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Exploring dental faculty awareness, knowledge, and attitudes toward AI integration in education and practice: a mixed-method study

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Abstract

Background Dentistry is shifting from traditional to digital practices owing to the rapid development of "artificial intelligence" (AI) technology in healthcare systems. The dental curriculum lacks the integration of emerging technologies such as AI, which could prepare students for the evolving demands of modern dental practice. This study aimed to assess dental faculty members' knowledge, awareness, and attitudes toward AI and provide consensus-based recommendations for increasing the adoption of AI in dental education and dental practice.

Method This mixed-method study was conducted via a modified version of the General Attitudes toward Artificial Intelligence Scale (GAAIS) and Focus Group Discussions (FGD). Four hundred faculty members from both public and private dental colleges in Pakistan participated. The quantitative data were analyzed using SPSS version 23. Otter.ai was used to transcribe the data, followed by thematic analysis to generate codes, themes, and subthemes.

Results The majority of the faculty members was aware of the application of AI in daily life and learned about AI mainly from their colleagues and social media. Fewer than 20% of faculty members were aware of terms such as machine learning and deep learning. 81% of the participants acknowledged the need for and limited opportunities to learn about AI. Overall, the dental faculty demonstrated a generally positive attitude toward AI, with a mean score of 3.5 (SD ± 0.61). The benefits of AI in dentistry, the role of AI in dental education and research, and barriers to AI adoption and recommendations for AI integration in dentistry were the main themes identified from the FGD.

Conclusions The dental faculty members showed general awareness and positive attitudes toward AI; however, their knowledge regarding advanced AI concepts such as machine learning and deep learning was limited. The major barriers identified in AI adoption are financial constraints, a lack of AI training, and ethical concerns for data management and academics. There is a need for targeted education initiatives, interdisciplinary and multi-institutional collaborations, the promotion of local manufacturing of such technologies, and robust policy initiatives by the governing body.

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Keywords Artificial intelligence, Dental education, Dental faculty, Knowledge, Awareness, Attitudes

Background

Artificial intelligence (AI) is a rapidly progressing field in computer science that focuses mainly on the automation of intelligent behavior [1]. In recent years, AI technology has advanced significantly with the development of machine learning (ML), which enables computers to learn from data and improve over time; artificial neural networks (ANNs), which act as artificial neurons and process data to make predications; and deep learning (DL), which involves deep neural networks (ANNs with many layers) to handle complex tasks like image recognition or natural language processing [1, 2]. These are also now the most commonly used AI technologies in dentistry [1, 3]. These systems have emerged from technological developments, the availability of data, and enhanced computation capability [1].

Dentistry is shifting from traditional practices to digital practices owing to the rapid development of AI technology in dental healthcare systems [1–5]. For instance, AI algorithms are now being used to interpret dental radiographs and CBCTs with high precision, to identify complex root canal anatomies, and to identify pathologies such as cavities, fractures, periodontal diseases, and even tumors that may not be visible to the human eye [6, 7]. In orthodontics, AI is now assisting in record keeping, diagnosis, patient management, treatment planning, and the design of personalized aligners [2]. In restorative dentistry, through computer-aided design and manufacturing (CAD/CAM) systems, AI helps optimize the design of dental prosthetics and the implant position [5]. This technological revolution places an additional burden on dental institutions and educators, challenging them to understand and effectively incorporate these technological advances into the syllabus for their students so that they can thrive and navigate the AI-driven digital healthcare environment [8, 9]. Although AI is being used in various universities worldwide, there is still a lack of dental education-specific guidelines to be adopted by dental institutions [10]. Moreover, recent published literature also highlights the lack of optimum training, awareness, and guidelines regarding the ethical use of AI among the dental fraternity [11–16].

Although the dental curriculum is robust in teaching basic and clinical science, it lacks the integration of emerging technologies such as AI in a comprehensive manner that prepares students for the evolving demands of modern dental practice [4, 9]. Without adequate training, dental graduates may find themselves underprepared for a workforce that increasingly relies on digital proficiency [17]. Recently, few experts in digital health, including AI and dental education, have identified the key domains to incorporate AI in the core dental curriculum of dentistry at both undergraduate and postgraduate levels [8]. In Pakistan, around 3700 dentists graduate from various dental colleges annually and provide their services both locally and internationally [18]. Therefore, it is crucial to regularly update the national dental curriculum to bring it on par with the global contemporary requirements and latest technologies, including AI.

The rapid development of AI technology makes it essential for dental faculty to be well-versed in AI and its ethical use, and therefore necessitates their formal or informal training [14]. Faculty members who are proficient in AI will be better equipped to utilize AI-based tools for students' education. Moreover, learning about new technology will cultivate a culture of lifelong learning among the educators and will ensure that they are at the forefront of technological innovation, thus setting a standard for excellence in both teaching and practice [10]. However, despite the growing presence of AI in dentistry, there has been limited research on how educators, particularly in developing countries with resource constraints, perceive and engage with AI [12, 13, 19].

Understanding dental faculty members' knowledge, perceptions, and attitudes toward AI is crucial for identifying potential barriers and opportunities for the effective adoption of AI in dental education and practice [11, 13–16, 19]. Moreover, this insight is compulsory for developing targeted educational initiatives, training programs, and policies that facilitate the successful integration of AI technologies into the dental curriculum and clinical workflow. Such initiatives are especially relevant in the developing world, where careful planning and best utilization of resources are critical for keeping up with global advancement in dental education and healthcare provision. Therefore, the aim of this study was to assess dental faculty members' knowledge, awareness, and attitudes toward AI in different dental colleges of Pakistan and provide consensus-based recommendations for increasing the adoption of AI in dental education and dental practice.

Methods

Study design and setting

This study employed a sequential mixed-method explanatory study design. The quantitative phase aimed to assess dental faculty members' knowledge, awareness, and attitudes toward AI by using the modified General Attitudes toward Artificial Intelligence Scale (GAAIS) [20], utilizing the recommended guidelines [21]. This was followed by a qualitative phase of the study [22] to provide recommendations for AI adoption in dental

education. Ethical approval for the study was obtained from the Ethics Committee of Shifa College of Dentistry, Islamabad (Reference number SCD-2023/06). Written informed consent was obtained from all the participants during each phase of the study. The study was conducted over a period of 9 months from July 2023 to March 2024.

Study participants and sampling

For the quantitative part of the study, purposive sampling was utilized to select a panel of 7 dental educationists who were well-versed with AI to establish the content validity of the modified GAAIS questionnaire [20]. In the next step, dental faculty members all over the country were requested to participate in the survey on the basis of the validated modified GAAIS questionnaire. The anticipated sample size (n) for the survey was a minimum of 385, which was calculated by using Andrew Fisher's formula ($n = Z^2P(1\text{-}P)/d^2$), with a Z-score of 1.96 for a confidence level of 95%, $P = 0.5$ (estimated proportion of population), and a $d = 0.05$ (5% margin of error). A stratified random sampling technique was employed to ensure equal participation of faculty members of private and government dental colleges from all regions of the country. Part-time or visiting faculty members were excluded from this study.

For the qualitative data, purposive sampling was employed. Focal group discussion (FGD) was conducted, comprising 10 participants, ensuring equal representation of gender, working domain, and professional qualifications. Invitations were sent through professional networks, ensuring diversity in the discussion. Priority was given to faculty members who expressed interest or had more exposure to AI in the field.

Data collection tool and procedure

Quantitative phase

The quantitative data were collected via a modified version of the General Attitudes Toward Artificial Intelligence Scale (GAAIS) [20]. Explicit permission to use the GAAIS was obtained from the original authors. The original questionnaire was modified, and questions were added to assess knowledge, awareness, and attitudes toward AI among dental faculty members. The content validity of the modified GAAIS questionnaire was obtained by calculating the content validity index of the items (I-CVI) as well as that of the modified scale (S-CVI) [23]. The experts rated the relevance of each item via a 4-point Likert scale ranging from 1 = not relevant to 4 = highly relevant.

This closed-ended survey questionnaire (Supplemental file; Annexure A) was divided into three sections. The first section collected demographic information such as age, gender, qualifications, workplace, and working domain. The second section focused on knowledge and awareness of AI applications in dentistry and included 8 items, each with different scoring criteria (yes/no, yes/no/somewhat, or categorical options). The third section was a modified version of the GAAIS, with 26 items in total (after establishment of a content validity index), with 15 items forming a positive subscale and 11 items forming a negative subscale. Responses from the modified GAAIS tool were scored on a five-point Likert scale: for positive statements, the score ranged from 1 (Strongly Disagree) to 5 (Strongly Agree), whereas for negative statements, the score was reversed.

The questionnaire via Google Forms was distributed from July-Dec 2023, among the targeted participants across the country via an online link through email and WhatsApp messages through the institutional and professional networks to ensure targeted participation. Participation in the survey was voluntary, and no financial or material incentives were offered. To ensure unique responses, and prevent multiple entries the participants were required to log in with their emails. The Google Forms built-in setting to limit the response to one per email address and a custom Google Apps Script were used, which temporarily recorded the respondent's email address at the backend without including it in the final dataset, thus maintaining anonymity. Reminders were sent after 2 weeks to ensure a high response rate. The participants were allowed to review and revise the responses before submission. Moreover, all the questions were set for mandatory response before submission. Therefore, incomplete responses were not accepted by the system.

Data analysis

For content validity, ratings of 3 or 4 were recorded as "1", and ratings of 1 or 2 were recorded as "0". The number of experts in the agreement was divided by the total number of experts to calculate the I-CVI. The average CVI score across all the items was the S-CVI of the entire scale. A CVI > 0.8 was considered good/adequate, and the items were retained. The survey data were entered and analyzed using IBM SPSS Statistics (version 23, IBM Corp., USA). The normality of the data was checked with the Kolmogorov–Smirnoff and Shapiro–Wilk tests. For Sects. 1 & 2, descriptive statistics, including frequencies and percentages, were calculated for all variables related to demographics and knowledge and awareness. For Sect. 3, attitudes were measured via a modified scale, and the means and SDs were calculated. Higher values on both the negative and positive subscales indicate more positive attitudes toward AI. The Cronbach's alpha value was calculated to determine the reliability of the modified questionnaire (acceptable > 0.5, good > 0.7, and excellent > 0.9). The Mann–Whitney U test was used to compare differences in attitudes based on gender, workplace, and working domain, whereas the Kruskal–Wallis

test was applied for comparisons across differences in attitudes on the basis of age groups. The significance level was set at a p-value of ≤ 0.05.

Qualitative phase

A semi-structured format was used for focus group discussion. The results of the quantitative phase formed the basis of the pre-structured questions used to start the discussion (Supplemental file, Annexure B). The FGD was conducted online on Zoom and continued over a period of 35–45 min. It was audio recorded after permission from the participants. The FGD was conducted by a trained moderator in the presence of two researchers to facilitate active participation and maintain a focus on the research objectives.

Data analysis

The data were transcribed via the Otter online application (otter.ai). The thematic analysis of the transcribed data was conducted following Braun and Clarke's six-step framework [24]. Initially, the transcribed data from the focus group discussion were read repeatedly for familiarization by two authors. Utilizing an inductive approach, the initial codes were generated manually by identifying meaningful segments of text relevant to the study objectives. Both researchers coded the transcript independently to reduce bias and ensure reliability. Discrepancies between the two transcripts were resolved via discussion. From the consolidated codes, potential subthemes were grouped based on conceptual similarity, and overarching themes were developed to represent broader categories. The final thematic structure was reviewed and validated by two other co-authors to enhance credibility and confirmability.

Results

Quantitative phase

The content validity of the modified questionnaire was established with the S-CVI = 0.82 of the scale and an I-CVI of all items above 0.8 except for two items (0.62 & 0.7) that were excluded from the questionnaire, so the final questionnaire for measuring attitudes towards AI had 26 items in total. For the survey, out of 1026 survey forms shared with the participants, a total of 400 responses were received from faculty members of private and government dental colleges till Dec 2023, resulting in a response rate of 38.9%.

The Kolmogorov–Smirnoff and Shapiro–Wilk tests revealed that the data were not normally distributed (p-value < 0.05). The majority of the respondents were female, accounting for 58% (232 participants); moreover, a significant portion of the participants, 63.7% ($n = 255$), were from clinical departments. The details of the demographic data of the study population are given in Fig. 1 (Supplemental file; Annexure C: Demographic summary Table).

The findings concerning the knowledge and awareness of AI among dental faculty members are summarized in Table 1. This indicates that majority of the (74%) participants were aware of AI applications in daily life and were also utilizing AI-based programs/applications (66.2%) in their professional work. A substantial number of the dental faculty learned about AI through professional discussions or colleagues (46%) and social media (41%).

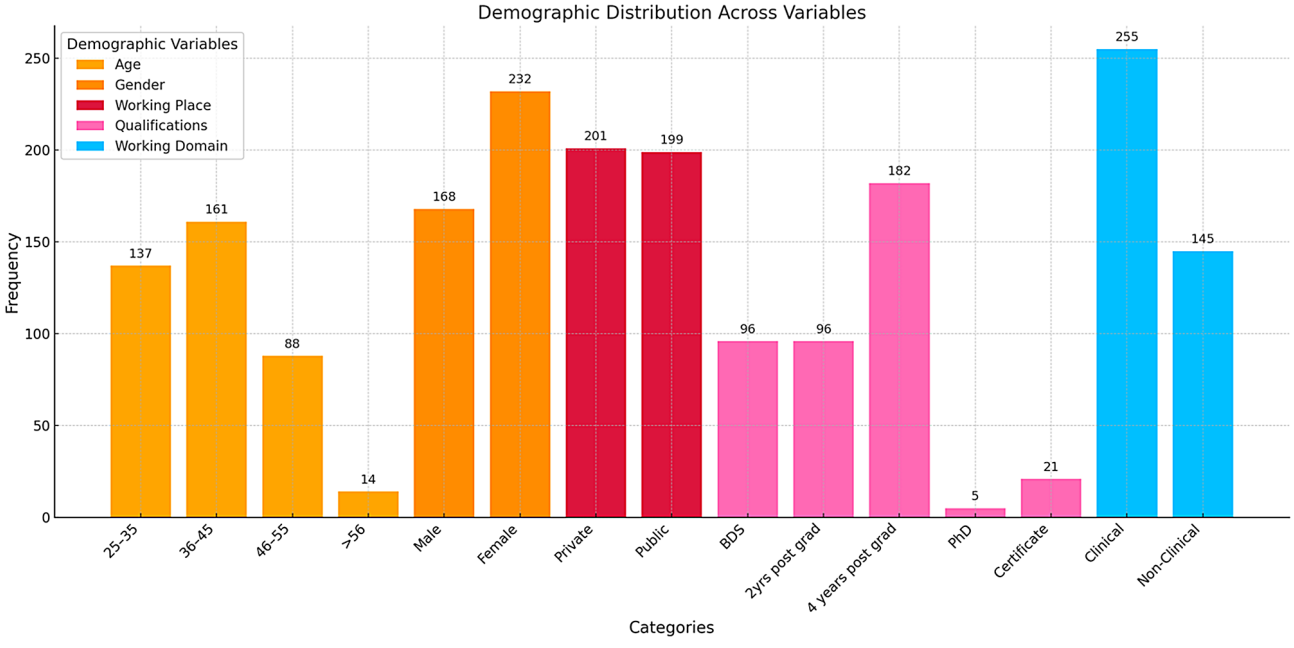

Fig. 1 Frequencies of demographic variables

Table 1 Knowledge and awareness of AI

Questions	Options	Frequency	Percentage
AI applications are widely used in daily life. Are you aware of these applications?	Yes	296	74.0
	No	104	26.0
How many applications of AI have you come across in your work?	None	135	33.8
	1–2	81	20.2
	3 or more	184	46.0
From where have you learned about AI?	media/social media	166	41.5
	From professional talks/colleagues	183	45.8
	friends/family	51	12.8
To update my knowledge of AI	I don't feel the need to learn much about AI despite the opportunities	75	18.8
	I do feel the need to learn but don't see many opportunities to learn about it.	325	81.2
Are you familiar with the terms Machine Learning and Deep learning	Yes	66	16.5
	Somewhat	89	22.25
	No	245	61.25
Are you familiar with the differences between ML &DL?	Yes	54	13.5
	Somewhat	53	13.25
	No	293	73.25
Expected time in which AI will impact career	in 5–9 years	92	23.0
	in 10–15 years	163	40.8
	in 16–20 years	79	19.8
	in 21–25 years	66	16.5
To learn about AI, what level of education you would like to take?	A Full day workshop	82	20.5
	Multiple workshop series	212	53.0
	Graduate-level education	38	9.5
	Masters in AI	68	17.0

However, the majority of the participants (81%) agreed that opportunities to learn about AI were limited.

With respect to the awareness of the terms machine learning (ML) and deep learning (DL), only 16.5% of the participants were familiar with them, and only 13.5% could differentiate between them. When asked about their preferred mode of education for learning AI, 53% (212 participants) favored multiple workshop series over other options. Approximately 40.8% (163 participants) of the dental faculty believed that AI would impact their careers in the next 10–15 years, whereas 23% (92 participants) thought that it would take 5–9 years. Tables 2 and 3 show the means and SDs of individual positive and negative GAAIS scale items, respectively. Overall, the dental faculty demonstrated a generally positive attitude toward AI, with a mean score of 3.52 (SD ± 0.36) for positive GAAIS and a slightly higher mean score of 3.65 (SD ± 0.35) for negative GAAIS. The reliability analysis revealed a Cronbach's alpha value of 0.61, which was considered acceptable.

Table 2 Means and SDs of positive GAAIS scale items

Positive scale Items	Mean	SD
Healthcare professionals should learn the fundamentals of AI	3.90	1.41
I am aware of the ethical implications of AI use in my field	3.87	0.73
I am optimistic about AI's role in my field	4.16	1.21
Artificial intelligence will transform the dental industry	4.12	0.70
Medical education should include AI.	3.88	1.43
AI developments will make dentistry, more exciting	2.71	0.96
AI is very helpful for the wellbeing	2.73	0.86
AI can perform better than a human being	3.24	0.88
Machines with AI are sometimes more efficient than people	2.32	1.00
I am using AI in my clinical work	3.41	0.93
I will happily invest in an AI system for my clinical work	3.01	0.97
AI has the potential to improve people's lives.	3.51	0.67
A future filled with AI will benefit a large portion of society	3.55	0.98
(AI)/CAD in health care will Reduce dentists' workloads	2.89	1.21
AI)/CAD in health care Will improve patient health care/management	3.18	1.15

Table 3 Means and SDs of the negative GAAIS scale items

Negative scale Items	Mean	SD
I am concerned about AI's role in my field.	4.22	0.71
I believe AI is a technology that must be carefully managed	4.04	0.85
My career is in danger due to AI technology	4.00	0.75
Soon AI will likely displace some human dentists, which scares me	3.98	0.73
AI will threaten the job security of people	2.64	0.90
AI is more dangerous than beneficial	3.84	0.60
People are being spied on using artificial intelligence.	3.92	1.38
I believe that AI systems make numerous mistakes.	2.55	0.84
I think there may be serious privacy issues with the use of AI?	3.75	0.99
(AI)/CAD in health care will deteriorate dentists' skills	3.49	1.31
People like me, will suffer as AI becomes more prevalent	3.68	0.85

The Mann–Whitney test revealed no significant difference in the attitudes of faculty members toward AI based on gender, workplace, or working domain ($p = 0.881$, 0.163, and 0.149 for negative GAAIS and $p = 0.824$, 0.653, and 0.868 for positive GAAIS, respectively) (Supplementary file; Annexure D: Table 1s). However, the Kruskal–Wallis test revealed a significant difference in attitudes toward AI in response to positive GAAIS statements across age groups ($p = 0.002$*) but no difference for negative GAAIS statements ($p = 0.090$) (Supplementary file; Annexure D: Tables 2s & 4s respectively). For positive

Table 4 Thematic analysis of the focus group discussion

Themes	Subthemes	Quotes
Benefits of AI in Dentistry	• Improved patient-centered care	*" by using data management tools like Dolphin in orthodontics, we can predict treatment outcomes, along with that streamline patient progress, identify the errors in treatment and modify the treatment mechanics"*
	• Enhanced diagnostic accuracy	*" the advanced imaging and predictive analysis are making revolution by diagnosis of precancerous lesions"* *" AI based programs make radiological diagnosis and analysis much more easy as compare to traditional methods"* *"AI based programs are utilizing data for forensic diagnosis as well"*
	• Assistance in treatment planning	*" using dental scanner for digital images and planning dental implants position on a AI based 3D software makes the treatment planning more convenient for us"*
	• Workflow assistance	*" if my appointment are automatically scheduled and patient data is maintained I will more time to invest on my patients"*
AI Assistance in Dental Education	• Incorporation of virtual reality, augmented reality and robotics based application for clinical learning	*" by using AI based programs that effectively simulate clinical scenarios our students can have firsthand experience with the fear of harming he patient"* *"Well! the good part is that these applications provide instant feedback, so student can improve their clinical practice"*
	• Assistance in student evaluation	*"AI based simulated scenarios can be effectively used in Objective structured clinical examinations (OSCEs)"*
	• AI applications for teaching and learning assistance	*" many of us are utilizing the AI based application to make the presentations and lesson plan for the students, it saves our time"* *"if students utilize these applications correctly, instead of just copy and pasting, they can use them as their study partners"*
AI and Research and Development	• AI as a research tool	*" AI tools for statistical analysis and citation manager can help student in research so that they can shift their focus from manual task on critical thinking and analysis"* *"AI tools can make the literature review much quicker and precise"*
	• Innovations in AI for dentistry	*" promoting and funding AI based project for innovation in dentistry can be fruitful for the patients locally as well as internationally"*
Barriers to AI Adoption	• Lack of faculty awareness and training	*" many of our faculty members are still unaware of the AI advances and definitely require training and guidance for their use"*
	• Financial and technical constrains	*"Most of the AI tools are not free, moreover data management systems like Dolphin and 3D CAD-CAM programs are quite expensive to afford in developing countries like ours"*
	• Ethical and legal concerns	*"Too much reliance of students on AI for learning or research can lead to lack of development of critical thinking and problem solving skills"* *"I am unsure if there are any guidelines that exist in terms of data protection when utilizing AI systems"*
Recommendations for AI Integration in Dentistry and Dental Education	• Integration of AI in dental Curriculum	*"Incorporation of module/courses of AI for undergraduates/graduates will ensure adoption of AI in dentistry in the future"* *"Students should be guided to use AI responsibly, as it cannot replace fundamental research skills"*
	• Training and capacity building of faculty/dental graduates	*"Basic digital skills are necessary for more advanced AI skills"* *"Affordable workshops should be offered more often by the institutions and organizations with the available resources to overcome the technical constrains faced by dentists during practice"*
	• Infrastructure development	*"We need resources allocations for CAD-CAM systems, diagnostic systems or VR simulators"* *"Support from government or international organizations can help to the acquire AI advance tools in key healthcare units"*
	• AI based public health care initiatives	*" due to availability of smartphones, AI based applications can play a major role in community dental health awareness, education and disease prevention"*
	• Interdisciplinary collaborations	*"Research collaborations should be ensured between dentistry, computer science, and engineering students so that we can help develop our own AI programs and applications"*

statements, post-hoc pairwise comparisons for age groups with Bonferroni correction revealed more positive attitudes toward AI (adjusted $p = 0.006$*) for group 2 (36–45 years) than for age group 1 (25–35 years) (Supplementary file; Annexure D: Table 3s). No statistically significant differences (adjusted $p > 0.05$) were found between the other age groups.

Qualitative phase

The thematic analysis of the FGDs conducted to gather the recommendations of dental faculty on the adoption of AI in dental education and dental practice is given in Table 4.

Discussion

Artificial intelligence is performing a transformative role in healthcare via its contribution to clinical practice, academics, and research. Supplementing essential dental skills with AI technology may advance current practices by predicting patient prognosis and providing precise diagnosis of a disease for personalized and targeted patient care. However, these reforms are strongly dependent on the attitudes and perceptions of the dental community. By combining quantitative findings with qualitative findings, this study aimed to contribute to the growing body of evidence on the awareness, attitudes, and perceptions of dental faculty members and highlight opportunities and challenges for AI adoption in dentistry [13, 16, 19, 25–28].

The survey revealed that most of the faculty members in this study were aware of basic AI-based daily life applications (74%) and were using them professionally (66.2%). This is comparable to results stated by a recent systematic review, which showed a basic AI knowledge score of 71.75% among dentists [29]. In contrast, in a global survey involving dental educators, only 31.1% of respondents used AI tools, while 24.5% were uncertain, and ChatGPT was the most used AI tool, followed by Turnitin and Grammarly [14]. However, despite having basic AI knowledge and awareness in our study population, there is a significant knowledge gap in advanced AI concepts such as machine learning and deep learning. This finding resonates with the findings of other similar studies involving healthcare professionals, suggesting superficial AI awareness [11, 12, 19, 25] and thus emphasizing the need for targeted AI educational initiatives [16, 30, 31].

For the faculty members, social media and professional talk were the primary sources of acquired AI knowledge. This highlights the growing role of social media in comparison to professional platforms for providing learning opportunities to dentists and other healthcare professionals, as underlined by other similar studies [11, 27, 32]. Moreover, the majority of the participants (81%) acknowledged the limited opportunities available to learn AI, thereby emphasizing the urgency of developing contextually relevant AI training programs. The study participants preferred workshop series (53%) on AI to increase their knowledge, which indicated that faculty members were more inclined toward interactive, hands-on sessions than traditional courses or lectures. Ai-Zubaidi et al. reported similar findings regarding faculty members' preferences for hands-on workshops and peer assistance for AI learning in classrooms and clinics [15]. This could be because workshops, apart from being more interactive, are more flexible in approvals than certification or graduation programs, which require appraisals from governing bodies, making them more adaptable to ever-developing fields such as dentistry and AI technology [17, 33]. The need for training of dental professionals in AI-related tools, including their ethical implications, was also highlighted by a recently conducted global survey [14].

Overall, dental faculty members showed positive attitudes toward AI, as evident by higher mean scores for both positive and negative GAAIS statements. The higher mean values for attitudes toward AI's potential to transform dentistry (mean = 4.12) and inclination to include AI in medical education (mean = 4.1) show an optimistic outlook. This is similar to the findings of recently published literature, which shows a positive attitude towards AI in dentistry [11, 26, 34]. Moreover, further analysis also revealed that faculty members aged 36–45 years demonstrated more positive attitudes toward AI adoption than other age groups. This may indicate that mid-career professionals are more enthusiastic about adopting new technologies owing to their experience with evolving trends in AI and dentistry. A recent pilot study conducted in a dental institute in Pakistan showed only 39.14% of dental educators had awareness about the role of AI in dentistry and that the professionals in the mid-career stage, i.e. Associate Professors, were more aware of AI tools as compared to younger professionals and postgraduate trainees [13]. These results thus emphasize the need for inclusion of AI-related courses in both undergraduate and postgraduate curricula.

The overall positive attitude toward AI adoption was also reflected in the faculty FGD. This was evident from the faculty's acknowledgment and understanding that AI's utility in dentistry spans imagery analysis, disease prediction, diagnosis, treatment planning, and patient management. This emphasized that despite their limited resources, faculty members are keen on adopting recent advances in AI in dental practice [3–7, 17]. The participants also highlighted the use of AI simulation-based programs for students' clinical learning and assessments. Moreover, the faculty showed a growing interest in the rapid influx of AI-based applications for assisting teaching and research and recommended faculty training in these aspects. A recent global survey also highlighted the potential benefits of AI in acquiring knowledge, clinical skills, decision making, research, and administrative affairs [14].

The negative attitudes toward AI were reflected by the lower mean values for the GAAIS attitude scale, which measured threats to job security (mean = 2.64) and mistakes expected by AI (mean = 2.55), which indicated apprehensions toward AI. Hossain et al. [28] and Aboalshamat et al. [27] reported similar concerns among dentists and physicians regarding their job security. Mesko et al. [35] emphasized that AI itself is not a job threat; instead, users of AI will probably replace those

who do not use AI. This highlights the importance of incorporating AI in dental education as a future necessity rather than a luxury.

The key barriers to AI adoption in dentistry identified by the faculty FGD included a lack of faculty training, financial constraints, and ethical concerns, which are consistent with other similar studies [11, 13, 15, 28]. Financial constraints were identified as one of the major factors because most institutions, either private or public, lack new technologies, such as CAD-CAM, dental scanners, patient management software, and other educational technologies, such as visual simulators. The lack of faculty training was another major barrier that led to the underutilization of AI resources and technology that are available in certain institutes. Similar concerns regarding the lack of training in AI tools, their accessibility, reliability, and lack of ability to assess clinical skills utilizing AI tools in dental education were also highlighted by Uribe et al. [14]. Other major concerns were ethical issues raised by the faculty regarding patients' data privacy and the fear of overreliance on AI by its users. Yilmaz et al. also stressed the caution of prioritizing patient privacy and data security when involving AI in healthcare services to avoid ethical and legal concerns [26].

To overcome the barriers identified in this study and facilitate the AI adoption in dentistry and dental education in the local context as well as in developing countries with limited resources, the dental community recommended a multi-pronged approach. The key strategies included: (1) designing longitudinal modules for AI education at the undergraduate level with basic concepts of artificial intelligence, machine learning, and deep learning in the initial academic years and advanced concepts related to its practical applications in diagnosis, prognosis, and patient management in the upcoming years, without compromising the development of critical thinking and problem solving abilities of the learners; (2) organizing hands-on training workshops for dentists and faculty to use the latest AI tools and applications in collaboration with industrial leaders and AI experts to build AI-related competencies; (3) offering career development programs in AI for dental professionals and faculty members to facilitate them in acquiring new skill sets that will enable them to work in alternate roles within the field; (4) designing online courses and webinars to make basic AI education more accessible for all, thus overcoming the constraints of time and distance; (5) encouraging collaboration with AI developers and dental professionals to promote research and local manufacturing of local technologies to overcome the obstacle of financial constraints; (6) building partnerships among private and government institutions to overcome the barriers of infrastructure and encourage investment by educational institutes in AI technologies to support clinical practice and research; (7) development of robust policies by governing bodies to address ethical issues of AI adoption without compromising professional autonomy and patient confidentiality; (8) inclusion of more robust tools and software in preexisting anti-plagiarism tool kits, along with education of AI users to use these tools in a responsible and ethical manner.

The results of this research have several significant implications for dental practice and education. The gaps in knowledge identified in terms of advanced AI technology, i.e., machine learning and deep learning, reinforce the case for formal and sequential faculty development interventions. Adding AI modules to current faculty training and ongoing education programs may establish core knowledge and confidence in employing these technologies. Also, the overall positive mindsets evident among teachers offer a perspective for institutions to move ahead proactively. This openness can be capitalized on to encourage early deployment of AI tools in the form of pilot projects, collaborative research studies, and incorporation of AI case studies and applications at the undergraduate and postgraduate levels. By linking the development of the faculty with curricular innovation, institutions can guarantee that future dental practitioners will be furnished with digital skills to excel in an AI-augmented healthcare sector.

Strengths and limitations

The main strength of this study is that it utilizes a mixed-method study design to gather in-depth information on dental faculty awareness, knowledge, and perception of AI and provide a comprehensive analysis and recommendations for AI adoption in dentistry. The inclusion of a mixed-method design allowed the triangulation of data from both the quantitative and qualitative phases to reduce bias for more robust results. The inclusion of the FGD allowed an in-depth exploration of the faculty's insight into the advantages of AI, barriers in its adoption, and recommendations to overcome these barriers in resource constrained settings.

This study was not without limitations. One of them was the potential for selection bias. The respondents may have been more interested or enthusiastic about AI than nonparticipants were, resulting in more positive attitudes being reported. The other limitations were its cross-sectional nature and being conducted in a single geographical region, which limits its generalizability. Moreover, the reliance on self-reported data may introduce the potential for social desirability bias, as the participants may under or overestimate themselves.

Future recommendations

Future studies should focus on developing and integrating AI education in the dental curriculum. These studies

should address the hurdles and challenges faced by curriculum developers, teachers, and students. Moreover, workshops, webinars, and other online courses designed for AI education should be evaluated for their effectiveness. A longitudinal study designed to track changes in knowledge, awareness, and AI adoption should be employed over a vast geographical scope for more generalizable recommendations for its effective adoption.

Conclusions

Dental faculty members demonstrated general awareness and positive attitudes towards AI applications in both clinical and nonclinical settings. However, their knowledge regarding advanced AI concepts such as machine learning and deep learning remains limited. Mid-career professionals showed greater optimism towards AI adoption than other age groups.

The major barriers identified in AI adoption were financial constraints, insufficient training, and ethical concerns related to guidelines for its use in data management and academics. Addressing these through targeted education initiatives, interdisciplinary and multi-institutional collaborations, promotion of local manufacturing, and robust policy initiatives by the governing body can facilitate effective integration of AI into dental education and practice.

Abbreviations

AI	Artificial Intelligence
ANNs	Artificial Neural Networks
CAD-CAM	Computer Aided Design and Computer Aided Manufacturing
CBCT	Cone Beam Computed Tomography
DL	Deep Learning
GAAIS	General Attitudes toward Artificial Intelligence Scale
FGD	Focus Group Discussions
I-CVI	Content Validity Index of Items
ML	Machine Learning
OSCEs	Objective Structured Clinical Examinations
S-CVI	Content Validity Index of Scale

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12909-025-07259-8.

Supplementary Material 1: Annexure A: Questionnaire for the assessment of Knowledge, awareness and attitudes towards AI, Annexure B: Moderator Guide for Focal Group Discussion, Annexure C: Demographic summary Table, Annexure D: Comparisons across Differences in Attitudes toward AI based on Demographic Variables

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Author contributions

SA and SRH conceived and designed the study. The survey data were collected and analyzed by SA, SRH, and MAA. Focal group discussions were conducted and transcribed by SA, SRH, MAA, AK, and AWQ. SRH and SA drafted the main manuscript. MMA, AK and AWQ reviewed the final manuscript.

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Data availability

The data generated and analyzed during the study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Shifa College of Dentistry, Islamabad (Reference number SCD-2023/06). Written informed consent was obtained from all the participants during each phase of the study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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