

ORIGINAL ARTICLE

Perception and Readiness of BDS Students Towards AI and Digital Dentistry in Pakistan

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ABSTRACT

Background: The swift integration of artificial intelligence (AI), deep learning algorithms, and digital workflows into clinical dentistry is transforming diagnostic accuracy, treatment planning, and restorative procedures globally. However, the level of awareness, clinical readiness, and perceived barriers among dental undergraduates in developing nations like Pakistan remain inadequately evaluated. Therefore, the current study was designed to evaluate the knowledge, self-reported familiarity, clinical readiness, perceived diagnostic utility, replacement anxiety, and ethical concerns regarding AI and digital dentistry among undergraduate Bachelor of Dental Surgery (BDS) students and house officers in Pakistan.

Material and Methods: A descriptive, cross-sectional study was conducted among undergraduate BDS students across all four academic years and clinical house officers (N = 251) using a validated, structured instrument distributed across major public and private dental institutions in Pakistan. Data were gathered on baseline demographics, general and domain-specific AI awareness, self-assessed competency, diagnostic trust, job replacement perceptions, ethical/legal concerns, and educational preferences. Data were evaluated using descriptive stats (frequencies and percentages) and inferential comparative analysis using SPSS Version 26.0.

Results: General awareness of AI technology was near-universal (98.1%, n = 246), and 80.1% (n = 201) reported basic awareness of AI applications within dental practice. However, domain-specific familiarity with specialized tools such as CAD/CAM workflow systems, automated caries detection algorithms, and intraoral digital scanning software was limited to 54.4% (n = 137). Active, routine clinical usage of AI tools was low at 8.8% (n = 22). A major proportion of participants (71.3%, n = 179) agreed that AI improves diagnostic accuracy in maxillo-facial radiology, yet 45.3% (n = 114) expressed skepticism regarding its complete reliability without direct human clinical oversight.

Conclusion: Undergraduate dental trainees in Pakistan demonstrate high conceptual awareness and favorable attitudes toward digital dentistry, yet exhibit significant gaps in hands-on clinical exposure and practical competency. To prepare future dental professionals for modern practice, regulatory authorities and academic leadership must integrate structured digital health and biomedical informatics modules into the undergraduate dental curriculum.

Keywords: Readiness, BDS Students, AI, Digital Dentistry, Pakistan

INTRODUCTION

The global healthcare landscape is undergoing a profound digital transformation driven by rapid advancements in artificial intelligence (AI), machine learning (ML), computer vision, and big data analytics^{1,2}. In clinical dentistry, these technological innovations have expanded beyond experimental paradigms into functional tools that enhance diagnostic precision, streamline clinical workflows, and optimize patient outcomes³. Digital dentistry encompasses a broad range of technologies, including computer-aided design and computer-aided manufacturing (CAD/CAM) systems, intraoral digital impressions, cone-beam computed tomography (CBCT) analysis software, automated cephalometric tracing, and deep-learning-based algorithms for early detection of dental caries, periodontal bone loss, and maxillofacial pathologies⁴.

Artificial intelligence applications in dentistry rely heavily on convolutional neural networks (CNNs), which are capable of analyzing complex radiographic and visual data with speed and precision⁵. In maxillofacial radiology, AI models have demonstrated diagnostic sensitivity and specificity comparable to and in some cases exceeding that of experienced clinicians in detecting periapical lesions, root fractures, and anatomical variations. In prosthodontics and restorative dentistry, CAD/CAM integration has modernized indirect restoration fabrication, reduced chairside time and enhanced marginal adaptation. Furthermore, AI-driven predictive modeling enables personalized treatment planning in orthodontics and periodontics, allowing clinicians to project tooth movement and disease progression with enhanced accuracy. Despite the growing global adoption of these tools, their implementation in low- and middle-income countries (LMICs) faces

structural challenges^{6,7}. In Pakistan, the adoption of digital dentistry is hampered by high infrastructural costs, inadequate software licensing, limited institutional access to advanced diagnostic technology, and a paucity of trained faculty. Consequently, significant variations exist in how dental institutions expose students to emerging technologies. While private healthcare centers and specialized postgraduate institutions may feature advanced CAD/CAM units or digital scanners, the standard undergraduate curriculum in many public and private dental colleges remains heavily reliant on traditional, analogue methods⁸.

Undergraduate dental training represents the primary stage for developing foundational clinical skills and professional attitudes. The current generation of dental undergraduates Bachelor of Dental Surgery (BDS) students and house officers will practice in an increasingly digitized clinical environment⁹. However, if trainees lack formal exposure to digital dentistry during their formative years, they may struggle to evaluate digital tools critically, leading to either total rejection or over-reliance on automated systems without proper oversight¹⁰. Understanding the current state of awareness, perception, self-reported readiness, and perceived barriers among dental trainees in Pakistan is essential for shaping future educational policies. Prior studies in regional contexts have primarily examined generic medical AI awareness, leaving a gap in data regarding domain-specific dental applications among Pakistani trainees. Therefore, this study was undertaken to evaluate the awareness, self-reported familiarity, clinical readiness, diagnostic trust, replacement anxiety, and ethical concerns regarding AI and digital dentistry among BDS students and house officers across Pakistan.

MATERIAL AND METHODS

Study Design and Target Population: This quantitative, descriptive, cross-sectional survey was conducted among

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undergraduate BDS students across all academic years (1st, 2nd, 3rd, and 4th professional years) and house officers completing their mandatory internship year across private dental institutions in Pakistan. A non-probability convenience sampling technique was utilized to recruit participants. The inclusion criteria comprised enrolled undergraduate BDS students (1st through 4th professional year) or registered house officers, affiliation with a recognized public or private dental institution in Pakistan and Provision of informed consent to participate in the study. The exclusion criteria included postgraduate trainees (FCPS, M Dent, MSc), practicing general dental practitioners, dental auxiliary staff, and individuals who submitted incomplete survey forms. Based on standard sample size estimation formulas for observational studies, a minimum sample size of 240 was targeted. A final sample of N = 251 valid responses was included in the definitive statistical analysis.

Data were gathered using a structured, self-administered questionnaire adapted from validated instruments used in published medical and dental education literature. The instrument was subjected to content validation by a panel of expert dental educators and biostatisticians to ensure domain relevance and clarity. A pilot study was conducted on a subgroup of 20 dental students (excluded from the final analysis) to confirm internal consistency, yielding a satisfactory Cronbach's alpha coefficient ($\alpha = 0.82$). The final questionnaire comprised 22 items divided into four distinct sections, section I: Demographic Characteristics: Gender, age, academic status (categorized into pre-clinical: 1st/2nd year; clinical: 3rd/4th year; and house officers), and institutional category (public vs. private). Section II: Awareness and Familiarity: Generic understanding of AI, awareness of specific dental AI applications (radiology, prosthodontics, orthodontics, endodontics), self-assessed competence, and clinical usage frequency. Section III: Perceptions and Diagnostic Trust: Agreement levels measured on a 5-point Likert scale regarding diagnostic accuracy, reliability without human oversight, fear of occupational replacement, and legal/ethical concerns. Section IV: Curricular Integration Needs: Perceived necessity of formal AI training, preferred educational methodologies (lectures, workshops, hands-on clinical modules), and institutional barriers.

The questionnaire was digitized using a secure electronic survey platform (Google Forms) and distributed through institutional communications, student representative networks, and professional digital channels across Pakistan. Clear introductory text detailed the study objectives, emphasized voluntary participation, guaranteed anonymity, and stated that completing the survey implied informed consent. Data collection spanned a four-month period. Data were extracted, cleaned, and coded into IBM SPSS Statistics Version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were compiled to summarize demographic parameters, awareness levels, and perception ratings using counts, percentages, means, and standard deviations. Responses on Likert scales were collapsed into three primary categories (Agree, Neutral, Disagree) for tabular clarity. Crosstabulations and Pearson's Chi-square (χ^2) tests were performed to assess associations between academic seniority (pre-clinical vs. clinical vs. house officer) and awareness/perception variables. Statistical significance was established at $p < 0.05$.

RESULTS

A total of 251 participants completed the evaluation. The demographic breakdown showed a female majority of 62.2% ($n = 156$), while males constituted 37.8% ($n = 95$) of the sample, reflecting gender distributions in Pakistani dental institutions. Categorization by academic status placed 31.5% ($n = 79$) of participants in pre-clinical years (1st and 2nd year BDS), 48.2% ($n = 121$) in clinical years (3rd and 4th year BDS), and 20.3% ($n = 51$) as house officers. Institutional distribution was balanced between public (53.4%, $n = 134$) and private (46.6%, $n = 117$) dental colleges. General awareness of artificial intelligence as a technological concept was high across all subgroups, with 98.1%

($n = 246$) confirming familiarity with the term. When assessed for domain-specific awareness in dentistry, 80.1% ($n = 201$) reported having heard of AI applications in dental practice.

However, detailed inquiry into functional familiarity with clinical tools revealed notable gaps. Only 54.4% ($n = 137$) demonstrated working knowledge of specialized systems such as CAD/CAM milling integration, intraoral digital scanners, or AI-based radiographic diagnostic modules. Furthermore, active clinical usage of dental AI technology was low: only 8.8% ($n = 22$) reported routine engagement with digital AI platforms in their academic or clinical routines. A significant majority (74.1%, $n = 186$) reported never having used an AI-driven dental tool, while 17.1% ($n = 43$) reported rare usage during demonstrations or clinical electives.

Cross-tabulation analysis showed a statistically significant association between academic seniority and functional familiarity ($\chi^2 = 18.42$, $p < 0.001$). House officers (72.5%) and clinical students (58.7%) exhibited significantly higher functional familiarity compared to pre-clinical students (35.4%).

Evaluations of trainee attitudes regarding diagnostic utility, system reliability, job security, ethics, and education showed distinct patterns across domains.

When asked about preferred formats for digital health instruction, 52.6% ($n = 132$) favored hands-on clinical workshops and simulation labs, 29.5% ($n = 74$) preferred integrated lectures within existing subjects (such as science of dental materials and oral radiology), and 17.9% ($n = 45$) expressed interest in elective certification courses.

Awareness and Usage Spectrum among BDS Trainees

Generic AI Awareness:	98.1% ($n = 246$)
Awareness of Dental AI Applications:	80.1% ($n = 201$)
Functional Knowledge of Dental AI Tools:	54.4% ($n = 137$)
Routine Clinical Usage of Dental AI:	8.8% ($n = 22$)

Perception Domain / Survey Statement	Agree (% / n)	Neutral (% / n)	Disagree (% / n)
Diagnostic Enhancement: AI integration significantly improves diagnostic accuracy in maxillo-facial radiology and pathology.	71.3% ($n = 179$)	21.1% ($n = 53$)	7.6% ($n = 19$)
System Reliability: Current AI diagnostic algorithms are reliable enough to make clinical decisions without human oversight.	18.3% ($n = 46$)	36.4% ($n = 91$)	45.3% ($n = 114$)
Occupational Replacement: AI and robotics will eventually replace human dental surgeons in routine clinical practice.	11.2% ($n = 28$)	23.1% ($n = 58$)	65.7% ($n = 165$)
Ethical & Legal Risks: Significant ethical, legal, and data confidentiality risks exist regarding AI implementation in dental care.	43.3% ($n = 109$)	31.2% ($n = 78$)	25.5% ($n = 64$)
Curricular Necessity: Formal modules on AI and digital dentistry should be made mandatory within the standardized undergraduate BDS curriculum.	68.8% ($n = 173$)	21.5% ($n = 54$)	9.7% ($n = 24$)

DISCUSSION

The findings of this evaluation illustrate a clear dichotomy between broad conceptual awareness and functional clinical competency among dental undergraduates and house officers in Pakistan. While generic familiarity with artificial intelligence approaches 98.1%, practical engagement with domain-specific dental applications remains constrained. This gap reflects broader trends in lower- and middle-income health systems, where digital transformation is often acknowledged theoretically long before the infrastructure and curriculum adapt to support hands-on implementation^{11,12}.

The finding that 71.3% of participants recognize AI's capability to enhance diagnostic accuracy in maxillofacial radiology demonstrates optimism regarding modern technology¹³. Deep-learning architectures, particularly convolutional neural networks, have shown notable success in detecting periapical radiolucencies, quantifying marginal bone loss, mapping mandibular canal proximity, and classifying impactions¹⁴. Dental trainees recognize these tools as supportive adjuncts capable of reducing human

error, accelerating diagnostic workflows, and minimizing inter-observer variability¹⁵.

However, this optimism is accompanied by cautious clinical judgment. A substantial proportion of respondents (45.3%) rejected the notion that AI platforms are sufficiently reliable to operate without direct human supervision¹⁶. This skepticism aligns with established literature emphasizing the limitations of medical AI algorithms, including vulnerability to out-of-distribution diagnostic inputs, lack of contextual patient understanding, training set bias, and opaque decision-making processes ("black-box" phenomenon)¹⁷. Trainees recognize that while an algorithm can analyze a digitized image, it cannot synthesize comprehensive patient histories, perform clinical palpation, or evaluate psychological parameters necessary for treatment planning¹⁸.

Crucially, the majority of respondents (65.7%) dismissed fears of occupational replacement, rejecting the premise that AI or robotic systems will render human dental surgeons obsolete. Clinical dentistry remains a procedure-intensive, highly tactile discipline that relies on fine motor control, real-time adaptive decision-making, and interpersonal empathy¹⁹. Trainees view AI as a collaborative tool that automates repetitive analytical tasks, freeing clinicians to focus on procedural execution, complex clinical reasoning, and patient communication²⁰.

Despite this positive view, ethical, legal, and regulatory concerns remain a prominent point of uncertainty. Nearly half of the participants (43.3%) acknowledged potential risks regarding patient data privacy, algorithmic liability, informed consent, and security in digital dentistry workflows²¹. In LMICs like Pakistan, where national frameworks governing digital health data privacy, medical software certification, and algorithmic accountability are still evolving, these concerns are especially relevant. Without clear legal guidelines regarding liability for AI-assisted diagnostic errors, clinicians face complex medico-legal challenges when integrating automated diagnostics into routine care^{22,23}.

The low rate of routine clinical usage (8.8%) points to significant institutional barriers across Pakistani dental schools. Structural constraints including high procurement costs for digital scanners and CAD/CAM software, limited institutional funding, lack of technical support staff, and a shortage of faculty trained in digital dentistry restrict student access to emerging tools. Consequently, learning remains predominantly theoretical, leaving trainees ill-prepared to navigate digital workflows upon entering modern private practices or international healthcare environments^{24,25}.

Addressing these challenges requires coordinated action by academic leadership and regulatory bodies, including the Pakistan Medical and Dental Council (PM&DC) and the Higher Education Commission (HEC). With 68.8% of participants advocating for mandatory curricular integration, there is a strong mandate for educational reform. Introducing dedicated modules on biomedical informatics, digital impression techniques, computer-aided restorative design, and ethical AI evaluation into the standard BDS curriculum particularly within oral radiology, science of dental materials, and prosthodontics would help bridge the gap between interest and clinical competency. Several limitations should be considered when interpreting the results of this study. First, the use of a non-probability convenience sampling technique may introduce selection bias, as students with greater baseline interest in digital health may have been more inclined to complete the electronic survey. Second, reliance on self-reported data introduces potential response bias regarding familiarity and competence levels. Third, while the sample included diverse academic years and institution types, the findings may not fully capture regional infrastructure disparities across all provincial

institutions in Pakistan. Longitudinal studies tracking cohorts before and after targeted digital curriculum interventions are recommended to better evaluate skill acquisition and clinical integration.

CONCLUSION

BDS students and house officers in Pakistan exhibit positive attitudes, low replacement anxiety, and high broad awareness regarding artificial intelligence and digital dentistry. However, functional familiarity, hands-on clinical exposure, and practical usage remain low due to institutional and curricular limitations.

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