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Systematic Review

Knowledge, attitude, and perception/practice towards artificial intelligence among dental students and dental professionals - a systematic review

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ABSTRACT

Artificial intelligence (AI) is a broad term encompassing advanced technologies that aim to mimic human intelligence in computer hardware and software, achieving human-level performance**.** By studying the attitudes and practices of dental professionals and students, we can better integrate AI into the dental field. Hence, the aim is to examine the knowledge, attitudes, and perceptions/practices towards AI among dental students and dental professionals. This study protocol was based on preferred reporting items for overviews of reviews (PRIOR) guidelines. A broad electronic search was carried out in the following databases, such as PubMed, Scopus, Google Scholar, Cochrane database of systematic reviews, and Trip database to find related studies and a total of 28 articles were selected for the systematic review. In this review, the average knowledge percentage among dental students was around 56.9, while dental professionals demonstrated a higher average percentage of 66.42. 82% of postgraduate students showed greater openness to integrating AI at an advanced level of dental education. The review suggests a way for dental students and dental professionals to improve their artificial intelligence understanding and skills.

Keywords: Artificial intelligence, Attitude, Knowledge, Dental students, Dental professionals, Perception

INTRODUCTION

Intelligence can be defined as the capability to acquire knowledge and solve problems. To replicate human intelligence, any system should include three basic types of intelligence: Perceptual intelligence, cognitive intelligence, and decision-making intelligence.[1,2]

Artificial intelligence (AI) is a broad term encompassing advanced technologies that aim to mimic human intelligence in computer hardware and software, achieving human-level performance.[3] AI has its roots in John McCarthy's proposal in 1956 and has since been applied in various fields such as robotics, computer vision, machine learning, and natural language processing.[4] Machine learning (ML) and deep learning (DL) are core technologies of AI. Machine learning involves teaching algorithms to analyze data for patterns, while DL employs complex neural networks to perform intricate tasks.[5]

AI offers significant opportunities and challenges in the healthcare domain. By analyzing extensive medical data, AI can enhance diagnostic accuracy and treatment effectiveness, detecting trends beyond human capability. However, it does have some limitations such as privacy concerns, algorithmic bias, and ethical dilemmas that necessitate a balance between AI and human expertise.[6]

The World Health Organization has cautioned that healthcare professionals must understand how AI works, as they will be using it soon. Using AI incorrectly could result in inaccurate diagnoses that can harm patients. Therefore, healthcare workers must have a clear understanding of the principles and algorithms that

underlie AI technology.[7] Robotic technology significantly enhances oral health and preventive dentistry by managing pain, correcting irregular dentition, and extending tooth lifespan. It also aids in dental education and endodontic procedures.[8]

Dental radiology has also been revolutionized by AI, specifically deep learning, which surpasses human capabilities, improving diagnostic accuracy and efficiency.[9] AI can help with tasks such as outlining cephalometric landmarks, detecting alveolar bone loss, dental caries, and periapical pathosis, analyzing facial growth, and auto-segmenting the inferior alveolar nerve. Furthermore, AI has been used for the screening of oral cancer and cervical lymph node metastasis and in the diagnosis and management planning of several orofacial illnesses.[10]

Salto et al highlight AI as the third revolution in histopathology, integrating it for quantitative cell count and immunohistochemistry marker measurement.[11] AI is being utilized in dental practices to assist periodontists in accurately diagnosing periodontal diseases and detecting oral conditions using convolutional neural networks.[12] The COVID-19 pandemic has accelerated the use of AI for personalized learning, despite concerns about its ethical implications, lack of teacher training, and the high cost of software.[13]

Evaluating both the advantages and ethical considerations of these technological advances is essential. Additionally, it is critical to understand how dental professionals and students feel about AI and how they incorporate it into their work. By studying the attitudes and practices of dental professionals and students, we can better integrate AI into the dental field. This research will enable us to correlate the relationship between dental expertise and AI technologies. As a result, this systematic review was designed to examine the knowledge, attitudes, and perceptions/practices towards AI among dental students and dental professionals.

METHODS

Protocol and registration

This study protocol was based on preferred reporting items for overviews of reviews (PRIOR) guidelines. The protocol of this systematic review was registered in the international prospective register of systematic reviews (PROSPERO) with the registration ID 487689. The first two authors analyzed the studies (RA and BH) and the consensus from the third author (AS) and fourth author (MK) resolved the discrepancies between the first two authors.

Study design and eligibility criteria

A systematic review was conducted based on the research question which includes the PECO statement: population (P): dental students and dental professionals, exposure (E): knowledge, attitude, and perception/practice towards AI, comparison (C): not applicable, and outcome (O): knowledge, attitude, and perception/practice towards AI among dental students and dental professional.

Inclusion criteria

This systematic review included descriptive or observational cross-sectional studies investigating knowledge, attitude, and perception of AI among dental students and professionals, which focused on original articles only in the English language from January 2021 to November 2023.

Exclusion criteria

The knowledge, attitude, and perception/practice among dental students and dental professionals other than artificial intelligence were excluded in this review. Systematic review, umbrella review narrative review, scoping review, and meta-analysis were excluded.

Search strategy

A broad electronic search was carried out in the following databases, such as PubMed, Scopus, Google Scholar, Cochrane database of systematic reviews, and trip database to find related studies. Studies conducted from January 2021 to November 2023 were included, and searches for relevant studies were performed till 30 November 2023. In case any relevant articles were found without full text during the search process, the corresponding authors were contacted through e-mail to retrieve the article. The search strategy conducted through various databases is shown in Table 1.

Study selection

The selection process was primarily done by 3 investigators independently. This was accomplished by having each investigator independently review the study's title and abstract. After the article search was done using the keywords and Boolean operators, the individual studies from each database mentioned above were noted down separately. Subsequently, references to those studies and duplicates were managed using the Zotero software. Within the software, duplicate studies are mentioned and can be easily identified and merged into a single study. The covered studies satisfied the minimum eligibility requirements. A detailed description of the eligible studies is described in the PRISMA flowchart (Figure 1).

The initial search resulted in a total of 3493 articles based on the title search in four different electronic databases namely PubMed, Google Scholar, Cochrane, and Trip database. Out of which PubMed 602 produced, Google Scholar 2371 produced, the Cochrane database yielded 4 articles and Trip database produced 515 articles. Among these results, a total of 2470 articles were eliminated due

to duplication, and 995 were eliminated after reading the abstract and title which was not found to be relevant. Based on the inclusion and exclusion criteria mentioned, a total of 28 articles were selected for the systematic review.

Data extraction

The data extraction for the last twenty-eight articles was performed using a data extraction form. It includes the first author's name, year of publication, aim, objectives, study design, study summary, implications, and benefits of the results (Table 2).

Quality assessment

The final analysis included 28 cross-sectional studies and the quality of the selected articles was assessed using the "modified Newcastle-Ottawa scale for cross-sectional studies". The quality score was based on the following categories: selection, comparability, and outcome. Based on this, the studies with 9–7 points are good, points with 5–6 points are satisfactory studies, and points with 0–4 are unsatisfactory studies (Table 3). The review manager software was used to identify the risk of bias in the selected studies. The risk of bias was categorized as high, unclear, or low (Figures 2 and 3).

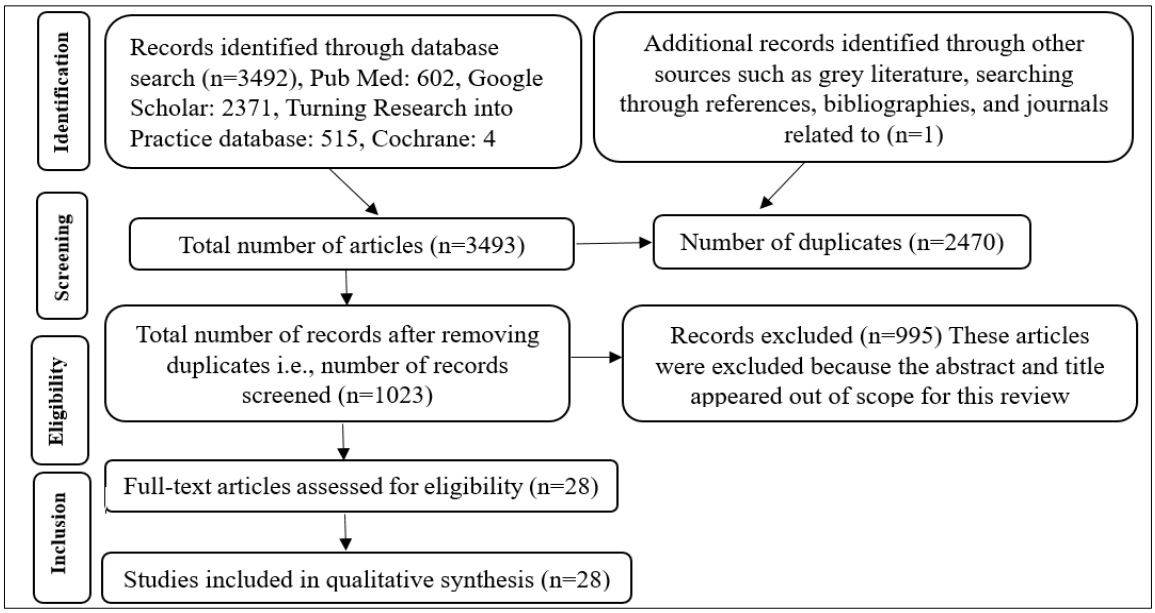

Figure 1: PRISMA flow diagram.

PRISMA: Preferred reporting items for systematic reviews and meta-analysis

Table 1: Summary of search strategy conducted through various databases.

No.	Keyword strings	Results obtained in Google Scholar (G)	Results obtained in PubMed (P)	Results obtained in Cochrane (C)	Results obtained in Trip database (T)	Articles screened from results according to the abstract and from 2021 to 2023 (G+P+C+T)
01	"Artificial intelligence"and "knowledge"and "attitude"and "perception"and "practice" and "dental students" and "dental professionals"	712	0	0	9	721
02	(artificial intelligence) OR (deep learning) OR (machine learning) AND (questionnaire) OR (knowledge) OR (attitude) OR (perception) OR (practice) AND (dental students) AND (dental professionals)	1658	548	0	480	2686
03	Artificial intelligence and questionnaire and dental	01	54	04	26	85
	Total	2371	602	04	515	3492

Table 2: Data extraction table.

S. no.	Author name and year	Objective	Study design	Study population and study setting	Sample size	Outcome
01	Abouzeid et al, 2021[8]	To assess the knowledge, attitude, and perception of dental students, dental school graduates/ interns, and postgraduate dentists regarding the role of robotics and artificial intelligence in oral health and preventive dentistry	An observational, cross-sectional study	Dental students, dental school graduates/interns, postgraduate dentists; King Khalid University, Saudi Arabia	570	The majority of respondents indicated that they possess knowledge, attitude, and perception of R and AI, with affirmative answers being given by 58.3%, 67.4%, and 60.3% of participants, respectively. Respondents expressed agreement that utilizing robotics (R) and AI in dentistry would lead to better outcomes and be beneficial overall. Additionally, most participants (83.3%) stated they would be willing to receive treatment with R/AI. Dentists had positive attitudes but inadequate knowledge of robotics /artificial intelligence. Inclusion in education could increase treatment efficiency.
02	Seram et al, 2021[14]	Attitude and perception of dental students towards AI	Cross-sectional survey	Undergraduate and postgraduate students; Dental Institute of Sri Ganganagar, Rajasthan	279	Almost half of undergraduate students and seventy-seven percent of graduate students stated that they were aware of the applications and usage of artificial intelligence. Regarding the idea of integrating AI in dentistry practice, around 61% of undergraduate students and 71.7% of graduate students received a positive response. It suggested that postgraduate students understood more regarding the potential applications of AI in dentistry; this difference in perception was shown to be statistically significant ($p<0.01$). Postgraduate students showed a higher knowledge of AI's potential in dentistry. Awareness-raising lectures should be organized for dental students.
03	Sajjad et al, 2021[15]	Awareness and perception of dentists regarding the role and future of AI in dentistry	Cross-sectional online survey	House officers, post-graduate trainees, general dental practitioners, and specialist consultant dental surgeons; Jinnah Sindh Medical University, Karachi	118	Out of the 118 participants, which is 83 (70.3%) of them were aware of the presence of AI-powered tools in dentistry. Among these participants, 75.9%, 77.1%, 10.8%, 28.9%, 39.8%, 2.4%, and 10.8% used digital intraoral radiographs, CAD-CAM, CBCT, digital dental records, clinical decision support system, and none of these tools in their dental practice, respectively. All the participants shared the opinion that AI applications should be an integral part of dental training. Most people know AI in dentistry but do not use AI tools in their practice. It is recommended for professionals to attend AI training to implement AI-related changes effectively.
04	Kalaimani et al, 2023[4]	Evaluation of knowledge, attitude, and practice (KAP) of artificial intelligence among dentists and dental students	Cross-sectional online survey	Dentists and dental students; Priyadarshini Dental College and Hospital, Chennai, India	1000	About 63.5% (635) were aware of AI, while 36.5% (365) were unaware, with a p-value of 0.000. Out of the 21 questions used to assess the KAP, 14 questions were significant with a p-value less than 0.05. Over 60% of the participants agreed that the dental curriculum should be updated with AI. 26.9% (269) of the participants agreed that AI will eventually replace the role of dentists. There were no significant differences between dental surgeons and dental students in the study. Dental surgeons and students have

Continued.

S. no.	Author name and year	Objective	Study design	Study population and study setting	Sample size	Outcome
						suggested updating the dental curriculum with AI. However, there is a lack of knowledge about deep learning models and AI websites among dentists.
05	Roganovic et al, 2023[13]	Responsible use of AI in dentistry: survey on dentists and final-year undergraduates perspectives	Cross-sectional online survey	Dentists and final-year undergraduates; School of Dental Medicine, University of Belgrade, Serbia	281	Final-year undergraduates (n=76) participated in a study that revealed their lack of knowledge about AI technology, with only 7.9% of them being familiar with its use. Additionally, the study found that only 34% of them believed that AI should be implemented. Logistic regression analyses were used to identify the underlying reasons for this skepticism which included a fear of being replaced by AI due to a lack of knowledge about the technology, as well as a lack of regulatory policy. The dental community's skepticism towards AI is associated with the lack of education, fear of replacement, and anxiety towards the absence of regulatory policies. There is a need for ethical debate and regulatory policies to ensure the safe and effective integration of AI into dental practice.
06	Ram et al, 2022[16]	Assessment of knowledge and awareness of AI and its uses in dentistry among dental students	Cross-sectional observational online-based study	Dental students; Saveetha University, Chennai, India	100	About 84% of the participants were aware of AI and its uses among dental students. The difference in the result is statistically significant ($p<0.05$). The majority of the participants were aware of artificial intelligence and its uses.
07	Chawla et al, 2023[12]	Knowledge, attitude, and perception regarding artificial intelligence in periodontology	Cross-sectional study	Periodontists; Jawahar Medical Foundation ACPM Dental College, Dhule	207	The survey revealed that 62% of the periodontists knew about AI, but only 24% of them knew about its working principles. Although most respondents agreed with the use of AI in periodontal diagnosis, 69% of them disagreed with its use in predicting clinical attachment loss. According to the survey, 80-82% of the respondents believed that AI should be included in postgraduate training and clinical practice. However, it was found that most periodontists do not use AI for diagnostic or research purposes. In addition, 49% of periodontists felt that AI could not replace them in the future as it does not have better diagnostic accuracy than periodontists. They are interested in using AI for diagnosis and treatment planning. More efforts are needed to educate them for effective implementation and personalized treatment.
08	Singh et al, 2023[17]	Attitude, perception, and barriers of dental professionals towards AI	Cross-sectional study	Undergraduate students, interns, and postgraduates; King George's Medical University, Lucknow, India	927	Social media platforms are the primary source of information about AI for 55.2% of respondents. Basic knowledge about AI in dentistry is possessed by 51.3% of the participants. According to 59.6% of the respondents, AI can be used as a "definitive diagnostic tool" in disease diagnosis. 66.5% of the respondents agreed that AI can be used for radiographic diagnosis of tooth decay. As per 71.3% of the participants, AI can be leveraged as a "treatment planning tool" in dentistry. 55.7% of the respondents expressed that AI should be included in undergraduate dental training. Both dental students

Continued.

S. no.	Author name and year	Objective	Study design	Study population and study setting	Sample size	Outcome
						were positive about AI's efficiency in diagnosis, treatment planning, and managing patient data. They identified a lack of technical resources and training personnel as barriers to the introduction of AI in dentistry
09	Al Samhori et al, 2023[6]	Attitude, awareness, and understanding of AI among medical and dental students in Jordan	Cross-sectional study	Medical and dental students; University of Jordan	800	The survey revealed that 38.8% had a tech family background. 35.0% used social media for AI info. 28.0% believed AI would improve medical diagnosis. Correlation showed a positive link between AI awareness and understanding (r: 0.491, p<0.001). Young medical and dental professionals view AI as a helpful partner and want to learn more about its potential in healthcare. This underscores the need for AI education in medical training.
10	Eschert et al, 2022[9]	A survey on the use of AI by clinicians in dentistry and oral and maxillofacial surgery	Pilot study	Dentists, specialist dentists, and oral and craniomaxillofacial surgeons; Dental Association of Westfalen-Lippe, Germany	1500	The majority of the participants rated their knowledge of AI as average (37.1%), below average (22.2%), or very poor (23.2%). The respondents were largely of the opinion that AI would enhance and bring consistency in diagnostics, with an average Likert score of 3.7±1.27. The most significant concerns included the accountability for machine errors, with a mean score of 3.7±1.3, as well as issues relating to data privacy or security, with an average score of 3.5±1.24, and the delegation of healthcare to large technology corporations with an average score of 3.5±1.28. Experts believe AI will enhance and standardize diagnostics in healthcare, but concerns remain over machine errors, data security, and healthcare being controlled by large tech companies: a recent study, insights into the acceptance of the use of AI in dentistry.
11	Murali et al, 2023[2]	Knowledge, attitude, and perception of dentists regarding the role of AI and its applications in oral medicine and radiology	Cross-sectional study	Dental undergraduate students (third and final years), interns, postgraduate students, faculty, and private practitioners; KLE Vishwanath Katti Institute of Dental Sciences, Belagavi; Saveetha Dental College and Hospital, Chennai	556	Most people were aware of AI (94.13%) and its fundamental principles (73.50%). Participants believed that AI might be utilized as a prognostic (80.65%) and quality control tool (81.30%), along with in forensic dentistry (74.13%), early cancer detection (77.82%), diagnostic and treatment plan formulation (88.47%), and early cancer detection (77.13%). People suggest educating people about AI through lectures, courses, and scientific meetings to increase awareness and understanding.
12	Asmatahasi et al, 2021[18]	Attitude and perception of dental students towards AI	Cross-sectional study	Dental students; Mamata Dental College, Khammam, India	270	Most students (89.63%) were already familiar with the term artificial intelligence, and a significant majority (77.04%) believed that AI would make significant advancements in dentistry. Additionally, a vast majority (89.63%) of the students agreed that AI applications should be included in both undergraduate and postgraduate dental training. Organizing seminars,

Continued.

S. no.	Author name and year	Objective	Study design	Study population and study setting	Sample size	Outcome
						lectures, and workshops for dental students can increase their understanding of AI and its applications in dentistry.
13	Keser et al, 2021[10]	Attitudes, perceptions, and knowledge regarding the future of AI in oral radiology among a group of dental students in Turkey	Online survey	4th and 5th-grade dental students; Marmara University, Istanbul, Turkey	140	Out of the 140 dental students who participated, 60% were already acquainted with the concept of AI. 92.9% of them expressed their desire to use a software/program that can assist in radiological diagnosis, and 37.9% believed that AI would have a future in Turkey. There was no significant difference in the responses of the two grades when it came to questions about the future and role of artificial intelligence in oral radiology ($p>0.05$). AI can analyze medical data and aid in clinical scenarios for diagnosis, treatment, and outcome prediction. As AI technology evolves, future dentists need to better understand it to analyze complex data in dentistry.
14	Elhijazi et al, 2022[19]	AI in dentistry: knowledge and perceptions of Moroccan students	Cross-sectional study	4th and 5th-year dental students; Mohammed VI University of Sciences and Health, Casablanca, Morocco	200	The course improved students' knowledge of AI significantly ($p<0.01$). Before the course, 43.50% and 73.7% of students had no knowledge of AI in general and its application in dentistry, respectively. After the course, 43.18% agreed AI is beneficial in dentistry, 25.37% were concerned about its use, and 44.77% believed ethical considerations are essential. This survey informed about improved knowledge and positive perceptions among dental students, with plans for further research on ethics.
15	Al-Qerem et al, 2023[3]	Exploring knowledge, attitudes, and practices towards AI among health professions students in Jordan	Online questionnaire	Health professionals (medicine/dentistry, pharmacy/pharmd, and others which included nursing and physical therapy); Jordanian health professional students via social media	483	The study found that participants studying medicine/dentistry had lower knowledge and attitude scores compared to those studying Pharm B/Pharm D. Similarly, those studying other medical fields had lower scores compared to those studying Pharm B/Pharm D. Barriers included lack of knowledge, access, time constraints, and curriculum gaps. This study highlights that improvement in medical education with AI topics is crucial as it can help students to be better prepared for AI integration, which is necessary for enhanced patient care and training. This study emphasizes the need to address barriers and harness AI's potential in medical education.
16	Ekici, 2023[20]	AI in oral and maxillofacial surgery: a survey on knowledge and attitudes of intern dental students	Observational survey study	Intern students; Afyonkarahisar Health Sciences University, Turkey	144	Around 29.6% of the students claimed they had a basic understanding of artificial intelligence technologies, while 58.5% were familiar with its use in oral and maxillofacial surgery. The primary sources of information for these students were social media, media, and web browsing. Most students had a positive attitude towards AI and believed it would enhance oral and maxillofacial surgery. However, only 38.2% of the students were worried that AI would replace maxillofacial surgeons in the future. Almost 94.6% of the students expressed their willingness to receive training on AI applications, and an overwhelming 99.3% showed a desire to use AI in oral and maxillofacial practices. Students do not have sufficient knowledge about artificial intelligence but they are interested in learning and using it in their

Continued.

S. no.	Author name and year	Objective	Study design	Study population and study setting	Sample size	Outcome
						work. To prepare future dentists, they should be given opportunities to learn about AI before and after they graduate
17	Karan et al, 2023[1]	Evaluation of attitudes and perception in students about the use of AI in dentistry	Cross-sectional, descriptive, observational study	1st to 5th-year dental students; Dental university students in the metropolitan region of Lima -Peru	163	According to a survey, the majority of students (86%) believe that artificial intelligence will result in significant advancements in the field of dentistry. However, almost half of the participants (45%) do not think that AI will replace dental professionals in the future. The respondents also agreed that the integration of artificial intelligence into dental education should be part of both undergraduate (67%) and postgraduate (72%) studies. The attitudes and perceptions of the students indicate that AI will lead to greater advances in dentistry. this suggests the bright future relationship between dentists and AI
18	Fernades et al, 2022[21]	Knowledge attitude and practice of dental students towards AI	Cross-sectional, descriptive study	1st to 4th-year dental students and interns; Narsinhbhai Patel Dental College and Hospital, Visnagar Siddhpur Dental College and Hospital, Siddhpur	558	According to a survey, the majority of students (86%) believe that AI will result in significant advancements in the field of dentistry. However, almost half of the participants (45%) do not think that AI will replace dental professionals in the future. The respondents also agreed that the integration of AI into dental education should be a part of both undergraduate (67%) and postgraduate (72%) studies. The study found that interns had better knowledge and attitudes towards AI than undergraduate students. To keep up with advancing technology, seminars and workshops on AI systems are needed to help dentists incorporate it into their practices.
19	Hamd et al, 2023[5]	A closer look at the current knowledge and prospects of AI integration in dentistry practice	Cross-sectional study	Academic staff and registered dentists and students in the final years of graduate hospitals, medical centers and universities; Princess Nourah bint Abdulrahman University, Saudi Arabia; University of Sharjah, Sharjah, United Arab Emirates	134	This survey indicated that there was enthusiasm for implementing AI in practice, but only medium to high levels of knowledge, and a lack of education and training programs. This suggests that organizations were not adequately prepared and needed to ensure readiness for AI integration. To improve AI integration in practice, it is essential to make an effort to ensure that professionals and students are ready. Additionally, dental professional societies and educational institutions must work together to develop training programs that can help dentists close their knowledge gaps.
20	Pauwels et al, 2021[22]	Attitude of Brazilian dentists and dental students regarding the future role of AI in oral radiology	Online survey	Participants in seminars (dental students, clinicians, researchers, and professors from local institutions) in 6	293	The majority of participants were dental students studying at the undergraduate level, accounting for 57% of the total. Before the lecture, there was a strong consensus among the participants regarding the different roles that AI can play in oral radiology and its anticipated impact. About one-third of the participants expressed concern regarding AI. However, after the lecture, the agreement regarding the different roles of AI in oral

Continued.

S. no.	Author name and year	Objective	Study design	Study population and study setting	Sample size	Outcome
				different locations in Brazil		radiology increased, overall excitement regarding AI increased, and concerns regarding the potential replacement of oral radiologists decreased. The study found a generally positive attitude toward AI, and the introductory lecture helped ease concerns about the effect of AI on the oral radiology profession. Considering the ongoing revolution of AI-augmented radiology, it is crucial to include AI topics in dental training curricula.
21	Bisda et al, 2021[23]	AI in medicine: a multi-national and multi-center survey on medical and dental students perceptions	Online survey	Medical and dental students from 63 countries	3133	Most students have a good understanding of AI and its current applications, with males, tech-savvy individuals, and students from developed countries having higher levels of agreement. Students see AI as a partner rather than a competitor, believe that it will revolutionize medicine and dentistry, and are eager to incorporate AI into their future practice, with 99% of students expressing their interest.
22	Kalburgi, 2023[24]	A questionnaire study on AI in periodontics	Cross-sectional study	Periodontics postgraduate students (PPG) and dental interns (DI)	127 Dis, 139PP Gs	Out of the total 266 respondents, 47.7% were dental interns, while 52.3% were postgraduate students. The average knowledge score for dental interns and postgraduates was 7.93 and 13.04, respectively. The analysis of the data showed that the knowledge of postgraduates was significantly higher than that of dental interns, with a p value less than 0.01. Therefore, it can be concluded that postgraduate students are more aware and knowledgeable than dental interns, and the integration of AI into academic curricula is increasingly crucial to bridge the knowledge gap between the two groups.
23	Aboalshamat et al, 2022[7]	Medical and dental professionals readiness for AI for Saudi Arabia Vision 2030	Cross-sectional study	Medical or dental students and graduates in Saudi Arabia	334	Using the validated instrument medical artificial intelligence readiness scale (MAIRS), this study indicates low levels of readiness for AI among medical and dental professionals, with most participants scoring 2.26 to 2.76 on a 1-5 scale. Dental professionals had better scores than medical professionals, but gender and qualifications did not affect readiness. Educational institutions and hospitals should include AI training to prepare future professionals for the upcoming AI ecosystem in Saudi Arabia.
24	Indu et al, 2023[11]	Assessment of knowledge, attitude, and practice regarding AI in histopathology: a cross-sectional study among oral pathologists	Cross-sectional study	Postgraduates, faculties, and consultant oral pathologists in India	171	Out of all the pathology specialists in India, only 8.8% have good knowledge, 70.2% have a positive attitude, and merely 4.1% use AI in diagnostic HP. Concerning years of experience, knowledge about AI in pathology significantly increased (p=0.001). In the future, 43.9% of OPs anticipate AI being integrated into HP in India. In conclusion, OPs in India have a favorable attitude towards incorporating AI into their pathology practice. To enable the integration of AI into diagnostic HP and improve its awareness, it is essential to take vital measures in this study.
25	Busch et al, 2023[25]	Medical student's perceptions towards artificial intelligence in education and practice: a	Cross-sectional study	4,313 medical, 205 dentistry, and 78 veterinary students	4594	Most of the students have positive attitudes (67.6%, n=3,091) towards AI in healthcare and want more AI teaching in their curricula. However, they reported limited general knowledge (75.3%, N=3,451) of AI, the absence of AI-related courses, and feeling inadequately prepared to use AI in their

Continued.

S. no.	Author name and year	Objective	Study design	Study population and study setting	Sample size	Outcome
		multinational, multicenter cross-sectional study		from 192 faculties in 48 countries		future careers (57.9%, N=2,652). This study highlights the need for integrating AI teaching into medical education
26	Khanagar et al, 2021[26]	Knowledge, attitudes, and perceptions of dental students towards AI in Riyadh, Saudi Arabia	Cross-sectional study	Dental students	423	In this study, 50.1% of participants lacked knowledge of AI principles, while 55.8% were unaware of AI use in dentistry. Social media was the main source of AI knowledge for 40.9% (n=324). 48.9% (n=207) agreed AI should be a part of postgraduate dental training. Despite low knowledge, participants believed AI would have a significant role in dentistry. To enhance AI knowledge, lectures, courses, and meetings should be offered.
27	Thulasi et al, 2022[27]	Knowledge attitude and practices of dental students and dental practitioners towards AI	Cross-sectional study	Dental students and practitioners across Chennai	200	In this study, about 70% of interns, 78.97% of post-graduates, and 77.95% of dentists with less than five years of experience have basic knowledge about A.I. technologies. The study also found that only 39.5% (with a p value of less than 0.05) agreed that AI has potential applications in medicine and dentistry. Additionally, 53.5% (with a p value of less than 0.05) think that AI cannot replace the role of the dentist in patient management or diagnosis in the near future. The study concludes that better evidence-based teaching and expanded application of AI tools in dental practice are necessary, as most participants recommended including the basic principles of AI in dental curriculums or as value-added courses during clinical training.
28	Baby et al, 2023[28]	Role of robotics and artificial intelligence in oral health education; knowledge, perception, and attitude of dentists in India	Cross-sectional study	Dental professionals	200	According to a study, 82.5% of dental practitioners had knowledge regarding AI, while 11.4% had no knowledge and 6.1% had some knowledge of this tool. 69.1% of the participants were knowledgeable regarding the use of AI in lesional diagnosis, and 71% had knowledge concerning the use of AI for imaging. 54.3% of them had knowledge of AI in oral hygiene, and 91.2% of participants had knowledge of robotics use in oral surgery. 77% of dentists had knowledge regarding the use of AI for the enhancement of clinical practice. Additionally, 95.5% had a positive attitude toward the use of AI in academics, and 69.1% had a positive attitude regarding AI incorporation in practice. However, only 5% of dentists considered AI better than human intelligence for diagnosis, and 10% believed that disparities can exist between AI-based and human diagnosis. The study concludes that while AI can be included in teaching courses in dental education, complete dependence on diagnosis should be restricted, and more research to achieve complete reliability should be done

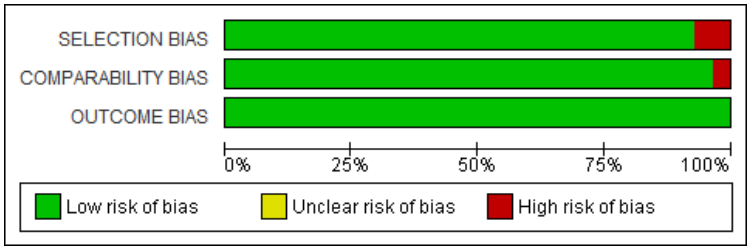

Figure 2: Risk of bias of included articles.

Green – low risk, red – high risk, yellow – unclear

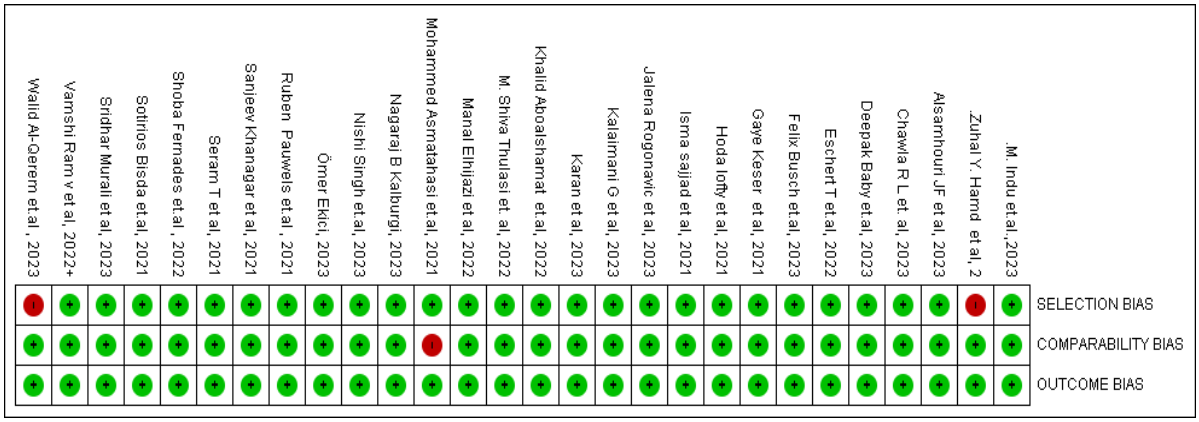

Figure 3: Bias summary of the included articles.

Table 3: Quality evaluation of the articles included: modified New Castle Ottawa scale for cross-sectional studies.

Author name and year	Representat-iveness of sample size (a/b=*) (c/d=-)	Samp-le size (a=*) (b=-)	Non respon-se rate (a=*) (b=-)	Ascertain-ment of exposure (a=**) (b=*) (c=-)	Compa-rability (a=*) (b=-)	Assessm-ent of outcome 1 (a/b/c=*) (d=-)	Outcome 2 (statis-tical test) (a=*) (b=-)	Sco-re
Abouzeid et al, 2021[8]	a*	a*	a*	a**	a*	b**	a*	9
Seram et al, 2021[14]	a*	a*	a*	a**	a*	b**	a*	9
Sajjad et al, 2021[15]	a*	a*	a*	b*	a*	c*	a*	7
Kalaimani et al, 2023[4]	a*	a*	a*	a**	a*	b**	a*	9
Roganovic et al, 2023[13]	a*	a*	a*	a**	a*	b**	a*	9
Ram et al, 2022[16]	a*	a*	a*	b*	a*	c*	a*	7
Chawla et al, 2023[12]	a*	a*	a*	a**	a*	b**	a*	9
Singh et al, 2023[17]	a*	a*	a*	a**	a*	b**	a*	9
Al Samhori et al, 2023[6]	a*	a*	a*	a**	a*	b**	a*	9
Eschert et al, 2022[9]	a*	a*	a*	a**	a*	b**	a*	9
Murali et al, 2023[2]	a*	a*	a*	a**	a*	b**	a*	9
Asmatahasi et al, 2021[18]	a*	a*	a*	b*	a*	c*	a*	7
Keser et al, 2021[10]	a*	a*	a*	a**	a*	b**	a*	9
Elhijazi et al, 2022[19]	a*	a*	a*	b*	a*	c*	a*	7
Al-Qerem et al, 2023[3]	a*	a*	a*	a**	a*	b**	a*	9
Ekici, 2023[20]	a*	a*	a*	a**	a*	b**	a*	9
Karan et al, 2023[1]	a*	a*	a*	a**	a*	b**	a*	9
Fernades et al, 2022[21]	a*	a*	a*	a**	a*	b**	a*	9
Hamd et al, 2023[5]	a*	a*	a*	a**	a*	b**	a*	9
Pauwels et al, 2021[22]	a*	a*	a*	b*	a*	c*	a*	7
Bisda et al, 2021[23]	a*	a*	a*	b*	a*	c*	a*	7
Kalburgi, 2023[24]	a*	a*	a*	b*	a*	c*	a*	7

Continued.

Author name and year	Representat-iveness of sample size (a/b=*) (c/d=-)	Samp-le size (a=*) (b=-)	Non respon-se rate (a=*) (b=-)	Ascertain-ment of exposure (a=**) (b=*) (c=-)	Compa-rability (a=*) (b=-)	Assessm-ent of outcome 1 (a/b/c=*) (d=-)	Outcome 2 (statis-tical test) (a=*) (b=-)	Sco-re
Aboalshamat et al, 2022[7]	a*	a*	a*	a**	a*	b**	a*	9
Indu et al, 2023[11]	a*	a*	a*	a**	a*	b**	a*	9
Busch et al, 2023[25]	a*	a*	a*	a**	a*	b**	a*	9
Khanagar et al, 2021[26]	a*	a*	a*	a**	a*	a**	a*	9
Thulasi et al, 2022[27]	a*	a*	a*	b*	a*	c*	a*	7
Baby et al, 2023[28]	a*	a*	a*	a**	a*	b**	a*	9

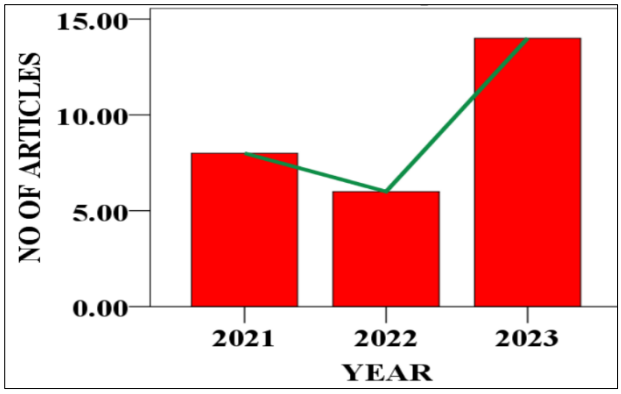

Figure 4: Year-wise representation of the included articles.

RESULTS

This systematic review includes 28 articles exploring the knowledge, attitude, and perception/practice toward AI among dental students and professionals. The findings reveal various viewpoints across various professions (Medical, Dental, and Pharmacy). In the subset of dental professionals, one article focused specifically on general dentists, two on dental specialists, and one on both. Meanwhile, eleven articles focused on dental students, seven specifically on undergraduate dental students, while four articles considered both undergraduate and postgraduate students. Notably, eight articles analyze the combined viewpoints of undergraduate students, postgraduate students, and clinicians. Additionally, three articles focused on medical and dental students together, and one article discusses the broader spectrum of medical, dental, pharmaceutical, and other students (nursing, and physical therapy). Lastly, one article delves into the insights of professionals in both dental and medical fields.

Knowledge of AI varies among students and professions of healthcare sectors in this review. Among dental students, the average knowledge percentage was around 56.9, while dental professionals demonstrated a higher average percentage of 66.42. The AI was 52.8% among medical and dental students, whereas, it was 63.2% among medical and dental professionals interestingly, combined undergraduate and postgraduate dental students had an average knowledge of 66%. However, dental specialists, including oral pathologists and periodontists, had lower knowledge (35.4%).

The opinions on AI varied among the dental community in this review. On average 66.61% of undergraduate and postgraduate dental students believe in AI's promising future in education. 51.21% of undergraduate students are interested in incorporating AI applications into their curriculum, while 82% of postgraduate students showed a greater openness to integrating AI at an advanced level of dental education. On the other hand, dental professionals such as practitioners and specialists expressed greater confidence in the applicability of AI, with an average percentage of about 64.

The majority of people had a favorable attitude towards AI when it came to using it as a diagnostic tool in the field of dentistry. Dental professionals hold a higher level of confidence in AI, with an average perspective of around 65%. However, dental students had a mixed view, with an average perspective of approximately 48%. The study also found that around 62% of oral pathologists possess knowledge about optimizing AI algorithms in conjunction with advanced whole slide imaging platforms. Additionally, 80% of periodontists believe that AI should be incorporated into clinical practices due to its valuable contribution to simplifying the analysis of radiographic images related to periodontal diseases.

Among all reported studies, there are some differences in the responses of dental students and dental professionals. Ram et al found that dental students had higher knowledge (84%) of AI-driven healthcare devices.[16] On the other hand, Khanagar et al reported the percentage (50%) of basic knowledge of AI's working principle among undergraduate dental students and dental interns.[26] Asmatahasin et al found that 89.63% of interns, undergraduate, and postgraduate dental students had awareness of the term AI, which was the highest reported percentage in this group.[18] However, Singh et al found that only 62.8% of undergraduate and postgraduate dental students had knowledge about AI's working principle.[17] Among dentists, Baby et al reported that 82.5% of participants knew about AI, while 62% of dental specialists were aware of AI.[28]

In studies conducted by Karan et al and Khanagar et al around 50% of dental students believed that AI could replace dentists in the future.[1] Whereas in a study done by Asmatahasin et al only 20.74% of students agreed that AI could potentially replace dentists, with the lowest percentage among interns, undergraduate, and postgraduate students.[18] In contrast, Kalburgi et al found that postgraduate students (5.27) scored higher in their favorable attitude towards the future application of AI compared to dental interns (3.19).[24] Among dental professionals, Deepak Baby et al found that 81.2% of practicing dental professionals were in favor of incorporating AI technology in their practice.[28] Similarly, Chawla et al found that 82% of periodontists believed AI should be a part of postgraduate training, and 80% felt that it should be used in clinical practice for ease of radiographic analysis of periodontal diseases and in a study performed by Bisdas et al 52.8% of medical and dental students agreed that they would usually or always incorporate AI in their future practice.[12,23]

Ömer Ekici et al found that 91.7% of undergraduate students and interns believe that AI tools can provide accurate diagnosis, treatment, and patient monitoring.[20] Similarly, Kesar et al reported that 92.9% of participants would like to use software/programs that can assist in radiological diagnosis.[10] However, in Khanagar et al's research, only 37.8% of participants agreed that AI can be useful in diagnosing intra-oral soft tissue lesions.[26] Postgraduate students (96.2%) showed more interest in using software programs for radiological diagnosis than undergraduate students (82.7%), as demonstrated by Seram et al.[14] Lastly, Singh et al thought that 52.28% of undergraduates and 55.04% of postgraduates agreed that AI can be used as a definitive diagnostic tool in diagnosing diseases.[17]

DISCUSSION

AI is a simulation of human intelligence developed in science and engineering. It enables thinking, learning, problem-solving, and decision-making through technological artifacts.[1] ML and DL are core technologies of AI. ML can help clinicians store and analyze medical knowledge and patient data, finding patterns in diagnostic data, improving treatment, discovering new drugs, and precision medicine, and minimizing human error. While Evidence-based dentistry typically requires randomized controlled trials to accomplish its goals, ML can accomplish them more quickly because it uses pre-existing data. However, handling medical data is difficult because there are many different sources of diagnosis, necessitating a substantial amount of training data that might be unavailable or systematically biased. Instead of only increasing the training data, ML models need to have higher-quality data in order to achieve greater precision. Additionally, ML cannot account for differing diagnoses by different clinicians using different data sources.[29] DL enhances algorithmic analysis and learning processes. It outperforms conventional machine learning and reaches higher accuracy in specific areas like face recognition, behavioral recognition, text translation, and medical images.[30]

Introducing AI into the dentistry curriculum

Traditional education models in medical schools can be scattered, ineffective, and expensive due to resources, faculty experience, and learning time. Thus, there are situations when experience-based training limits the training opportunities. Xu suggests that the large language model (LLM) in chatbots may help with preclinical education in the future since they are convenient, cost-effective, and offer rapid data recovery and systematic integration.[31] Baby et al showed that 95.5% of dental personnel agreed to the use of artificial intelligence in academics.[28] But a similar study done by Al Samhori et al found that only 13% of the population utilizes information about AI in universities.[9] Thurzo et al demonstrated that AI can enhance dental education in both theoretical and practical aspects. In theoretical education, AI can analyze patient data, create plans, and simulate scenarios. In practical education, AI can manage patient telemonitoring, provide virtual training, and enhance student assessment.[32] However, Kim et al suggest that dental educators should incorporate critical thinking skills into AI curricula to help students properly interpret data and intentionally create visual predictions before referring to AI in order to prevent proxy errors. Data security, privacy, as well as potential third-party intervention are all important to be covered in curricula. Thus, maintaining academic integrity is essential when integrating AI into curricula, necessitating explicit rules about plagiarism, referencing, and citation.[33]

Importance of AI integration in dental educational programs

Faculty play a crucial role in curriculum development and evaluation, and institutional administrations plan and design faculty development activities. However, the dental teaching workforce in India lacks formal training in teaching methods and technologies during postgraduation training. Regular faculty development programs (FDPs) can offer promising results for training faculty and improve academic performance in healthcare institutions. Incorporating FDPs could lead to future health profession courses and education, enriching learners' knowledge and skills.[34] Chawla et al noticed that 82% of periodontists believe AI should be included in postgraduate training, however, Indu et al observed that only 39.6% of oral pathologists had a basic knowledge of the application of AI in pathology practice.[11] According to Sharma et al, dentistry graduates need more training in AI technologies, including computer and software engineering, data extraction, and statistical concepts, to use AI in healthcare effectively. The patient safety and well-informed decision-making depend strongly on the digitalization of healthcare, especially electronic health records (EHRs). They recommend that graduates receive the required training in order to use EHRs in clinics and institutions. Shifts to the

program could improve dental knowledge even more in a data-rich environment, encouraging participatory, personalized, predictive, and preventive dentistry.[35]

Integrating AI into dental practice procedures

According to Alam et al, AI has enormous potential for application in dental imaging. AI can achieve very high levels of accuracy in tasks like bone segmentation, caries detection, and tooth segmentation, exceeding what can be done with conventional methods. They predicted that, in order to improve both the accuracy and efficiency of dental diagnoses and treatment planning, dental professionals will probably use more AI-driven tools and applications in their daily work.[36] A study by Ekici et al reported that 91.7% of undergraduate students believed AI tools increased diagnosis, treatment planning, and emergency tele-assistance, AI-based virtual dental assistants improve clinic efficiency, reduce errors, and reduce the workforce.[20] Baby et al found that 81.2% of dental professionals support the integration of artificial intelligence technology in their practice.[28] Ding et al highlight the use of AI in various fields, including operative dentistry, periodontics, and oral and maxillofacial pathology, for diagnosing dental caries, root fractures, periodontitis, and tumors, and in orthodontics for predicting and planning treatments based on skeletal patterns and anatomic landmarks and in prosthodontics for crown preparations, shade matching, and dental arch classification.[30] In her review, Tiwari et al investigated the possible applications of ChatGPT in public dental health education, clinical practice, research, and academic writing. They understood that ChatGPT's concept and uniqueness are based on the activity of the human brain highlighting its possible importance in the dental field. Diagnosing dental caries is essential to the effective application of treatment.[37] An improved YOLOv7-AP-CBAM model has been proposed by Ayhan et al for precise tooth detection, numbering, and caries detection in bitewing radiographs.[38]

AI's ethical challenges in the dental field

In the review of Mörch et al, 45 ethical issues about the use of AI in dentistry were reported in 22 studies. The issues focused on six principles: responsibility, democracy, privacy, equity, and solidarity.[39] According to Duggal et al, modern healthcare technology raises various ethical issues such as informed consent, patient rights, transparency, consumer rights, and satisfactory performance under different conditions. Transparency should be ensured by developer, and patients should have the ability to view, edit, and remove their data, and stakeholders should have simple access to technological requirements. Legal and regulatory measures should be implemented, and conflicts of interest should be declared. There should be a strong system in place to track and assess the security and operational performance of AI technology. It's also essential to carefully integrate AI applications in dentistry.[40]

The integration of AI into dental education and practice is an important milestone to improve the effectiveness and precision of diagnosis and treatment planning in the dental field. Using machine learning and deep learning technology advancements can change dental clinical practices and teaching methods. Dental professionals need to get proper education and training to learn how to use AI tools and apps efficiently. Prioritizing privacy, ensuring data security, and prioritizing ethical issues are all necessary for the proper use of AI in dentistry. Dental practitioners may reduce risks and take all the advantages of AI by taking this action.

AI has been more effective throughout COVID and has introduced innovation into dentistry, all of which have been crucial in reaching patients. Many AI apps have been released both during and after COVID, opening the door for a plethora of research projects. In view of this, the post-COVID articles, or those published between 2021 and 2023, were taken into consideration for this review.

CONCLUSION

Evidence from this review indicates that the dental students and dental professionals had a positive attitude, and positive perceptions but the majority of them had average knowledge about AI. The review suggests a way for dental students and dental professionals to improve their artificial intelligence understanding and skills. Improvements that prioritize knowledge management and the efficient application of AI technology are needed. Most institutions try to incorporate the dental and continuing education training required for successful AI integration. Clinical results and decision-making can be improved by developing ethical competency in AI-based dentistry education, training, clinical practice, and research. It is important to introduce dental professionals and students to the use of these tools so they can incorporate them into their future practices.

Recommendations

Further intervention-based research is needed to know the levels of knowledge on AI and its practical applications among dental professionals and dental students.

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