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The Effect of Magnification on Detecting Errors in Endodontic Access Cavities: A Randomized Controlled Experimental Study

Endodontik Giriş Kavitesi Hazırlarken Yapılan Hataların Tespitinde Büyütmenin Etkisi: Randomize Kontrollü Deneysel Bir Çalışma

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ABSTRACT

Objective: The aim of this randomized controlled experimental study is to investigate whether the use of magnification is effective in the detection of errors made by dental students during the preparation of endodontic access cavities.

Methods: Forty preclinical dental students at third year participated in the study. Participants were randomly assigned into two groups: a control group that evaluated the samples with the naked eye, and a microscope group that utilized a magnification system. In the first phase, 26 extracted tooth samples were distributed to both groups. Participants were asked to examine the samples and record any observed errors on a standardized evaluation form. Subsequently, the microscope group received training under magnification and was then instructed to assess a different set of 26 tooth samples both with the naked eye and under magnification. The same set of samples was also evaluated by the control group to ensure standardization. Statistical analysis was performed using the paired t-test and the Wilcoxon signed-rank test.

Results: A statistically significant increase *(P* < .05*)* was observed in the microscope group's ability to detect errors, particularly those located at the pulpal floor of the access cavity.

Conclusion: The findings suggest that incorporating magnification systems into undergraduate dental education may enhance students' error detection skills, thereby contributing to improved clinical outcomes.

Keywords: Dental education, endodontics, access cavity preparation

ÖZ

Amaç: Bu randomize kontrollü deneysel çalışmanın amacı, diş hekimliği öğrencilerinin, endodontik giriş kavitesi preparasyonu esnasında meydana gelen hataları algılamalarında büyütme kullanımının etkili olup olmadığını incelemektir.

Yöntemler: Çalışmaya 40 diş hekimliği preklinik 3. sınıf öğrencisi katılmıştır. Çıplak gözle değerlendirme yapan kontrol grubu ve büyütme sisteminden yararlanan mikroskop grubu olmak üzere, rastgele olarak 2 grup oluşturulmuştur. İlk aşamada, 26 adet diş örneği her iki gruba dağıtılarak, katılımcıların örnekleri incelemesi ve olası hataları değerlendirme formuna kaydetmeleri istenmiştir. Daha sonra mikroskop grubuna büyütme altında eğitim verilmiş ve ardından farklı 26 adet diş örneğini hem çıplak gözle hem de büyütme altında değerlendirmeleri sağlanmıştır. Aynı örnekler kontrol grubuna da değerlendirilmek üzere sunulmuştur. Verilerin analizinde bağımlı gruplar için t-testi ve Wilcoxon işaretli sıra testi kullanılmıştır.

Bulgular: Mikroskop grubunda, özellikle giriş kavitesinde pulpa tabanında meydana gelen hataların algılanmasında anlamlı bir artış görülmüştür *(P* <,05*)*.

Sonuç: Diş hekimliği lisans eğitiminde büyütme sistemlerinin kullanımına yer verilmesinin, öğrencilerin hataları fark etme becerisini artırarak klinik başarıya katkı sağlayabileceği sonucuna varılmıştır.

Anahtar kelimeler: diş hekimliği eğitimi, endodonti, giriş kavitesi preparasyonu

INTRODUCTION

According to the Glossary of Endodontic Terms of the American Association of Endodontists, the endodontic access cavity is defined as the opening prepared in a tooth to gain entrance to the root canal system for the purpose of cleaning, shaping and obturating.[1] The endodontic access cavity is considered the most critical technical step in root canal treatment. [2]

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The complex anatomy of root canals can result in areas that remain uncleaned during irrigation and shaping procedures in endodontic treatment, allowing microorganisms to persist. Additionally, the failure to detect or adequately treat the canals within the endodontic system is a significant factor contributing to the continuation of the disease after treatment.[3–5]

Furthermore, errors made during the preparation of the access cavity can lead to numerous complications, ranging from missed root canals to root perforations. All of these factors negatively affect the prognosis of endodontic treatment.[6]

For an ideal endodontic treatment, it is essential to prepare an access cavity appropriate for the tooth. Access cavity preparation involves evaluating the outline form, cavity walls, cavity floor and the varying relationships between canal orifices. It also includes exposing all canals in the endodontic system, providing straight-line access to the apical portion of the root canals and completely removing the pulp chamber roof to facilitate instrumentation.[2]

With the adequate completion of this stage, optimal cleaning and shaping of the root canals can be achieved.[7] Preparation of the access cavity involves working in a visually and spatially restrictive environment.[8] If the clinician can view more clearly and magnified, they are able to assess and treat it more effectively.[9] Objects can be enlarged by either magnifying or bringing them closer. Magnification systems assist in conventional endodontic procedures by aiding in the preparation and completion of the access cavity, the precise shaping of root canals and the thorough three-dimensional filling of the root canal system.[9] It has been demonstrated today that magnification systems in dentistry are a technology that enhances visibility within the oral cavity.[10]

The challenges encountered in endodontic treatment are partly due to the limited field of view during the procedures. This situation necessitates that the clinician possesses significant practical knowledge and tactile skill.[11] However, studies have shown that endodontic treatment is frequently performed by graduating practitioners. Surveys indicate that students often feel inadequate in performing endodontic procedures, while only a small proportion of graduated practitioners consider themselves competent.[5,12]

Although there are studies addressing procedural errors made by clinicians or undergraduate students in endodontic treatment, there is a lack of literature on the awareness of these errors. Endodontic education and competency are essential components of all undergraduate dental programs.[2] Additionally, focusing on and evaluating the access cavity preparation stage during preclinical training can highlight areas for improvement in endodontic education, thereby ensuring the provision of high-quality training. The aim of this study is to observe the impact of magnification systems in detecting the errors during preparation of endodontic access cavities. Should positive results be achieved, the goal is to integrate more advanced magnification systems into the training program.

METHOD

Sample Size Determination

Power analysis was conducted using RStudio with the pwr [13]and simr [14]packages.[13,14] For the paired t-test, assuming an effect size of 0.87, a sample size of 20 pairs, and a significance level of 0.05, the calculated power was 0.96. For Wilcoxon's signed-rank test, based on an effect size of 0.88, 20 pairs, and 1,000 simulations, the mean estimated power was 0.95.

These results indicate that the sample size is sufficient to detect the expected effects with adequate power.

Blinding:

Blinding was not applied in this study, as the evaluator (the researcher) was aware of the group allocation of the participants. However, this was not considered to introduce bias, since the identification of access cavity errors was based on objective criteria and did not require subjective interpretation.

Study Design

This study was conducted in April 2024 by the Department of Endodontics and the Department of Basic Medical Sciences at Çankırı Karatekin University Faculty of Dentistry. It was approved by the Çankara University Health Sciences Ethics Committee on March 19, 2024 (Meeting No: 12).

The study included preclinical third-year undergraduate dental students (n=40). Participation in the study was based on voluntary consent (Figure 1).

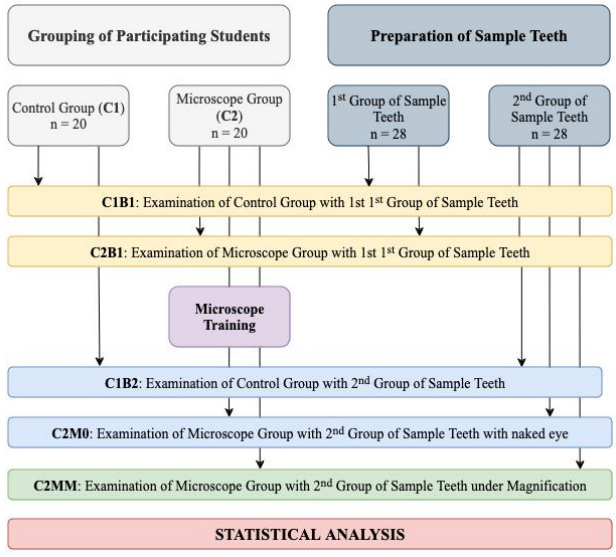

Figure 1. Method Flow Diagram

A total of 56 tooth samples, including anterior, premolar and molar teeth, were used in the study. Initially, suitable access cavities were prepared by an experienced endodontist using diamond fissure burs, diamond round burs and stainless-steel round burs (KaVo Kerr, Biberach, Germany) under water cooling. Two tooth samples with flawless access cavities and two with attached pulp stones were set aside (Figure 2 and Figure 3). The remaining 52 teeth were intentionally subjected to access cavity errors. The Global Rating Scale was used at this stage. The reason for this was to ensure standardization in classifying and assessing cavity errors. The scale includes three main categories, each with subcategories detailing specific types of errors: outline form, cavity walls and cavity floor. Examples of each type of error were created based on these subcategories.[15]

Each access cavity error listed in the table was applied to two tooth samples. Subsequently, the tooth samples were divided into two groups (n=26), with each group containing one flawless cavity, one tooth with an attached pulp stone and one tooth with an access cavity error (n=24). The samples in both groups were numbered from 1 to 28.

Participants were provided with a blank data sheet listing potential access cavity errors. They were asked to record the numbers of the teeth with observed errors in the appropriate places on the table.

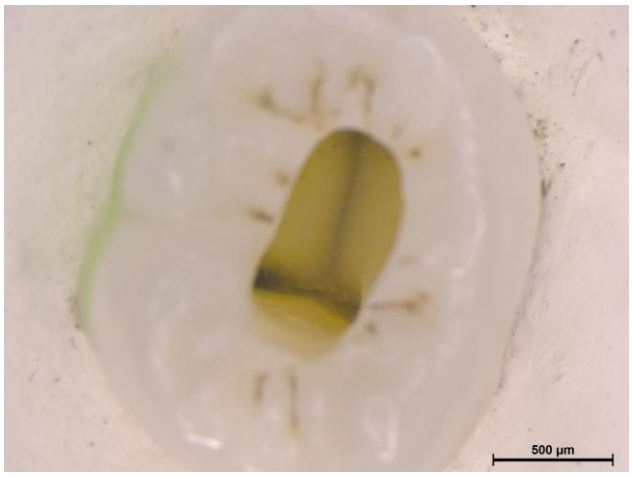

Figure 2. Sample Tooth for Optimal Cavity

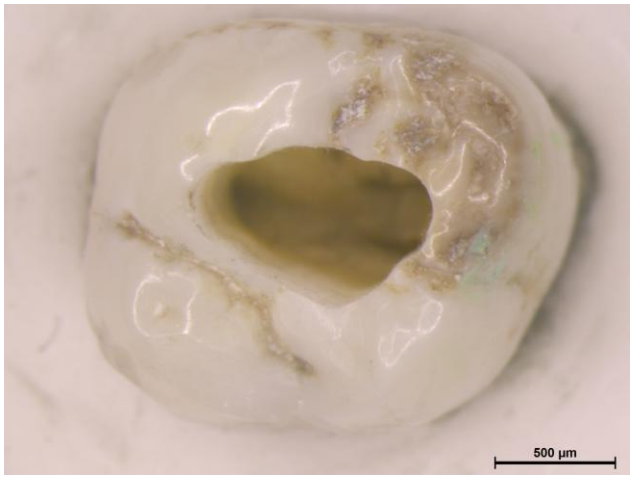

Figure 3. Sample Tooth for Pulp Stone

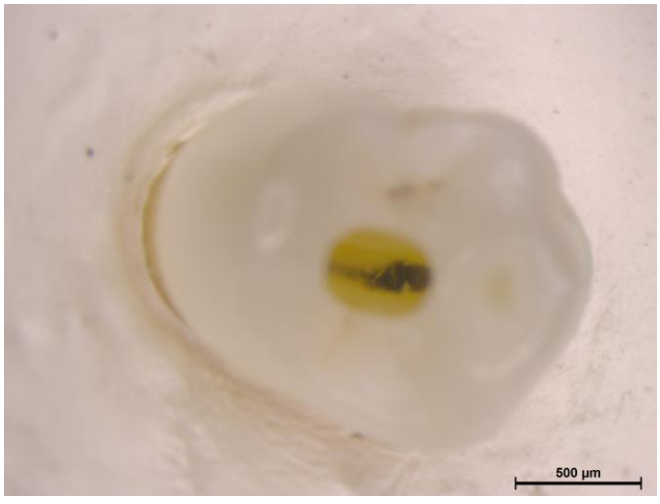

Figure 4. Sample Tooth for Outline Form Cavity Error

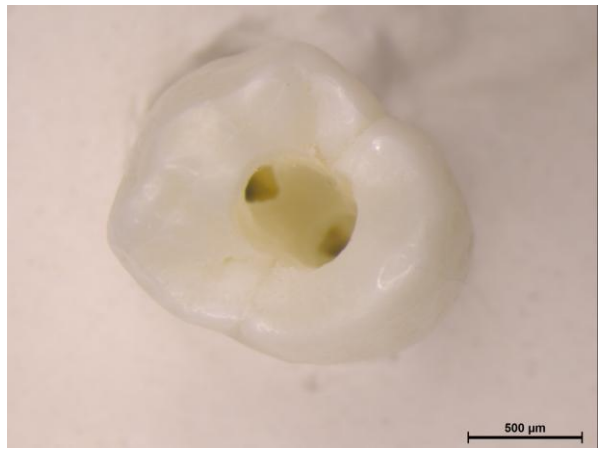

Figure 5. Sample Tooth for Cavity Walls Error

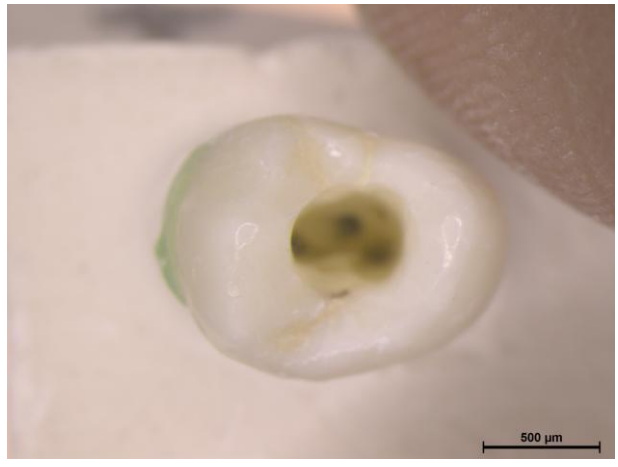

Figure 6. Sample Tooth for Cavity Floor Error

In the Global Rating Scale, Outline Form access cavity errors involve the access cavity being prepared larger or smaller than required (Figure 4). Cavity Walls errors encompass mistakes ranging from excess wall material containing overextended dentin that obstructs the canal entrance to excessive widening that compromises the structural integrity of the tooth (Figure 5). Cavity Floor errors include mistakes ranging from the creation of a hollow in the cavity floor to perforations (Figure 6). [15]

Initially, all participants (n=28) were given the same set of tooth samples and were asked to evaluate them with the naked eye and complete the table accordingly. Then, the participants were randomly divided into two groups based on the last digit of their student numbers: the Control group (C1, n=20) and the Microscope group (C2, n=20). The Microscope group received 4 hours of training from an experienced endodontist using a stereomicroscope (Leica M125, Microsystem Srl, Buccinasco, Milano, Italy) under magnification. The training aimed to increase awareness by examining tooth structure under different magnifications and observing the appearance of teeth with endodontic access cavities and access cavity errors under magnification. After the training, this group was given new tooth samples (n=28) with access cavity errors that they had not previously seen. They were asked to first evaluate these samples with the naked eye and then under the stereomicroscope at 8x magnification and complete the table accordingly.

The Control group, which did not receive training, was provided with the same samples that had been evaluated by the Microscope group after their training, in order to ensure standardization of the samples. They were asked to evaluate the samples with the naked eye and complete the data table accordingly.

For ease of statistical analysis and application, the evaluations were grouped as follows: initial naked eye assessment (B1); naked eye assessment after microscope training (M0); assessment under magnification after microscope training (MM); and naked eye evaluation of samples previously assessed by the microscope group (B2).

Statistical Analysis

Statistical analyses were conducted using the R programming language (2024.4.2.764) within the RStudio integrated development environment (IDE) at a 0.05 level of significance.[16,17] The Shapiro-Wilk normality test, paired t-test and Wilcoxon signed-rank test were used for determining the differences between groups' means.

RESULTS

Forty preclinical dental students were included in the study. The participants were randomly divided into two groups: the Control group (C1, n=20) and the Microscope group (C2, n=20). Both groups evaluated a total of 56 tooth samples, categorized as follows: flawless cavity (n=1), cavity with an attached pulp stone (n=1) and cavities with access cavity errors (n=24). The samples with access cavity errors were assessed under three main categories according to the Global Rating Scale: Outline Form, Cavity Walls and Cavity Floor. The average scores for each group and criterion were calculated and shown in Table 1.

The Shapiro-Wilk normality test was applied to the data in each group and category to determine the type of statistical test to be used in subsequent analyses. Normality tests indicated that data were normally distributed only for the Cavity Walls criterion in the C1 group at the B2 stage (*P* = .2775*),* and for the Cavity Walls criterion in the C2 group across all stages (B1*: P* = .541; M0*: P* = .696; MM: *P* = .154).

The B1 stage values of the C1 and C2 groups were compared and no statistically significant differences were found in any category (Table 2 for *P*-values). This result indicates that there was no difference in scores between the students in the two groups prior to the microscope training.

Similarly, the scores of students who did not receive microscope training were compared between the B1 and B2 stages and no statistically significant differences were found in any category (Table 3 for *P*-values).

In the final stage, the B1, M0 and MM values of students who received microscope training were compared within the group. A Paired T-test was used for the Cavity Walls category, as the data were normally distributed, while the Wilcoxon signed-rank test was used for the other categories.

No statistically significant differences were observed in the comparisons of B1-M0, B1-MM and M0-MM for the Flawless Cavity and Outline Form categories.

Although no significant difference was found between B1-M0 in the Cavity Walls, Cavity Floor and Pulp Stone Existence categories, significant differences were observed when these values were compared with the MM values. The *P*-values for the comparisons can be seen in Table 4.

Table 1. Summary of averages for each group and stage

Group	Stage	Perfect Cavity	Outline Form	Cavity Walls	Cavity Floor	Pulp Stone Existence
C1	B1	1.19	3.19	5.38	0.69	0.38
C1	B2	1.32	3.13	5.31	0.75	0.44
C2	B1	1.32	3.00	5.27	0.68	0.36
C2	M0	1.27	2.86	5.32	0.73	0.41
C2	MM	1.36	2.95	6.86	1.50	0.91

Table 2 . Mann-Whitney U test to compare B1 values for group C1 and group C2

	***P* value**
Perfect Cavity	.7945
Outline Form	.4591
Cavity Walls	.8683
Cavity Floor	.8517
Pulp Stone Existence	.9577

Table 3. Wilcoxon signed-rank test to compare B1 and B2 values for group C1

	***P* value**
Perfect Cavity	.8211
Outline Form	.7768
Cavity Walls	.8241
Cavity Floor	1
Pulp Stone Existence	1

Table 4. *P-values* for statistical comparison of averages

Perfect Cavity*	**M0**	**MM**
B1	.7728	.7728
M0		.484
Outline Form*	**M0**	**MM**
B1	.2986	.7656
M0		.4237
Cavity Walls**	**M0**	**MM**
B1	.91	< .01
M0		< .01
Cavity Floor*	**M0**	**MM**
B1	.8244	< .01
M0		< .01
Pulp Stone Existence*	**M0**	**MM**
B1	.8016	< .01
M0		< .01

** Wilcoxon signed-rank test.*

*** Paired t-test*

DISCUSSION

The present study included third-year preclinical students who had completed the theoretical training on the practical stages of endodontic treatment (such as access cavity preparation, errors occurring during access cavity preparation, root canal instruments, cleaning and shaping of root canals, complications during preparation, root canal filling, etc.) and had practiced on real teeth in the preclinical setting. It is well known that errors in endodontics frequently result from a lack of knowledge of tooth pulp anatomy or the incorrect use of burs or instruments.[18] For this reason, preclinical third-year students who had completed their training and practiced on real teeth were selected. This ensured the evaluation of students who were familiar with standard access cavities and potential errors. Additionally, despite receiving theoretical instruction, students reported difficulties in recognizing the errors they made during preclinical exercises. Thus, the study was conducted with willing and voluntary participants.

It is well known that procedural errors such as ledges, perforations and broken files play a direct role in the success of endodontic treatment. One of the primary priorities to prevent these errors is the proper preparation of the endodontic access cavity. An error occurring during the preparation of the access cavity can pave the way for procedural mistakes and negatively affect the prognosis of endodontic treatment.[19] The occurrence of these errors is a significant obstacle to the success of endodontic treatment. A study reported that the most common errors made by undergraduate dental students were gouging during access cavity preparation and the formation of ledges during instrumentation. Additionally, the study showed that students tended to excessively enlarge the access cavity during its preparation.[20] Moreover, there is a possibility of misunderstandings regarding errors through theoretical education alone, as detecting these errors requires careful examination (checked by probing). Additionally, a lack of knowledge can further contribute to the occurrence of these errors.[2]

The use of magnification systems, by enhancing visibility, has contributed to the advancement of both conventional endodontic and surgical treatments. A recent study emphasized the importance of magnification in endodontic procedures, demonstrating that both dental loupes and operating microscopes significantly improve the precision and outcomes of treatments. This is corroborated by findings that magnification tools, such as dental loupes and operating microscopes, enhance the precision of endodontic procedures, leading to improved treatment outcomes.[21]

In conventional endodontics, magnification has been shown to be beneficial in various areas, including the preparation and completion of access cavities, the diagnosis of microfractures, the identification of untreated or hidden canals, the management of calcified canals, perforation repair, retrieval of broken files, evaluation of canal preparation and the three-dimensional filling of canals.[9,22]

Microscope-level magnification facilitates the visual measurement of the depth of bur entry into a canal and helps distinguish between the pulp chamber and the floor when the distance is small and there is no distinct tactile sensation of the bur reaching the pulp chamber ceiling. Microscopes provide a microscopically sensitive tactile feel, allowing the dentist to associate differences in tactile sensations with microscopic variations in the depth of bur penetration into the pulp. This expertise enhances awareness at the levels of the roof of the pulp chamber, pulp chamber and pulp floor.[23]

A study conducted in Canada compared the development of third-year students in access cavity preparation using operational microscopes versus standard training methods. The group using operational microscopes was found to be significantly more successful.[15] This study was conducted with the belief that magnification could enhance the awareness of preclinical students who reported difficulty in detecting access cavity errors, particularly those occurring in the cavity walls or floor. The use of magnification systems was implemented with the expectation that it would be beneficial, contribute to preclinical training and potentially be integrated into preclinical education if positive results were achieved. The results of our study, which showed that gouging and perforations in the cavity floor were significantly more discernible under magnification, support this notion.

When theoretical training is provided, visual inspection with the naked eye may suffice for detecting the errors related to the Outline Form. To assess the Outline Form, one must understand how the boundaries and shape of the access cavity should be. In our study, the lack of a statistical difference between the Control and Microscope groups was considered an expected outcome.

Detecting Cavity Walls errors requires not only theoretical training but also good visibility. Although no statistical difference was found between the Control and Microscope groups, an increase in the number of Cavity Walls errors identified was observed in the Microscope group (M0) after training with magnification and subsequent inspection with the naked eye. This increase is attributed to the improved perception of errors, such as overextended dentin, which are difficult to identify or perceive without magnification.

According to the study results, a statistically significant difference was found between the Microscope group (MM) and the Control group (C1) when Cavity Floor errors are evaluated under magnification. After microscope training, when examined with the naked eye (M0), the detection of existing hollows in the cavity floor increased, but no statistical difference was observed. Under magnification, however, the detection of both hollows and perforations increased significantly and this increase was statistically significant. In endodontic treatments, the field of view is often limited.[11] This limitation is particularly felt more acutely during the evaluation of the cavity floor. The increase in the detection of errors in the cavity floor under magnification is thought to result from magnification compensating for the restricted field of view.

Although no statistically significant difference was found between the Control and Microscope groups in the assessment of flawless cavities, an increase was observed in the number of flawless cavities identified by the Microscope groups (M0, MM) after microscope training. Since the decision for a flawless cavity primarily considers the external form of the cavity, theoretical knowledge is of primary importance. Given that the groups participating in the study had completed their theoretical training, the lack of statistical difference is considered normal. The increase in the number of correctly identified flawless cavities is thought to be related to the enhanced level of awareness following microscope training.

A statistically significant difference was found between the Control group and the Microscope group in the identification of adhered pulp stones in the pulp floor. This difference is thought to be due to the limited field of view during the observation of the cavity floor, with magnification compensating for this restriction and even providing enhanced visibility.

Studies have indicated that there are no statistically significant differences in endodontic mishaps across different tooth types or groups.[20,24] However, there are studies that report a higher incidence of entry cavity errors in molar teeth compared to other types.[25] There is no clear consensus on this issue. Therefore, in our study, entry cavity errors were analyzed across anterior, premolar and molar teeth to provide insights into the occurrence of these errors in different types of teeth.[26] Studies have shown that students frequently perceive themselves as inadequate in root canal treatment and exhibit a lack of confidence.[20,27] A study by Alghamdi et al. observed that undergraduate dental students often lack confidence in performing root canal treatments, which may contribute to the occurrence of procedural errors. This observation is consistent with research indicating that a lack of confidence among undergraduate dental students can lead to an increased incidence of procedural errors during endodontic treatments.[20] In the current study, the self-confidence of the students was not assessed.

CONCLUSION

Entry cavity preparation is undeniably the most crucial stage of root canal therapy. Complete removal of the pulp chamber roof, direct access to the canals, locating all the canals, ensuring proper instrumentation

and achieving three-dimensional canal filling are essential for ideal root canal therapy. During this phase, particularly in the educational stage, magnification systems can help prevent potential errors and enhance awareness. According to the results of the current study, there was an increase in the perception of errors, particularly in the pulp floor, in the group evaluated under magnification.

While magnification systems are frequently used in specialized endodontic training and advanced endodontics, their use has become more widespread today. Incorporating magnification systems into undergraduate dental education and student practice will contribute to increased awareness in the field of dentistry and endodontics, as well as to the implementation of successful treatments.

Limitations

The lack of blinding of the evaluator may be considered a limitation, although objective assessment criteria were used to minimize potential bias.

To utilize the magnification system, permissions were obtained to use the laboratory at ÇAKÜ Faculty of Science and the stereomicroscope was employed. Due to the high cost and the recent establishment (2020) of the dental faculty, an operational microscope is not yet available at our institution. Given the positive results obtained, it is planned to apply for a project and integrate an operational microscope into the undergraduate dental education program, as it is believed to contribute to the education of dental students

Ethics Committee Approval: This study was approved by the Çankırı University Health Sciences Ethics Committee on March 19, 2024 (12th Meeting).
Informed Consent: Participation of third-year dental students undergoing preclinical training in the study was voluntary.
Peer-review: Externally peer-reviewed
Author Contributions: Concept – E.G.Ş.; Design- E.G.Ş.; Supervision- E.G.Ş., S.Ş.; Resources- E.G.Ş., S.Ş.; Data Collection and/or Processing- E.G.Ş.; Analysis and/or Interpretation- E.G.Ş.; Literature Search- E.G.Ş.; Writing Manuscript- E.G.Ş.; Critical Review- E.G.Ş., S.Ş.
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