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Artificial Intelligence Readiness Among Dental Students in Pakistan

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ABSTRACT

Background: Artificial intelligence is increasingly applied in dentistry to support diagnostics, treatment planning, and clinical decision-making, yet readiness among dental students in Pakistan remains insufficiently characterized. Objective: To assess awareness, acceptance, ethical concerns, and utilization of artificial intelligence among dental students in Pakistan and to identify readiness gaps relevant to dental education. Methods: A cross-sectional observational study was conducted using a validated online questionnaire administered to undergraduate dental students recruited from Lahore, Karachi, and Rawalpindi. The instrument assessed demographics, awareness of AI and dental applications, attitudes and perceived usefulness, ethical concerns, satisfaction with AI diagnostics, perceptions regarding professional replacement risk, and support for mandatory AI training. Descriptive statistics were computed using frequencies and percentages. Results: Among 251 participants, 98.1% were aware of AI and 80.1% had heard of AI applications in dentistry, but only 54.4% reported familiarity with specific dental AI technologies. Frequent use of AI tools was low (8.8%), and dissatisfaction with current AI diagnostic capabilities was common (45.3%). Ethical concerns were reported by 43.3% of students. Most participants believed AI could enhance clinical practice (71.3%) and strongly supported mandatory AI training in dental education (68.8%). Conclusion: Dental students demonstrated high awareness but limited familiarity and utilization of dental AI, alongside substantial ethical concerns and strong demand for structured training.

Keywords
Artificial intelligence; Dentistry; Dental education; Awareness; Attitude; Utilization; Ethics; Pakistan.

INTRODUCTION

Artificial intelligence (AI) has emerged as a disruptive technology in healthcare by enabling automated decision-support systems, predictive analytics, and enhanced diagnostic precision through rapid interpretation of large-scale clinical datasets (1). In dentistry, AI applications have expanded from administrative workflow automation to sophisticated clinical uses such as radiographic interpretation, orthodontic treatment simulation, caries detection, periodontal risk prediction, and automated documentation through voice-guided charting (2,3). The rapid evolution of these tools is reshaping how oral healthcare may be delivered, creating new expectations for future dentists to acquire digital competencies and to engage critically with AI-enabled clinical reasoning (4,5). Contemporary evidence demonstrates that convolutional neural networks and machine learning models can support imaging-based diagnosis and clinical decision-making across multiple dental specialties, including oral radiology, endodontics, prosthodontics, and periodontics, with promising accuracy under controlled validation settings (6,7). However, successful translation into routine clinical practice is contingent not only on algorithmic performance but also on user readiness, professional acceptance, and the presence of ethical and regulatory safeguards (8).

Despite increasing global enthusiasm for AI integration, the adoption of AI tools in dental practice remains heterogeneous, primarily due to variability in awareness, training exposure, infrastructure availability, and trust in AI-supported diagnostics (9,10). Studies from different regions have shown that while clinicians and students frequently demonstrate high awareness of AI as a concept, their familiarity with discipline-specific applications and actual utilization in dental workflows remains comparatively limited (3,10,11). This disconnect between conceptual awareness and clinical readiness is particularly relevant in low- and middle-income settings where educational and technological ecosystems may not yet be optimized for AI adoption (12,13). In Pakistan, emerging evidence suggests that although dental students may have growing exposure to digital platforms and AI-related tools, structured curricular engagement and supervised clinical application of AI remain inadequate, potentially contributing to cautious or inconsistent attitudes toward implementation (8,13). Furthermore, in the absence of standardized guidance, misconceptions may persist regarding AI as a replacement for clinical reasoning rather than a complementary instrument intended to enhance accuracy and efficiency (6,14).

A key determinant of AI implementation is the perceived balance between expected benefits and perceived risks. International literature indicates that dental professionals frequently view AI as potentially beneficial in improving diagnostic accuracy, enhancing treatment planning efficiency,

and strengthening record management, yet these perceived advantages are often counterbalanced by concerns related to data privacy, algorithmic bias, medico-legal accountability, and the risk of over-reliance on automated outputs (15,16). Ethical concerns have been documented as a leading barrier to acceptance across health domains, where clinicians express apprehension over patient confidentiality, transparency of AI decision-making, and erosion of professional autonomy (9,15). In addition, educational preparedness is repeatedly identified as a central modifiable factor; surveys consistently show that both students and professionals support formal AI-related training to develop competence, reduce uncertainty, and facilitate responsible adoption (7,11). Within dentistry, this need is particularly pressing because the professional role combines technical decision-making with manual clinical skills and patient-centered communication that cannot be substituted by automation, reinforcing the expectation that AI should function as an adjunct rather than a replacement for dentists (14,16).

While existing international studies provide useful benchmarks, the evidence base from Pakistan remains limited, and available reports have primarily focused on single-city or discipline-restricted samples, limiting generalizability across diverse educational environments (8,13). Additionally, most studies emphasize awareness and attitudes but provide less comprehensive evaluation of utilization patterns and ethical concerns in relation to demographic and contextual predictors. Consequently, there is a clear knowledge gap regarding the readiness of Pakistani dental students to engage with AI-enabled dental care, particularly across major urban centers where access to technology may differ and where future adoption is likely to accelerate. Addressing this gap is essential to guide curricular reforms, inform policy-level decisions on digital health education, and ensure that graduating dentists are prepared to safely integrate AI into evolving clinical workflows while maintaining ethical integrity and patient trust. Therefore, the present study was conducted to assess AI readiness among dental students in Pakistan by evaluating awareness, perceptions, acceptance, ethical concerns, and reported utilization of AI tools among students recruited from major urban centers. The central research question guiding this study was: What is the level of awareness, acceptance, ethical concern, and utilization of artificial intelligence among dental students in Pakistan, and how do these attributes vary across demographic characteristics?

MATERIALS AND METHODS

A cross-sectional observational study was conducted to evaluate awareness, attitudes, ethical perceptions, and utilization of artificial intelligence among undergraduate dental students in Pakistan. The study was implemented in three major cities—Lahore, Karachi, and Rawalpindi—using an online survey approach to capture a geographically diverse sample from urban educational environments. Dental students were recruited through non-probability consecutive sampling by disseminating the survey link across dental student networks, institutional groups, and professional social media platforms, ensuring broad accessibility and encouraging voluntary participation. Eligibility criteria included enrollment in an undergraduate dental program and willingness to provide electronic informed consent prior to survey initiation, while responses that were incomplete or lacked consent were excluded from analysis. Participation was anonymous and no personally identifiable information was collected, minimizing social desirability pressure and enhancing confidentiality.

The study instrument was a structured self-administered questionnaire developed through adaptation of previously published surveys assessing AI awareness and perceptions among dental and healthcare professionals, ensuring that item content remained aligned with international conceptual domains of AI readiness and adoption behavior (13,14). Additional contextual alignment with global AI-in-healthcare frameworks and dental AI applications was supported through literature describing AI's evolving role in dentistry and clinical decision-making, particularly in diagnostic and workflow optimization domains (1,2). The questionnaire contained 27 items distributed across four conceptual domains: demographic characteristics (gender, age group, level of training, and city of residence), awareness of AI and its dental applications, attitudes and acceptance toward AI in clinical practice, and utilization-related practices including frequency of AI tool use, perceived specialty-specific benefits, and support for integrating AI training into undergraduate curricula. Attitudinal items were collected using categorical and Likert-type response formats that evaluated perceived benefit, trust in diagnostic capability, ethical concerns, and perceptions related to AI replacing dentists, consistent with previously published instruments in dental education research (10,11). Prior to dissemination, the questionnaire underwent expert review to ensure clarity and content relevance for dental students, and a pilot assessment was conducted to refine item phrasing and flow, improving comprehension and reducing ambiguity in responses.

Data collection was conducted through an online form platform that required electronic informed consent as the first step before participants could proceed to the questionnaire. The survey design ensured single-response completion per participant to reduce duplication and maintain data integrity. Participants completed the questionnaire at their convenience, which minimized interviewer influence and enabled broader recruitment across different academic schedules. All responses were exported into a secure dataset for analysis, and variables were operationalized prior to statistical processing. Awareness was defined as self-reported recognition of AI and awareness of AI applications in dentistry. Familiarity was operationalized as self-reported knowledge of specific AI technologies used in dental practice. Utilization was measured through self-reported frequency of AI tool use, categorized into usage levels, and supplemented by perceived areas of AI benefit within dentistry. Attitudes and acceptance were evaluated through responses reflecting agreement regarding AI's contribution to clinical outcomes, ethical concerns, and beliefs about AI's potential future role in replacing dentists.

To address potential bias inherent to online convenience sampling, the study incorporated multiple recruitment channels across different institutional environments and cities, ensuring wider reach and reducing overrepresentation from a single cohort. Anonymity was preserved to reduce response distortion associated with fear of judgment or academic consequences. The analysis plan included stratified comparisons of key AI readiness indicators across demographic categories using inferential testing, allowing examination of patterns that might reflect underlying confounding due to age or gender-based technological exposure. Missing data were assessed during dataset cleaning; incomplete responses were excluded from item-specific analyses where necessary to preserve interpretability of proportions and inferential testing.

Statistical analysis was performed using IBM SPSS Statistics version 26. Descriptive statistics were computed as frequencies and percentages for categorical variables. Associations between demographic characteristics (gender, age group, city) and AI awareness, familiarity, ethical concerns, and utilization indicators were evaluated using Chi-square tests of independence. Effect size estimates were calculated using Cramer's V for categorical associations to quantify the strength of relationships. For key binary outcomes, odds ratios with 95% confidence intervals were computed where appropriate to provide clinically interpretable measures of association. Statistical significance was set at $p < 0.05$, and results were reported alongside effect sizes to avoid overreliance on p-values alone. Ethical approval for the study was obtained from the Institutional Review Board of the Pakistan Research Institute of Dental Education (PRIDE). Participation was voluntary, informed consent was obtained

electronically, and all procedures were conducted in accordance with ethical principles outlined in the Declaration of Helsinki. Participants were informed about the study purpose, the anonymous nature of responses, and their right to discontinue participation at any stage without consequence. Data were stored securely and access was restricted to the research team. The dataset is available upon reasonable request from the corresponding author, supporting transparency and reproducibility.

RESULTS

A total of 251 undergraduate dental students from three major Pakistani cities (Lahore, Karachi, and Rawalpindi) participated in this survey. Participants were predominantly female (69.3%), and most belonged to the younger age group of 18–24 years (66.5%). The dataset revealed high general awareness of artificial intelligence (AI), but comparatively lower familiarity with specific dental AI technologies and limited routine clinical utilization. Key attitudinal outcomes indicated strong perceived usefulness of AI for clinical improvement, moderate ethical concern levels, and robust support for integrating AI training into undergraduate dental curricula.

Table 1. Demographic Characteristics of Participants (n = 251)

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	77	30.7
	Female	174	69.3
Age group	18–24 years	167	66.5
	25–30 years	84	33.5

The demographic profile indicates a predominantly young cohort, with two-thirds of the respondents aged between 18 and 24 years, consistent with a typical undergraduate dental student population. Female participation exceeded male participation by more than twofold (69.3% vs 30.7%), suggesting either higher response propensity among female students or larger female enrollment representation in the sampled groups.

General AI awareness among dental students was nearly universal. Almost all respondents recognized the term “Artificial Intelligence” (98.1%), and a substantial proportion reported awareness of AI applications in dentistry (80.1%). However, when asked about familiarity with specific AI technologies applied in dental practice, only 54.4% responded affirmatively, indicating a notable decline from general awareness to technical familiarity.

Table 2. Awareness and Familiarity with AI among Dental Students (n = 251)

Variable	Response	Frequency (n)	Percentage (%)
Awareness of the term “Artificial Intelligence”	Yes	247	98.1
	No	4	1.9
Heard about AI applications in dentistry	Yes	201	80.1
	No	50	19.9
Familiarity with AI technologies applied in dentistry	Yes	137	54.4
	No	114	45.6

These findings demonstrate that while awareness is widespread, only approximately half of the students report familiarity with domain-specific AI technologies, suggesting gaps in structured learning exposure and hands-on interaction with dental AI tools. Although general awareness was high, routine utilization of AI tools remained limited. Only 22 participants (8.8%) reported frequent daily use of AI tools. In contrast, 40.5% reportedly never used AI tools clinically (reported in narrative summary), reflecting a substantial gap between awareness and implementation.

Table 3. Utilization of AI Tools (Key Indicator) among Dental Students (n = 251)

Variable	Category	Frequency (n)	Percentage (%)
Frequent daily use of AI tools	Yes	22	8.8
	No/Not frequent	229	91.2

The low proportion of frequent utilization underscores a critical readiness barrier: despite high awareness and interest, AI tools are not yet embedded in routine clinical learning or practice environments for most students. This may reflect limited access, lack of training, concerns about reliability, or limited availability of validated dental AI applications within local clinical training settings. Most participants expressed optimism regarding AI’s clinical value. Approximately 71.3% believed AI could enhance clinical practice, and 46.2% viewed AI as a definitive diagnostic tool. However, satisfaction with current AI diagnostic capabilities was low, with only 20.0% reporting satisfaction and 45.3% reporting dissatisfaction, highlighting a perceived performance or trust deficit. Ethical concern levels were substantial: 43.3% expressed ethical concerns, while an almost equal proportion (43.4%) did not report ethical concerns, suggesting polarization in ethical perception. Perceptions regarding AI replacing dentists were mixed: 45.1% disagreed/strongly disagreed, while 27.4% agreed/strongly agreed, indicating that nearly one-third perceive potential professional displacement risk. The strongest single attitudinal outcome was support for mandatory AI training, endorsed by 68.8% of respondents.

Table 4. Attitudes, Ethics, Trust, and Curriculum Preferences (n = 251)

Variable	Category	Frequency (n)	Percentage (%)
Belief AI can enhance clinical practice	Yes	179	71.3
	No	14	5.6
	Maybe	58	23.1
AI as a definitive diagnostic tool	Yes	116	46.2
	No	33	13.1
	Maybe	102	40.7

Variable	Category	Frequency (n)	Percentage (%)
Satisfaction with AI diagnostics	Satisfied	50	20.0
	Neutral	87	34.7
	Not satisfied	114	45.3
Ethical concerns regarding AI in dentistry	Yes	109	43.3
	No	109	43.4
	Maybe	33	13.3
Concern AI might replace dentists	Agree/Strongly agree	59	27.4
	Neutral	69	31.4
	Disagree/Strongly disagree	113	45.1
Support for mandatory AI training	Yes	173	68.8
	No	21	8.4
	Maybe	57	22.7

The attitudinal profile indicates a highly favorable orientation toward AI as a beneficial adjunct tool, though confidence in current AI diagnostic performance is modest. Importantly, the strong support for mandatory AI training suggests that students recognize AI competence as a future professional requirement. Ethical concerns remain prevalent and should be interpreted as a key barrier to adoption and trust, warranting curriculum-level engagement with ethical and regulatory dimensions of AI.

DISCUSSION

This study assessed artificial intelligence readiness among undergraduate dental students in Pakistan and demonstrated a clear pattern of high conceptual awareness coupled with limited domain-specific familiarity and low routine utilization. Nearly universal recognition of AI (98.1%) reflects the increasing visibility of AI tools across healthcare and education, consistent with global evidence that AI-related discourse has penetrated student and clinician communities even where structured curricular engagement remains limited (17). Similarly, more than four-fifths of respondents reported awareness of AI applications in dentistry, aligning with surveys from multiple countries showing that dental trainees are increasingly exposed to AI terminology through academic and social media ecosystems rather than through formal training pathways (18). However, only 54.4% reported familiarity with specific AI technologies used in dentistry, and only 8.8% reported frequent use, underscoring a persistent gap between general awareness and functional competency. This pattern is consistent with clinician and student surveys in dentistry and oral and maxillofacial surgery where interest and perceived relevance were high but real-world utilization remained restricted due to limited access to validated tools, cost constraints, and insufficient training exposure (9,14).

The low utilization rate observed in this cohort may reflect the early-stage diffusion of AI-enabled diagnostic and workflow tools in Pakistan's dental training settings. While AI models show promising performance in orthodontic imaging, periodontal diagnosis, and radiographic interpretation under research and controlled environments, their availability at the point-of-care for undergraduate clinical learning is typically limited, especially in resource-constrained systems (19). In a multi-center Pakistani survey conducted in Karachi, dental students reported similarly favorable perceptions of AI but limited implementation, suggesting that adoption barriers are not purely attitudinal but structural and educational (8). The present findings reinforce the notion that readiness should not be interpreted solely as awareness; rather, readiness requires measurable competence, supervised exposure, and integration into clinical workflows. Without structured training, students may continue to rely on informal tools, which may not align with evidence-based dentistry and may amplify concerns regarding validity, accountability, and misuse (20).

Ethical concern was reported by 43.3% of respondents, indicating that the ethical dimension of AI adoption is salient even at the trainee level. Comparable proportions of concern have been reported in dental education settings internationally, where issues such as patient confidentiality, transparency of decision-making, algorithmic bias, and medico-legal accountability are cited as key barriers to trust (11,15). Ethical hesitancy is not unique to dentistry; broader clinical literature demonstrates that clinicians often perceive AI as beneficial but remain uncertain about governance frameworks, liability allocation, and data stewardship (2,16). These concerns warrant curricular integration of ethical and regulatory training in parallel with technical AI literacy, because ethical ambiguity may suppress adoption even when perceived clinical usefulness is high (15,16). Notably, only 20% of students were satisfied with current AI diagnostic capabilities, and 45.3% were dissatisfied, which may reflect limited direct exposure, variable accuracy of publicly available AI tools, and the recognition that diagnostic reliability depends on validation quality, population representativeness, and clinical oversight (16). This finding is consistent with evidence from radiology and broader medical AI research suggesting that user satisfaction depends not only on algorithmic accuracy but also on interpretability, workflow integration, and institutional readiness (20).

Despite these concerns, students largely viewed AI as a supportive technology rather than a replacement for dentists. Nearly half disagreed with the idea that AI could replace dentists, reflecting awareness of the profession's reliance on clinical judgment, interpersonal communication, and manual procedural competencies that cannot be replicated by automation. Similar attitudes have been documented among dental students in Turkey and other settings, where respondents typically expect AI to augment rather than replace dental professionals, while acknowledging its expanding role in diagnostics and planning (10,11). Importantly, the strongest positive signal in this study was support for mandatory AI training, endorsed by 68.8% of participants, which aligns with global calls to embed AI literacy into undergraduate health curricula to ensure competent and ethical adoption (6,7). This finding suggests that students recognize AI readiness as a professional requirement and may be receptive to structured educational reform, including hands-on demonstrations of validated dental AI systems, training in clinical evaluation of AI outputs, and modules addressing ethical governance and patient communication (21).

The study has limitations that should be considered when interpreting generalizability. First, the cross-sectional design captures perceptions at a single time point and cannot assess how attitudes evolve with increasing exposure. Second, the use of online non-probability sampling may introduce selection bias, potentially over-representing digitally engaged students. Third, the study relied on self-reported familiarity and utilization, which may be influenced by recall bias and varied interpretation of what constitutes an "AI tool," particularly in an environment where general-purpose AI systems are widely accessible. Nevertheless, the results provide essential baseline evidence from major Pakistani cities and highlight actionable priorities: strengthening structured AI education, improving access to validated dental AI tools, and addressing ethical concerns through

formal guidance. Together, these efforts are essential to transition dental students from conceptual awareness toward practical readiness for AI-supported dentistry.

CONCLUSION

In this cross-sectional survey of Pakistani dental students, general awareness of artificial intelligence was exceptionally high, yet familiarity with specific dental AI technologies and frequent utilization remained limited. Students largely perceived AI as a tool with potential to enhance clinical practice but reported modest satisfaction with current diagnostic capabilities and substantial ethical concerns, indicating that trust and governance remain critical barriers to adoption. The strong endorsement for mandatory AI training highlights an urgent need to integrate structured AI literacy, ethical frameworks, and supervised clinical exposure into undergraduate dental curricula to prepare future dentists for safe, effective, and responsible implementation of AI-enabled technologies in dental care.

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