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The technical quality of root canal filling performed by undergraduate students in pre-clinical education: Instructor versus ChatGPT-4o assessment

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Purpose: The present study aims to compare the radiographic technical quality of root canal fillings performed on 3D-printed resin and extracted natural teeth, and to examine the agreement between endodontist educator assessment and analysis performed by an artificial intelligence-based chatbot (ChatGPT-4o).

Methods: After theoretical training and practical demonstration, 3rd-year undergraduate students performed root canal treatment on 108 printed resin teeth and 108 extracted natural teeth. In the radiographic examination, parameters such as root canal filling length, filling continuity, apical transport, perforation, and instrument fracture were evaluated by both an experienced instructor and ChatGPT-4o. The technical quality of root canal filling and all procedural errors were compared between the printed teeth and extracted teeth groups using the chi-square test. Interexaminer reliability was measured between the instructor and ChatGPT-4o.

Results: Regarding overall root canal quality, 34% of extracted teeth were acceptable and 66% were unacceptable, while 45% of printed teeth were acceptable and 55% were unacceptable. There is no statistically significant difference between the acceptability rates of extracted teeth vs printed teeth ($p>0.05$). It was observed that the extracted teeth had more under-filled canals and fewer adequately filled canals than expected, whereas printed teeth were more likely to be adequately filled ($p<0.05$). There was no difference between sample types having adequate or inadequate filling continuity ($p>0.05$). Apical transportation, perforation, and instrument fracture rates did not differ significantly between extracted and printed teeth. Cohen's kappa value is 0.210, and the inter-observer agreement was 62%. These results indicated low agreement between the instructor and ChtaGPT-4o significantly ($p<0.05$).

Conclusion: The overall quality of the canal filling applied by undergraduate students on 3D-printed resin and extracted teeth was similar. ChatGPT-4o evaluation did not demonstrate a high level of agreement with the endodontist instructor.

Keywords: 3D printed teeth; artificial intelligence; preclinical education.

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Introduction

The target of dental education is to train individuals to perform their profession in a reliable, skillful, and effective manner (1). The educational journey of dental students includes both theoretical and practical training throughout their studies (2). Pre-clinical training contributes to the development of motor skills and the acquisition of relevant experience in a safe environment. It also allows students to develop the skills necessary to practically apply their theoretical knowledge (3). In preclinical years, endodontic and restorative procedures are traditionally performed on extracted teeth or artificial models using various instruments (4).

With the rapid advances in technology and the increased availability of 3D printers, the overall potential for using printed models in dental education has attracted considerable interest, particularly for training dental students and enhancing dentists' practical skills (5). Three-dimensional printing enables the production of new models that reflect the anatomy of the root canal in endodontics (6).

The success of root canal treatment (RCT) depends on the proper cleaning, shaping, and consequently root canal filling. The methods used to determine the outcome of endodontic treatment are usually based on radiographic evaluation (7). Unfavourable treatment outcomes have often been associated with technically unacceptable root canal fillings (8). Examining the radiographic quality of their own root canal fillings and understanding their adequacy may help undergraduate students achieve better results (9).

While observational studies are an effective tool for clinical management, clinical audits can also help dental educators to identify curricular deficiencies, methodological problems, and issues with instruments or materials (10). Therefore, it is essential to continuously review the clinical training outcomes for undergraduate dentistry.

In recent years, artificial intelligence (AI)-assisted systems have become increasingly embedded in dental education (11). In particular, large language models (LLMs) and chatbots such as ChatGPT have the potential to be used in clinical decision support systems and student training (12). Previous studies have found that ChatGPT provides students with fast and accessible information and that ChatGPT requires students to learn how to ask the right questions to get the best answers (13,14)

Various studies have shown that ChatGPT's medical image analysis and clinical evaluation capabilities are limited (12,15). However, new versions can be expected to improve in assessing the quality of pre-clinical applications in dental undergraduate education. The present study aims to compare the radiographic technical quality of root canal fillings performed on 3D-printed resin and extracted natural teeth and to examine the agreement between endodontist educator assessment and analysis performed by an artificial intelligence-based chatbot (ChatGPT-4o).

Materials and Methods

This observational study has been written in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) 2007 guidelines and was approved by the Scientific Research Ethics Committee of the University of Lokman Hekim (No: 2025/098, Date: 28/04/2025).

and conducted according to the Declaration of Helsinki. Figure 1 shows the STROBE flowchart illustrating the study protocol of the present. The total number of samples required for our study was determined as at least 159 in the G*Power software by using the effect size of a previously conducted study (16). This study was conducted by examining the radiological records of resin (simulated) or extracted (human) teeth that underwent root canal treatment in the preclinical courses of 3rd-year undergraduate students at Lokman Hekim University Faculty of Dentistry. The students had no previous practical experience in root canal preparation and filling. The students were given theoretical instruction and a demonstration of the RCT protocol before each application. A total of thirty-six students participated in the study. Each student was required to provide one incisor, one premolar, and one molar tooth, either maxillary or mandibular. This ensured that each participant performed procedures on three distinct tooth types, allowing for standardization across specific tooth groups rather than random allocation. Consequently, each student carried out endodontic procedures on a total of six teeth, consisting of three 3D-printed teeth and three extracted human teeth, each representing a different tooth group. Table 1 shows the numerical distribution of samples used by students according to tooth groups. The practical training sessions were organized in two phases: Initially,

Table 1. Numerical distribution of samples used by students according to tooth groups

	Printed teeth	Extracted Teeth
Maxillary incisor	18	20
Mandibular incisor	18	16
Maxillary premolar	23	19
Mandibular premolar	13	17
Maxillary molar	10	12
Mandibular molar	26	24
Total	108	108

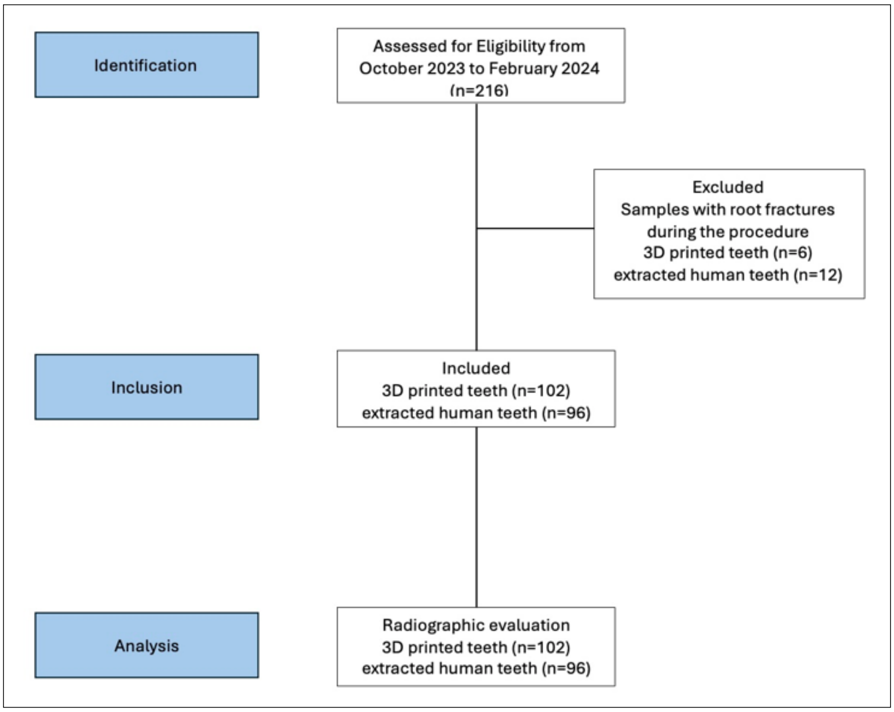

Fig. 1. STROBE flow chart of the present study protocol.

students performed RCT on 3D-printed teeth, followed by treatments on extracted natural teeth. Extracted teeth without any curvature or calcification were used. During these sessions, students worked sequentially on incisors, premolars, and molars. For each tooth sample, students were allocated 2 hours to complete the RCT procedure. In total, each student treated six teeth—three extracted natural teeth and three 3D-printed teeth covering the different tooth types mentioned. Endodontic access cavity preparation, root canal detection, instrumentation, master cone control, and canal-filling steps were checked by the instructor during the students' application. A total of 108 printed resin teeth and 108 extracted natural teeth were treated. The printed teeth (Dental Education Models, Ancorax Technology, Ankara, Türkiye) used by all students were models produced from the same resin-based material.

RCT procedure

Initially, an endodontic access cavity was created in all samples. For the determination of working length, a K-type hand file no. #10 or #15 was advanced until it was seen from the apex of the root. Then, the working length was determined by subtracting 1 mm from the length. Canals were prepared using K and H-type hand files up to #40 apical tip size with standard preparation technique. Irrigation was performed with sodium hypochlorite during shaping procedures. Canals were dried with paper points. The lateral condensation technique was used for root canal filling using gutta-percha and sealer.

Inclusion criteria

• Single or multi-rooted 3D printed resin and an extracted permanent tooth

• RCTs were conducted by a third-year undergraduate student under the supervision of a senior endodontist instructor between October 2023 and February 2024.

Exclusion criteria

• Samples where root fractures occurred during the procedure

Radiographic examination

Finally, 94 extracted and 102 printed teeth were included for examination. Then, 2D digital radiography was taken of all samples using the parallel technique. All radiographs were taken with the same X-ray device (RX DC NewTom, Bologna, Italy) with the same dose, and parameters (0.180 mAs, 60 kvp/8mA). All radiographs were scanned with the Carestream CS 7200 phosphor plate scanning system and transferred to Tropy DICOM. All images were evaluated in a dark room by a single examiner who had 7 years of experience in endodontics. Each root canal filling was evaluated radiographically for continuity, and the apical extension of filling materials, apical transportation, perforation, and instrument fracture. For the technical quality of root canal fillings, the quality guidelines for endodontic treatment (European Society of Endodontology, 2006) were adopted as the gold standard. According to these guidelines, the prepared root canal should be filled; the prepared and filled canal should maintain the original canal shape, there should be no visible gaps between the filling material and the canal walls, and no visible canal space should be present beyond the end point of the root filling. A root filling was defined as satisfactory when both the continuity and the apical extension of the filling materials were rated as acceptable.

The radiographic images obtained in this study were standardized (maximum resolution: 1920x1080 pixels, file format: TIFF) and digitally archived after being numbered sequentially.

Evaluation of the images was conducted by another researcher using the ChatGPT-4 model, accessed through Google. To eliminate any potential effects from cookies and cache, a previously unused email address was employed for each evaluation. Additionally, the browser's search history and cookies were cleared before each case evaluation, and a new chat window was opened for each case to minimize the influence of previous responses.

For assessment, radiographic images were uploaded to the chat interface, and the following standardized evaluation text was provided to the ChatGPT-4 model:

"Could you please evaluate the root canal treatment shown in the photograph based on the following parameters?

Radiological parameters:

Root canal filling length: The root canal filling should extend up to 2 mm short of the radiographic apex. Obturation should neither be overfilled nor underfilled. (overfilled, acceptable, short)

Continuity of the root canal filling: The root canal filling should appear continuous and uniform throughout the canal length, without gaps, voids, or separations. (adequate, inadequate)

Apical transportation (Present/Absent)

Perforation (Present/Absent)

Instrument fracture (Present/Absent)"

Responses from the model were recorded in an Excel spreadsheet (Microsoft), transferred to the database, and analyzed as part of the study.

The radiographic assessments conducted by the human examiner and ChatGPT-4o were performed independently. The AI model and the examiner did not have access to each other's evaluations.

Assessing the technical quality of root fillings and detecting iatrogenic errors were noticed in the following factors.

Canal filling length: The root canal filling should extend to within 2 mm of the radiographic apex. The obturation should not be overfilled or underfilled.

Continuous filling: The root canal filling should appear continuous and uniform without voids, gaps, or separations along the length of the canal.

Iatrogenic errors: Presence or absence of any apical transportation, perforation, and instrument fracture.

Statistical analysis

All statistical analyses were performed using the JAMOVI software (ver.2.6.44, Sydney, Australia). The technical quality of root canal filling and all procedural errors were compared, using the chi-square test, for the results of the printed teeth and extracted teeth groups. Cohen's Kappa was used to measure the agreement between the observer and ChatGPT 4.0.

Results

Table 2 and Table 3 show percentage values and the number of examination results. Regarding overall root canal quality, 34% of extracted teeth were acceptable and 66% were unacceptable, while 45% of printed teeth were ac-

Table 2. Descriptive results of endodontist examiner assessment

	Frequency %	
	Printed teeth (n=102)	Extracted teeth (n=94)
Canal filling length		
Over-filled	2% (n=3)	3% (n=4)
Adequate	77% (n=79)	79% (n=57)
Under-filled	19% (n=20)	18% (n=33)
χ^2 Tests	p=0.037	
Continuity of filling		
Adequate	47% (n=48)	47.8% (n=45)
Inadequate	52.9% (n=54)	52.1% (n=49)
χ^2 Tests	p=0.909	
Apical transportation		
Absence	97% (n=99)	95.7% (n=90)
Presence	2.9% (n=3)	4.2% (n=4)
χ^2 Tests	p=0.620	
Perforation		
Absence	100% (n=102)	97.8% (n=92)
Presence	0 (n=0)	2.1% (n=2)
χ^2 Tests	p=139	
Instrument fracture		
Absence	96% (n=98)	92.5% (n=87)
Presence	3.9% (n=4)	7.4% (n=7)
χ^2 Tests	p=0.284	

Table 3. Overall quality of root canal filling in extracted or printed teeth

	Examiner		
Tooth type	**Acceptable**	**Unacceptable**	**Total**
Extracted teeth	32 (34%)	62 (66%)	94
Printed teeth	46 (45%)	56 (55%)	102
Total	78	118	196

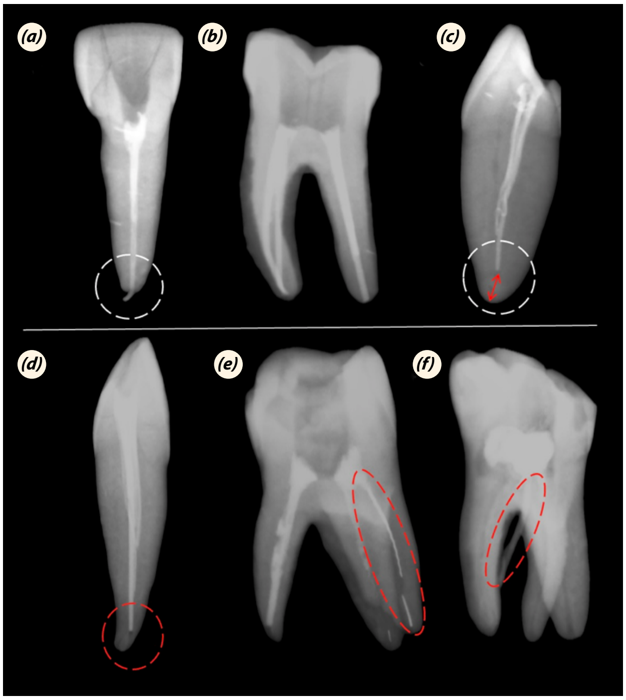

Fig. 2. The radiographic images demonstrated **(a)** over-filled root; **(b)** acceptable canal filling; **(c)** under-filled and inadequate filling; **(d)** apical transportation; **(e)** instrument fracture; and **(f)** perforation.

ceptable and 55% were unacceptable. There is no statistically significant difference between the acceptability rates of extracted teeth vs printed teeth ($p>0.05$). The chi-square test results showed a significant relationship between sample type and canal length ($p<0.05$). It was observed that the extracted teeth had more under-filled canals and fewer adequately filled canals than expected, whereas printed teeth were more likely to be adequately filled. There was no difference between sample types having adequate or inadequate filling continuity ($p>0.05$). Apical transportation and perforation rates did not show any significant difference between extracted and printed teeth. There is no statistically significant difference between instrument fracture rates in extracted and printed teeth ($p>0.05$). The occurrence of instrument fracture remains at very low levels for both groups (3.9% and 7.4%).

Table 4. Intra-examiner reliability between the examiner and ChatGPT-4o

Method	Cohen's Kappa for 2 Raters
Subjects	196
Raters	2
Agreement %	62
Kappa	0.210
z	2.94
p-value	0.003

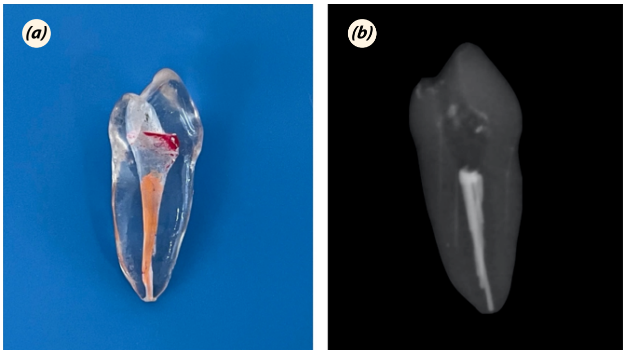

Fig. 3. The figure represents the 3D printed mandibular premolar tooth model **(a)** and its radiographic image **(b)**.

Figure 2 shows radiographic images of root canal-filled extracted teeth. Figure 3 shows a printed tooth model with a canal filling and its radiographic image.

Interobserver agreement was assessed for the examiner and ChatGPT-4o in Table 4. Cohen's Kappa value is 0.210, indicating a weak agreement between the examiner and ChatGPT-4o. The directly observed agreement rate between observers was 62%. Since the p-value is 0.003, this low agreement is not random but is statistically significant.

Discussion

In this study, the quality of root canal treatments performed by undergraduate students on extracted and 3D-printed teeth was evaluated using radiographic analysis. There are still limitations to using extracted human teeth in dental courses, such as ethical concerns, collecting sufficient numbers of samples, and the risk of infection transmission (17). The 3D printing method allows samples to be designed in various sizes and inclination levels with advantages such as reproducibility (5,18).

Our finding showed that the type of tooth used does not significantly affect the overall quality of the filling. In terms of overall root canal quality, only 34% of the treatments on extracted teeth, and 45% on printed teeth, were found to be acceptable. When analyzing canal length, extracted teeth were found to have a higher number of under-filled canals and fewer adequately filled canals than expected. In contrast, printed teeth were more likely to have adequately filled canals. It is difficult to reach the apex due to calcifications and complex canal anatomy in extracted teeth (19,20), and these factors may contribute to this difficulty.

In two previous evidence-based studies, no significant difference was found between training with artificial teeth and extracted teeth regarding the technical results of root canal filling (21,22). It has been reported that procedures performed on artificial teeth did not always indicate students' performance on natural teeth (4).

No significant differences were found in parameters such as filling continuity, apical transportation, perforation, and instrument fracture between extracted and printed teeth. This indicates that these complications occurred at similar rates in both types of specimens and supports the reliability of the instrumentation and obturation techniques used.

Gancedo-Caravia et al. (23) highlighted that micro-computed tomography data-based printed dental models were considered anatomically similar to natural teeth by evaluators. However, they also reported that students' treatment performance decreased as the anatomical difficulty of the artificial teeth increased. Moreover, the special endodontic training models developed by Yekta-Michael et al. (24) using 3D printing technology, were positively evaluated by both students and instructors; the modified versions, in particular, were reported to offer more realistic experiences in procedures such as canal shaping.

Models like ChatGPT are expected to be used in clinical treatment simulations. The concept of a "clinical ward assistant" suggests that future chatbots could be customized and trained to use evidence-based content taught in didactic courses to help educate students and residents both in the clinic and in preparation for clinical work (25). For this reason, the present study utilized the ChatGPT-4o model as a representative example of an AI-based chatbot to explore its potential contributions to endodontic education.

The significant finding of this study was the weak agreement between the ChatGPT-based evaluations and those of a human examiner (κ=0.210), indicating fair but limited consistency. This suggests that current AI models are not yet reliable enough to act as autonomous evaluators in preclinical dental education. Nevertheless, they may still serve as useful supplementary tools to enhance student feedback—particularly under instructor supervision—provided that their outputs are critically reviewed due to potential issues with accuracy and reliability. This aligns with previous reports indicating that AI models often struggle to match expert judgment in complex, high-skill domains (15,26).

Although AI-based chatbots such as ChatGPT are considered to have significant potential in medical image analysis and clinical decision-making, it should be noted that ChatGPT-4o is not specifically trained for radiographic image interpretation and was not provided with any clinical context in this study. Its performance, therefore, reflects general-purpose visual reasoning. This may explain why a previous study using visual prompts found that ChatGPT-4o performs worse in image-based questions (e.g., radiological images) than in text-based ones (27). Another study showed that the accuracy of ChatGPT in image-based questions improved when clinical context was provided and decreased when context was absent (14). Since this study used only visual prompts, this limitation may help explain the low interobserver agreement observed. Previous studies also highlighted that although ChatGPT has potential in clinical decision-making, there is a risk of generating inaccurate or fabricated information such as hallucinations (28-30).

Due to concerns about the accuracy, originality, and ethical aspects of information generated by ChatGPT, its use in clinical and academic settings should be approached with caution, and all outputs must be reviewed by experts. Garg et al. (31) emphasized that while ChatGPT can be supportive in patient education, clinical documentation, and research processes, its accuracy and ethical dimensions must be carefully evaluated.

The "zero-shot" method used in this study refers to the model performing a task without prior training on that specific task or examples. Instead, it relies solely on general training data and a given prompt. This approach allows direct evaluation without the need for task-specific training or examples. Its advantages include rapid applicability and low cost, while its disadvantages include lower accuracy, reliability, and consistency in complex tasks. Zero-shot methodology is important because it allows models like ChatGPT to be adapted across various fields with ease. The approach used in this study yielded results consistent with previous zero-shot research (14,28,29). However, in the context of this study, the absence of any clinical background or descriptive text beyond the radiographic image likely contributed to the limited diagnostic accuracy of ChatGPT-4o. Future studies should compare zero-shot performance with context-enhanced prompts.

Within the limitations of this study, the samples were the students' first experience with RCT application. Also, according to our preclinical training program, students practice directly on printed and extracted teeth to increase their manual skills, and reinforce the treatment protocol before practicing on phantom models. The canal filling quality was assessed on 2D radiographs due to their ease of use during the educational process, and their accessibility by students. Future studies can examine applications across different educational models to evaluate student performance and measure the development of ChatGPT or another AI tool.

Conclusion

According to the findings of this study, while the type of sample significantly affects the adequacy of root canal filling length, it does not considerably influence the overall quality of the treatment. Printed teeth appear to be an effective alternative in preclinical education, particularly in terms of standardization and reproducibility. However, the educational value of natural teeth should not be overlooked.

AI-assisted evaluation methods, especially when used with visual content, currently show limited accuracy. ChatGPT offers promise in medical image interpretation and clinical decision support, but its performance in image-based tasks remains limited, particularly in the absence of clinical context. Therefore, these systems should only be used under expert supervision and supported by ethical and methodological standards. Future studies are needed to improve the accuracy and reliability of AI-based systems.

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Conflict of Interest: None declared.

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Informed consent: Not applicable.

Data availability statement: The data can be provided by the corresponding author upon request of the readers.

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