study, the outcomes of endodontic treatments performed by undergraduate students over a period of 24-52 months were evaluated using the PAI method.

Previous studies have indicated that in cases where endodontic treatment is successful, the majority of lesions completely heal within 2 years, with only 3-5% requiring three or more years for complete "conventional radiographic healing".[19,20] A systematic review assessing treatment success have suggested adopting a follow-up period of at least 3 years instead of 2 years.[21] Therefore, in this study, a minimum follow-up period of 24 months was set, and the results were compared before and after 36 months. Teeth with follow-up radiographs between 24-36 months and 36-52 months showed no significant differences in both intra-group and inter-group pre-treatment and post-treatment PAI scores. While various studies have reported an increase in periapical healing rates with longer follow-up durations, this result supports the notion that periapical lesions exhibit substantial healing within 2 years.[22,23]

There was no significant difference between pre-treatment and post-treatment PAI scores for male and female. However, when comparing pre-treatment and post-treatment PAI scores, a significant decrease was observed in female's scores compared to pre-treatment, while no significant difference was seen in male. Epidemiological studies have generally reported that gender does not have a significant impact on endodontic treatment success.[24,25] However, in contrast to these studies, similar to the present study, Marquis, et al.[26] reported higher endodontic treatment success rates in female compared to male. While many studies examining the relationship between age and endodontic treatment success have stated that there is no significant relationship between these two parameters, Imura, et al.[7] found that age does affect endodontic treatment success and demonstrated that the success rate was higher in the 50-59 age group compared to other groups they examined.[27-29] In the current study, a significant decrease in post-treatment PAI scores compared to pre-treatment was observed in patients aged 42 and above, while no significant change in PAI scores was observed in patients aged below 42.

Due to their status as the first permanent teeth to erupt and their susceptibility to decay and pulpal diseases, various studies have shown that mandibular first molars are the most commonly treated teeth with root canal procedures in the permanent dentition.[30] Consistent with the findings of these studies, the current study observed that among all teeth, mandibular molars were the most frequently treated. However, while there was no significant difference in pre-treatment PAI scores among different tooth groups, significant differences were detected in post-treatment PAI scores. Higher PAI scores were observed post-treatment in mandibular molar teeth and maxillary anterior teeth compared to other tooth groups. Various studies examining the success of root canal treatment have indicated that mandibular molars tend to have the lowest success rates, whereas maxillary anterior teeth exhibit higher success rates.[31] This discrepancy might arise from unequal pre-treatment lesion sizes or different distributions of endodontically treated teeth among all tooth groups.[31] While there was a significant decrease in PAI scores post-treatment in maxillary premolar teeth, no significant change was observed in PAI scores for other tooth groups. In alignment with this study, Dammaschke et al.[31] reported a better prognosis for maxillary premolar teeth compared to other tooth groups, while Wiemann et al.[32] stated that premolar teeth have lower success rates than anterior teeth. These conflicting results could be attributed to variations in follow-up durations and the numerical distribution of included tooth groups in the studies.[31-33]

The pre-treatment PAI scores of teeth treated by 4th-year students were higher compared to those treated by 5th-year students. However, upon assessing post-treatment PAI values, it was found that teeth treated by 5th-year students exhibited statistically higher scores than those treated by 4th-year students. Furthermore, although there was no statistically significant difference in PAI scores for teeth treated by 5th-year students, a statistically reduction in PAI scores was observed for teeth treated by 4th-year students. This outcome may stem from the allocation of single-rooted teeth to 4th-year students, while multi-rooted teeth and more challenging cases were assigned to the more experienced 5th-year students.[9] In line with our findings, studies have highlighted that many students require more practical experience in performing molar endodontics.[34,35]

According to this study, the most commonly performed secondary procedure was tooth extraction (14%), which is similar to the extraction rates (15.3%) reported in the study by Dammaschke et al.[31] that investigated the long-term survival of endodontically treated teeth. In numerous studies, it has been reported that teeth with crowns have a higher survival rate compared to non-crowned teeth.[36,37] Similarly, with this study results, there was a significant decrease in PAI scores for teeth with crowns, supporting this claim.

This study has limitations due to its retrospective nature and lack of control over variables. Other limitations of the study include the lack of assessment of initial symptoms, the vitality of the tooth, and lesion sizes, which are important for prognosis at the beginning of treatment. The non-standardized use of rubber dams during treatment, neglect of curved roots, canal filling, and restoration quality, as well as the absence of knowledge about clinical signs and symptoms during the follow-up period, can be considered as other limitations of the study. Previous evidence regarding the impact of general health on endodontic treatment outcomes is contradictory.[38,39] In this current study, the proportion of individuals with systemic diseases was small (<20%), which precluded investigating the potential effects of overall health on endodontic treatment outcomes. Despite the limited sample size, the results of this study partially corroborate the data obtained from previous research. However, there is a scarcity of high-quality studies evaluating the outcomes of endodontic treatments performed by students. Moreover, it has been reported that the instruments and techniques used, evaluation criteria, follow-up durations, and sample sizes can significantly impact the results of studies. To more precisely determine all prognostic factors influencing the prognosis of endodontic treatment, there is a need for longer-term research with larger sample sizes and higher-quality evidence.

5. Conclusion

Within the limitations of this retrospective study, factors such as academic term, tooth type, and the presence of crowns were identified as influential prognostic factors for endodontic

treatment outcomes. It has been observed that 4th year students tend to exhibit higher success rates as compared to their 5th year counterparts. Upon closer inspection, it can be inferred that this is likely due to the fact that the dental cases treated in 4th year are typically less complex in nature, often involving anterior and premolar teeth. This ultimately results in a higher likelihood of successful treatment outcomes for these students. In addition, more favorable treatment results were obtained in patients older than 42 years and in maxillary premolars. Emphasizing the enhancement of endodontic education during undergraduate dental training is essential to achieve better treatment results. It is anticipated that future studies focusing on this topic and encompassing student clinics from different universities will be beneficial for evaluating the success of endodontic treatments conducted by dental students.

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