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ORIGINAL ARTICLE

Comparison of diagnoses made by dentistry students and by artificial intelligence dentists

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Abstract

Objectives: The introduction of artificial intelligence (AI) about great changes in the field of dentistry, but it has not yet been fully determined in which areas it will make a positive contribution to dentistry students. The objective of our study was to compare the diagnostic accuracy of undergraduate students (fourth-year dentistry students [4DS] and final-year dentistry students [5DS]) and AI when examining panoramic radiographs.

Methods: Fifty panoramic radiographs and 1602 teeth were examined by 50 4DS who had not received a clinical practice internship, 50 5DS, and an AI application. The participants and the AI application evaluated the teeth seen in each radiograph one by one in terms of caries, fillings, teeth with root canal treatment, periodontal loss, extractions, crowns, teeth with apical lesions, and impacted and extracted teeth. Findings were recorded in an Excel chart. Chi-square analysis was used to compare diagnostic success between the groups.

Results: The results indicate that there was a statistically significant difference in the identified accuracy of caries, fillings, and extractions between the AI application and undergraduate students ($p < 0.05$). Although AI showed more identified accuracy in teeth with apical lesions, impacted teeth, and teeth with root canal treatment than in undergraduate students, there was no significant difference between them ($p > 0.05$).

Conclusion: AI exhibited better results than undergraduate students especially in the detection of caries and fillings. AI could improve undergraduates' accuracy in detecting caries, fillings, and extractions and help them make accurate treatment decisions. In cases where dentistry students are examining patients using panoramic radiographs, employing AI programs during their clinical training to confirm and strengthen the student's diagnosis may be a promising new development.

KEYWORDS
artificial intelligence, communication, diagnosis, dentist trust, machine learning, patients

1 | INTRODUCTION

Early detection of disease helps to improve outcomes and minimize risk factors.[1] For a correct diagnosis, it is important to evaluate the patient's history (anamnesis), physical examination, and radiological findings as a whole, and to benefit from the developing technology in combination with the physician's clinical knowledge and experience. To prevent differences arising among clinicians, automated dental radiographic diagnostic support can be useful to assist diagnosis.[2] Clinicians visually evaluate radiographs by examining the characteristics of these images. However, this process can sometimes be subjective and time-consuming.[3]

AI aims to use machines to solve any problems that can be solved by human intelligence. Machine learning is a subfield of AI that involves analyzing data by introducing algorithms and models. In healthcare, patterns that predict outcomes and make diagnoses can be identified by training machine learning algorithms on large data sets. This helps clinicians make informed decisions and improves how they diagnose.[4] AI methods are adept at automatically diagnosing complex patterns in imaging data and providing precise quantitative analysis.[5] Outputs determined by artificial learning can reduce both the rate of misdiagnosis and underdiagnosis in dental practice and the daily workload of clinicians, given the increases in the amount of medical data that is occurring day by day.[6]

In dentistry, in addition to identifying caries, detecting pathologies, planning orthodontic treatment of crooked teeth, and making dental implants with robotic surgery, AI applications have attracted attention with regard to their use in various other areas, including organizing patient appointments, handling insurance and paperwork, and keeping medical records. AI is an important guide to achieving effective learning and teaching.[7] In addition, AI can help with the educational aspect of dentistry. By analyzing the data, it is possible to see how students learn and to identify their deficiencies in specific areas and skills. AI has the potential to significantly enhance the learning experience for students and improve educational outcomes when applied to university teaching.[4] However, studies may be needed on the impact of AI on treatment decisions, health gains, or the costs that arise from the diagnosis and decision-making process of clinicians and undergraduate students. We thus aimed to compare the accuracy of undergraduate students and an AI application when assessing panoramic radiographs with regards to specific conditions (caries, fillings, teeth with root canal therapy, periodontal loss, extractions, crowns, teeth with apical lesions, and impacted and extracted teeth). The null hypothesis was that there would be no differences between examiners.

2 | MATERIALS AND METHODS

Ethical approval was received from the Health Sciences Ethics Committee of Ankara Yıldırım Beyazıt University, with decision date/number 14.06.2023/06-298. We retrospectively examined panoramic radiographs of patients who attended the dentomaxillofacial radiology clinic in the Faculty of Dentistry at Ankara Yıldırım Beyazıt University between April and June 2022 for a consultation. It was observed that a total of 1461 patients attended the clinic during this period. The radiographs of 50 patients who met the criteria were included in this retrospective study. The inclusion criteria were as follows[1]: healthy individuals aged between 18 and 50 years[2]; referral to Restorative Dentistry and Endodontics dental clinics[3]; absence of any image artifacts on radiographs[4]; and having at least one of the following variables: decay, filling, periodontal loss, canal, dental crown, teeth with apical lesions, and impacted and extracted teeth. In order to use their panoramic radiographs in the research, the patients were informed about the purpose and content of the study and the use of the images, and they were asked to read and sign an informed consent form. The radiographs were anonymized and the patients' names, surnames, age, gender, Turkish ID numbers, etc., were hidden.

Fifty radiographs and 1602 teeth were examined by 50 fourth-year dentistry students (4DS) who had not received a clinical practice internship, 50 final-year dentistry students (5DS), and an AI application. All the radiographs were evaluated by three faculty members from the Department of Oral and Maxillofacial Radiology, Endodontics and Restorative Dentistry with over 10 years of clinical experience. Their consensus decision was recorded as the gold standard. All participants evaluated the whole teeth seen in each panoramic radiograph in terms of caries, fillings, teeth with root canal treatment, periodontal loss, extractions, crowns, teeth with apical lesions, and impacted and extracted teeth. The findings were recorded in an Excel chart.

The AI application used was an online platform. The radiography was uploaded to the AI program (DentisToday, https://apps.apple.com/tr/app/dentistoday/id6482289821?l=tr) via mobile app, and then the results of the diagnoses made using the algorithms were saved in Excel format. The program identified caries, fillings, canals, periodontal disease, extractions, crowns, teeth with apical lesions, and impacted and extracted teeth as present/absent on the panoramic radiograph (Figure 1).

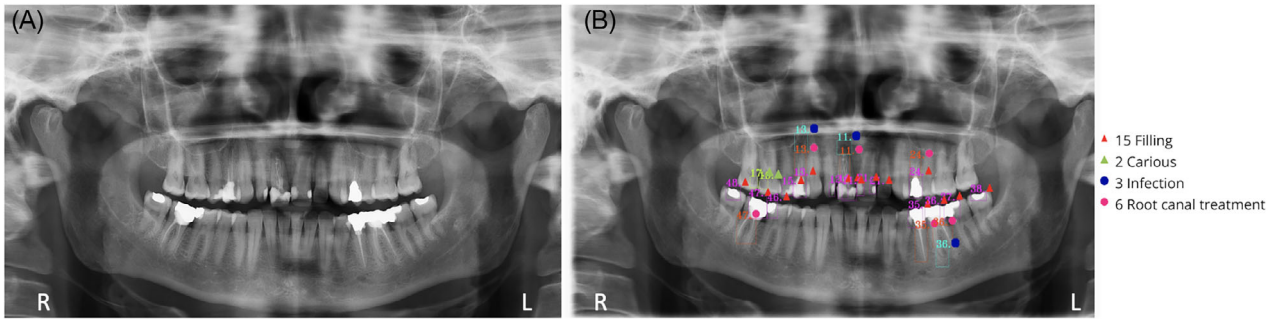

FIGURE 1 Panoramic radiograph (A) and artificial intelligence (AI) output image (B) with detection squares and symbols for detected diseases (fillings, caries, apical lesions, etc.), as well as the Fédération Dentaire Internationale (FDI) notation of the affected tooth.

TABLE 1 Percentage of accuracy of identifying caries, fillings, extractions, crowns, and periodontal loss of artificial intelligence (AI), fourth-year dentistry students (4DS), and final-year dentistry students (5DS).

	AI (%)	4DS (%)	5DS (%)
Caries	90.6	87.9	88.7
Filling	92.8	88.1	89.2
Extraction	100	91.1	91.4
Teeth with root canal treatment	96.6	96.7	96.3
Impacted teeth	99.8	99.5	99.5
Crown	98.1	97.1	97.3
Apical lesion	98.3	97.7	97.6
Periodontal loss	93.6	87.3	93.1

2.1 | Statistical analysis

All statistical analyses were performed using the SPSS 26.0 (IBM). Chi-square analysis was used to compare the success of the results between groups. Descriptive findings in the research were expressed as frequency and percentage. In the study, statistical significance was taken as $p < 0.05$.

3 | RESULTS

Interobserver agreement was checked to establish the gold standard ($K = 0.95$). In cases where there was disagreement, observers came together to conclude. The percentage of accuracy of identifying caries, fillings, extractions, crowns, and periodontal loss in the AI, 4DS, and 5DS were compared according to the gold standard.

Table 1 shows the percentage of accuracy of identifying caries, fillings, extractions, crowns, and periodontal loss of AI, 4DS, and 5DS.

3.1 | Comparison of AI and 4DS

When we compared AI and 4DS, there was a statistically significant difference in identifying caries, fillings, extractions, crowns, and periodontal loss ($p < 0.05$). AI made more correct identifies than the 4DS in these cases. When the accuracy of identifying teeth with apical lesions, impacted teeth, and teeth with root canal treatment was evaluated, no significant difference was observed between the AI and the 4DS (Table 2).

3.2 | Comparison of AI and 5DS

When we compared AI and the 5DS, there was a statistically significant difference in accuracy of identifying caries, fillings, and extractions ($p < 0.05$). AI made more correct results than the 5DS in these cases. When the accuracy of identifying of teeth with apical lesions, impacted teeth, crowns, periodontal loss, and teeth with root canal treatment was evaluated, no significant difference was observed between the AI and the 4DS (Table 3).

3.3 | Comparison of 4DS and 5DS

When we compared the 4DS and 5DS, there was a statistically significant difference in fillings and periodontal loss ($p < 0.05$). 5DS made more correct results than 4DS in these cases. When the accuracy of identifying of teeth with apical lesions, impacted teeth, crowns, caries, and teeth with root canal treatment was evaluated, no significant difference was observed between the 4DS and 5DS (Table 4).

4 | DISCUSSION

The student-centered learning (SCL) model has begun to be developed and applied in the field of dentistry in combination with the latest technological developments. SCL is designed to enhance students' learning experiences.[8] After their theoretical training, dentistry students improve their skill levels by performing clinical practice with patients.[9] In this type of learning, dentistry students can integrate

TABLE 2 Comparison of identification achievements of artificial intelligence (AI) and fourth-year dentistry students (4DS).

	Group				
	AI	4DS	Total	x^2	*p*-value
Caries					
False diagnose	150	9658	9808	10.794	0.001*
	9.38%	12.07%	12.02%		
True diagnose	1450	70,342	71,792		
	90.63%	87.93%	87.98%		
Filling					
False diagnose	115	9489	9604	32.997	0.001*
	7.19%	11.86%	11.77%		
True diagnose	1485	70,511	71,996		
	92.81%	88.14%	88.23%		
Extraction					
False diagnose	0	7158	7158	156.926	0.001*
	0.00%	8.95%	8.77%		
True diagnose	1600	72,842	74,442		
	100.00%	91.05%	91.23%		
Teeth with root canal treatment					
False diagnose	54	2666	2720	0.009	0.925
	3.38%	3.33%	3.33%		
True diagnose	1546	77,334	78,880		
	96.63%	96.67%	96.67%		
Impacted teeth					
False diagnose	4	418	422	2.264	0.132
	0.30%	0.52%	0.52%		
True diagnose	1596	79,582	81,178		
	99.80%	99.48%	99.48%		
Crown					
False diagnose	31	2309	2340	5.069	0.024*
	1.90%	2.89%	2.87%		
True diagnose	1569	77,691	79,260		
	98.10%	97.11%	97.13%		
Apical lesion					
False diagnose	28	1842	1870	2.138	0.144
	1.80%	2.30%	2.29%		
True diagnose	1572	78,158	79,730		
	98.30%	97.70%	97.71%		
Periodontal loss					
False diagnose	103	10,129	10,232	55.404	0.001*
	6.40%	12.66%	12.54%		
True diagnose	1497	69,871	71,368		
	93.60%	87.34%	87.46%		

* = indicate the statistically significant difference ($p < 0.05$).

their basic knowledge and apply it to new clinical situations. SCL thus aims to lead to correct decision-making and better treatment processes. Researchers have also recommended that various teaching and assessment methods be specifically tailored to students' learning abilities and needs.[8] On the basis that all successful treatment depends on the correct diagnosis of the disease,[10] we conducted this study to investigate whether dentistry students need

TABLE 3 Comparison of identification achievements of artificial intelligence (AI) and final-year dentistry students (5DS).

	Group				
	AI	5DS	Total	x^2	*p*-value
Caries					
False diagnose	150	9026	9176	5.719	0.017*
	9.40%	11.30%	11.20%		
True diagnose	1450	70,974	72,424		
	90.60%	88.70%	88.80%		
Filling					
False diagnose	115	8678	8793	21.855	0.001*
	7.20%	10.80%	10.80%		
True diagnose	1485	71,322	72,807		
	92.80%	89.20%	89.20%		
Extraction					
False diagnose	0	6900	6900	150.747	0.001*
	0.00%	8.60%	8.50%		
True diagnose	1600	73,100	74,700		
	100.00%	91.40%	91.50%		
Teeth with root canal treatment					
False diagnose	54	2978	3032	0.529	0.467
	3.40%	3.70%	3.70%		
True diagnose	1546	77,022	78,568		
	96.60%	96.30%	96.30%		
Impacted teeth					
False diagnose	4	405	409	2.065	0.151
	0.30%	0.50%	0.50%		
True diagnose	1596	79,595	81,191		
	99.80%	99.50%	99.50%		
Crown					
False diagnose	31	2168	2199	3.57	0.059
	1.90%	2.70%	2.70%		
True diagnose	1569	77,832	79,401		
	98.10%	97.30%	97.30%		
Apical lesion					
False diagnose	28	1881	1909	2.482	0.155
	1.80%	2.40%	2.30%		
True diagnose	1572	78,119	79,691		
	98.30%	97.60%	97.70%		
Periodontal loss					
False diagnose	103	5537	5640	0.571	0.450
	6.40%	6.90%	6.90%		
True diagnose	1497	74,463	75,960		
	93.60%	93.10%	93.10%		

* = indicate the statistically significant difference ($p < 0.05$).

to use AI to make correct diagnoses. For this purpose, we compared the accuracy of identifying of caries, fillings, teeth with root canal treatment, periodontal loss, extractions, crowns, teeth with apical lesions, and impacted and extracted teeth of 4DS, 5DS, and an AI application when examining panoramic radiographs.

The study found that AI had a higher percentage in terms of correctly identifying the presence of caries,

TABLE 4 Comparison of identification achievements of fourth-year dentistry students (4DS) and final-year dentistry students (5DS).

	Group				
	4DS	**5DS**	**Total**	x^2	***p*-value**
Caries					
False diagnose	9658	9026	18,684	2.424	0.117
	12.07%	11.28%	11.68%		
True diagnose	70,342	70,974	141,316		
	87.93%	88.72%	88.32%		
Filling					
False diagnose	9489	8678	18,167	4.081	0.010*
	11.86%	10.85%	11.35%		
True diagnose	70,511	71,322	141,833		
	88.14%	89.15%	88.65%		
Extraction					
False diagnose	7158	6900	14,058	0.591	0.230
	8.95%	8.63%	8.79%		
True diagnose	72,842	73,100	145,942		
	91.05%	91.38%	91.21%		
Teeth with root canal treatment					
False diagnose	2666	2978	5644	1.787	0.101
	3.33%	3.72%	3.53%		
True diagnose	77,334	77,022	154,356		
	96.67%	96.28%	96.47%		
Impacted teeth					
False diagnose	418	405	823	0.206	0.650
	0.52%	0.51%	0.51%		
True diagnose	79,582	79,595	159,177		
	99.48%	99.49%	99.49%		
Crown					
False diagnose	2309	2168	4477	0.456	0.451
	2.89%	2.71%	2.80%		
True diagnose	77,691	77,832	155,523		
	97.11%	97.29%	97.20%		
Apical lesion					
False diagnose	1842	1881	3723	0.418	0.518
	2.30%	2.35%	2.33%		
True diagnose	78,158	78,119	156,277		
	97.70%	97.65%	97.67%		
Periodontal loss					
False diagnose	10,129	5537	15,666	149.097	0.001*
	12.66%	6.92%	9.79%		
True diagnose	69,871	74,463	144,334		
	87.34%	93.08%	90.21%		

* = indicate the statistically significant difference ($p < 0.05$).

extractions, root canal-treated teeth, periodontal loss, apical lesions, and crowns using panoramic radiographs than the 4DS and 5DS. For this reason, the null hypothesis was rejected. The results of the present study also demonstrated that the correct identification of caries and fillings were significantly different in AI than in the other groups. Since the interpretation of enamel and dentin losses on radiography in the diagnosis of caries varies according to clinicians,

a significant difference was observed between the AI and student groups in the study, and it can be thought that the diagnosis of caries was correlated with the experience of the clinicians.[11] Some studies have shown that AI can improve caries detection and is more sensitive than dentists.[12–16] The outcomes of this study were consistent with those of previous research.

Diagnosis of periapical pathologies generally varies depending on the skill and experience of clinicians. It is very important to distinguish these lesions on radiographs with AI support to eliminate them and prevent incorrect or missed diagnoses.[3] The accuracy of using AI-supported programs in periapical lesion's identification varies depending on the variety of imaging techniques. The highest percentage of these diagnoses with AI is made when examining radiographs taken with cone beam computed tomography (CBCT),[17–19] followed by periapical[20] and panoramic radiographs.[21,22] Ekert et al.[21] evaluated panoramic radiographs and reported that AI was sensitive to lesion's identification and facilitated the time taken by clinicians to make a diagnosis. Orhan et al.[19] reported that the AI model they used with CBCT in their study successfully detected 142 out of 153 teeth that had periapical lesions. The superior imaging capabilities of CBCT compared to panoramic radiographs may explain the higher sensitivity of the AI tool in CBCT analyses.

The present study found that both AI and the students were able to correctly identification of apical lesions at a high percentage and that there was no significant difference between the groups. It is possible that the similarity in the results between these groups was due to the random selection of panoramic radiographs that were not classified according to the size of the lesions. Today, panoramic radiography is still routinely used in the first examination, and panoramic radiography is still used for diagnosis in the first examination in our faculty. Periapical and panoramic radiographs are both limited by inherent factors, including superimposition of anatomical structures, geometrical distortion, anatomical noise, and a two-dimensional representation. Studies showed that panoramic radiographs showed low sensitivity to detecting periapical lesions.[23,24] CBCT overcomes the limitations of panoramic radiographic imaging by providing accurate insights into the multiplanar details of the tooth and bony structures, But it is not used as a routine diagnostic tool in clinics for excessive radiation exposure. Although CBCT has superior features than panoramic radiography, there are still concerns about false-positive results in diagnosing periapical lesions.[25]

Furthermore, a periapical lesion must reach 30%–50% bone mineral loss before it becomes radiographically visible[26] and its visibility depends on the lesion of size. Since these lesions present as specific images on the radiographs and the ability to diagnose become easier as the size increases, there was no difference between the groups in terms of diagnosing lesions.

Artificial intelligence (AI) increases quality efficiency in healthcare services and reduces costs and human/system errors.[6] Additionally, advantages such as saving time, automating, and standardizing many manual and skill-requiring tasks, and reducing workload have also been reported.[6] On the other hand, it also has disadvantages such as the engineers developing the algorithm not having sufficient medical knowledge, the radiologist who will use the algorithm not knowing the subject, requiring multidisciplinary work as it may cause errors due to misuse and interpretation, and requiring a large amount of data for image analysis. Additionally, the sensitivities of AI programs vary depending on the modality.

AI technologies still support and make improvements in dentistry.

Data are frequently locked within systems that are isolated, customized, and only partially interoperable. For AI, the data of each patient are complex, multidimensional, and sensitive. This requires precision in analyzing data and applying triangulation or validation options. For this reason, we preferred to use panoramic radiography, which was previously coded into the AI program and used for diagnosis in our clinic.

The quality of radiographic images may affect the results of any studies.[23] To diagnose some pathological conditions, it is necessary to use specific radiographs (CBCT for lesions, bitewing for caries, etc.) That the current study used one kind of radiograph to detect various types of pathology may constitute a limitation.

AI replacing humans in the field of healthcare may pose a great risk. There may be concerns about data protection and data security and leaving critical medical decisions to computers.[27] AI may demonstrate excellent results in diagnosis but may experiences difficulties in clinical situations that the human brain is better able to relate to, so clinicians should reinforce the diagnoses made through physical examinations and anamneses. There is a large number of studies about students' perceptions and attitudes toward AI, but no studies exist regarding the use of AI by dentistry students.[28,29] The quality of students' educational outcomes can be enhanced through a basic curriculum that includes the combined use of AI and examination techniques in the diagnosis of oral and dental structures.[30] During the training, AI should not only be programmed to make the correct diagnosis but should also provide students with options that will give them the right information in cases of misdiagnosis.

In the present study, we aimed to compare the performances of AI and undergraduate students in terms of making the accuracy of identification of caries, fillings,

teeth with root canal treatment, periodontal loss, extractions, crowns, teeth with apical lesions, and impacted and extracted teeth. AI showed better results in identifying pathologies than undergraduate students. As a result of our study, even a student who has not entered the clinic can successfully diagnose routine cases through panoramic radiographs as a result of the theoretical and preclinical practical knowledge they receive. In light of this information, further studies could be conducted on whether AI contributes to students' awareness and skills in identifying the condition of teeth through dental radiographs and whether these contributions can improve how students learn. In the early stages of the education process, multidisciplinary cases that will increase students' perception levels and AI-supported simulation models (e.g., VR models) can be created. Unlike the current narrow AI system that only solves specific tasks, embodied AI should aim to solve complex tasks similar to humans. Super AI of the future can be created by combining natural cognition, ChatCPT, open AI applications, image processing, and AI applications. These approaches can lead to new learning models. We think that these practices will make positive contributions to students' learning in their preclinical education.

5 | CONCLUSION

The use of AI could improve undergraduates' accuracy in detecting caries, fillings, and extractions and help them make accurate treatment decisions. In cases where dentistry students are examining patients using panoramic radiographs, employing AI programs during their clinical training to confirm and strengthen the student's diagnosis may be a promising new development.

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CONFLICT OF INTEREST STATEMENT

The authors declare they have no conflicts of interest.

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