



Decoding Artificial Intelligence in Dentistry: Current Trends, Challenges, and the Path Forward

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Abstract:

Introduction

Artificial Intelligence (AI) is transforming healthcare by offering innovative solutions in diagnostics, treatment planning, and disease prevention. In dentistry, AI applications span radiology, orthodontics, endodontics, and restorative procedures, enhancing accuracy and efficiency. Despite its potential, the extent of AI awareness, knowledge, and adoption among dental professionals remains unclear, necessitating a focused investigation.

Methodology

A cross-sectional survey was conducted among 100 dental professionals, including practicing dentists, academics, and postgraduate students across various specialties. Participants were recruited through online and offline channels, adhering to inclusion criteria of a minimum Bachelor of Dental Surgery (BDS) qualification and active engagement in clinical practice or teaching. A structured questionnaire comprising five sections assessed demographics, AI awareness and attitudes, knowledge, barriers to AI adoption, and educational preferences. The tool's reliability was validated (Cronbach's alpha = 0.8) through a pilot study. Data collection involved voluntary participation with informed consent.

Results

The study revealed high awareness (84%) of AI applications in dentistry, with participants acknowledging its utility in enhancing diagnostic accuracy and efficiency. However, significant barriers to AI adoption were identified, including a lack of technical knowledge, inadequate infrastructure, and ethical concerns. The majority of participants expressed a strong preference for AI-focused educational programs, emphasizing hands-on training and workshops.

Conclusion

The findings underscore the need to address technical and infrastructural barriers to foster AI integration in dentistry. Targeted educational initiatives are essential to bridge the knowledge gap and equip dental professionals with the skills required to leverage AI effectively. This study provides a foundation for developing strategic interventions to promote AI adoption, ensuring its seamless incorporation into routine dental practice.

Keywords: - Artificial Intelligence, Dentistry, Knowledge, AI Applications.

Introduction: -

Artificial Intelligence (AI) is the science and engineering devoted to the development of machines that employ sophisticated algorithms to replicate human cognition, learning, and problem-solving abilities [1]. In recent years, AI has begun to revolutionize medical practice, capitalizing on advancements in digitized data collection, machine learning, and computational infrastructure. These advancements are propelling AI into domains traditionally dominated by human expertise [2].

The integration of AI in healthcare holds transformative potential, promising to enhance diverse aspects such as disease diagnosis [3], personalized treatment strategies, and laboratory diagnostics. Leveraging vast datasets and identifying intricate patterns, AI frequently surpasses human performance in specialized areas, offering greater accuracy, cost efficiency, and reduced processing time while minimizing the likelihood of human error. This cutting-edge technology is poised to redefine personalized medicine, optimize pharmacological dosing, advance population health management, and establish rigorous clinical guidelines. Moreover, AI can deliver virtual health assistance, support mental healthcare, enrich patient education, and foster an enhanced trust between patients and healthcare providers [4].

In dentistry, AI and neural networks are advancing rapidly, especially within dental radiology, where they play a pivotal role in diagnostic procedures, treatment planning, and prognostic assessments. Neural networks, particularly artificial and convolutional networks, are employed in restorative dentistry for caries detection [5], in endodontics to identify lesions and root fractures [6], in orthodontics to assist in treatment planning and growth evaluation [7], and in dental surgery to guide implant placements and detect osseous lesions [8]. AI also contributes significantly to periodontology, with applications for assessing alveolar bone degradation and forecasting periodontitis progression [9]. These technologies herald a new era of precision, efficacy, and time efficiency, although further research remains essential to integrate AI seamlessly into routine dental practice [10].

Hence this study was planned with the aim to provide a detailed understanding of the current state of AI knowledge, awareness, and adoption among dental professionals. The findings help to identify specific barriers to AI implementation and guide the development of targeted educational programs to enhance AI integration in dentistry.

Methodology: -**Study Design**

This cross-sectional survey was conducted among practicing dentists, dental academics, and postgraduate dental students across different specialties. Participants were recruited from dental institutions, private clinics, and professional dental forums after informing them about the purpose of the study.

Inclusion: -

The study will include dental professionals with a minimum qualification of Bachelor of Dental Surgery (BDS) who are currently engaged in clinical practice, teaching, or postgraduate studies. Participants must be willing to provide informed consent to participate in the study.

Exclusion: -

Individuals currently enrolled in the Bachelor of Dental Surgery (BDS) program will be excluded.

Questionnaire Validation

The questionnaire was developed based on a comprehensive review of relevant literature and expert input. A pilot study was conducted with 20 dental professionals to ensure the feasibility of the study and clarity, relevance, and reliability of the questionnaire. Feedback from this pilot study was used to refine the questionnaire before its final distribution. Reliability testing using Cronbach's alpha yielded a value of 0.8, indicating good internal consistency.

Sample Size

A sample size of 100 participants was estimated. Sample size calculation was performed using OpenEpi software (version 3), with:

- Power set at 80%.
- Two-sided significance level (1-alpha) fixed at 90%.
- Prevalence of AI knowledge taken as 84% from existing literature.

The final calculated sample size was 89 participants. To account for a 10% non-response rate, the sample size was rounded to 100.

Data Collection Tool

The primary data collection tool for this study was a structured questionnaire designed specifically for this purpose. It comprised five sections: Demographics, which gathered baseline information on participants' age, gender, role, education level, specialization, and dental experience; Awareness and Attitude Toward AI, which assessed participants' familiarity with AI applications in dentistry and their attitudes toward its integration; Knowledge of AI, which evaluated their understanding of key AI concepts, technologies, and applications in dental practice; Hurdles in Using AI, which identified barriers to AI adoption, including technical, ethical, and infrastructural challenges; and Educational Preferences, which explored participants' preferences for AI-related training and education.

Data Collection Procedure

The finalized questionnaire was distributed to participants through both online and offline channels. Online distribution was done using platforms such as Google Forms, shared via email and professional dental groups on social media. Offline, hard copies were made available during professional dental events, workshops, and conferences. Participation was voluntary, and informed consent was obtained from all participants prior to data collection.

Data analysis:

All data was statistically analyzed using OpenEpi software (version 3) keeping the power at 80%, two-sided significance level (1-alpha) fixed at 90% and alpha at 0.05 and result was presented in the form of tables and graphs.

Result: -

The survey primarily attracted a youthful demographic within the age range of 22 to 30, largely composed of interns and postgraduates, with a smaller representation from clinicians and academicians. Female

participants outnumbered males, and most respondents reported having less than five years of professional experience, with a minority indicating more extensive experience.

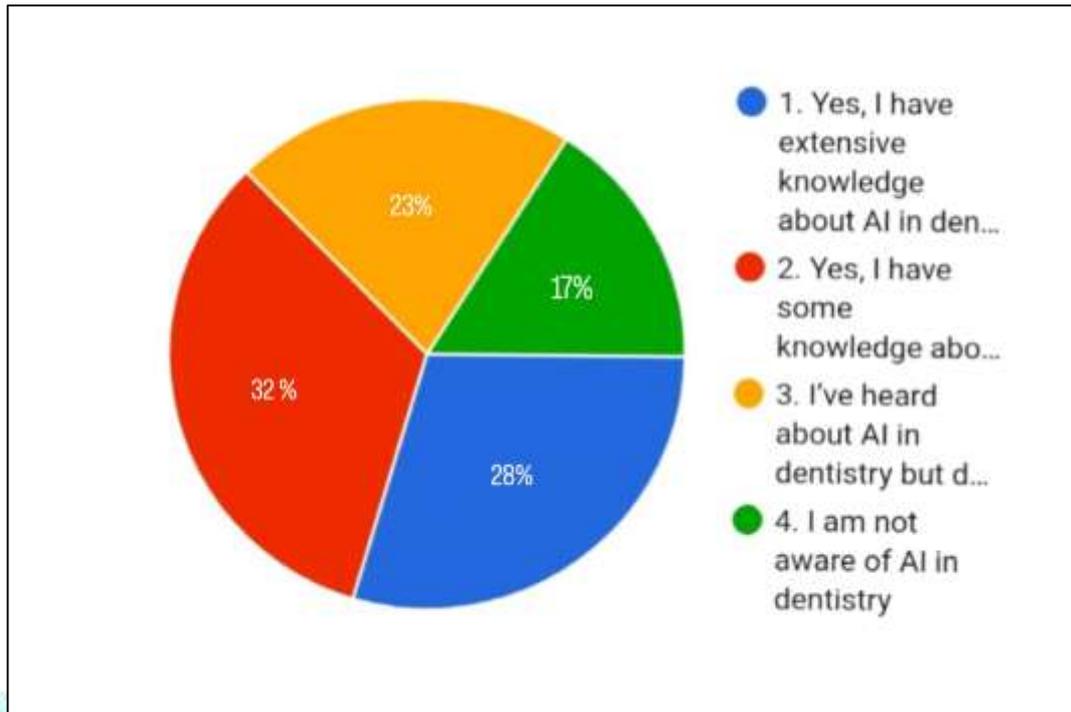


Fig. 1- Question - "Have you heard about the use of AI specifically in the field of"

As illustrated in Fig. 1, a survey of 100 participants evaluating awareness of artificial intelligence (AI) in dentistry disclosed that 32% demonstrated profound comprehension, while 17% exhibited a complete lack of awareness regarding the subject.

The survey also highlighted a spectrum of awareness regarding AI applications in dental treatment planning, with 42% of participants demonstrating extensive knowledge, contrasted by 5% exhibiting complete unfamiliarity with the concept.

Table. 1- Question- "Have you encountered AI technologies designed for early diagnosis of oral cancers ?"

Awareness level	Percentage of respondents
Fully aware	36%
Slightly heard of them	24%
Heard, but lack detailed understanding	30%
Extremely unaware	10%

As illustrated in Table 1, the survey on awareness of AI technologies for the early detection of oral cancers revealed that 36% of respondents possessed comprehensive knowledge, while 10% were entirely oblivious to such advancements. The analysis of dental professionals' awareness of AI in analysing dental health records revealed a varied understanding, with some demonstrating comprehensive knowledge and others entirely unaware of its applications. Participation in workshops or seminars also varied, with a portion having attended multiple events, while a smaller group showed no interest. Opinions on trust in AI-generated treatment recommendations versus clinician expertise were divided, with some expressing full trust in AI and others relying solely on clinician judgment. Ethical and privacy concerns regarding AI in dentistry were notable, with significant apprehension among participants, though many maintained a neutral stance without a definitive opinion.

Table. 2- Question- “Which AI tool is commonly used for analysing dental X-rays and CBCT scans?”	
AI Tool option,	Percentage of respondents
All of the above	43.2%
Deep learning algorithms	29.1%
MRI imaging	16.4%
Radiographic film	11.3%

As delineated in Table 2, the survey assessing commonly employed AI tools for analysing dental X-rays and CBCT scans demonstrated a spectrum of responses. The predominant selection, "All of the above," garnered 43.2%, signifying a nuanced recognition of the multifarious AI technologies, such as deep learning algorithms and advanced radiographic systems, pivotal to dental imaging. Conversely, the least selected option, radiographic film, at 11.3%, underscores lingering familiarity with conventional methodologies, despite their marginal incorporation into AI-driven frameworks. The survey highlighted varied perspectives on AI applications in dentistry. Most respondents recognized the multifaceted utility of “computer vision,” while fewer associated it with patient communication, indicating some conceptual gaps. AI’s benefits in diagnostics were widely acknowledged, particularly its ability to enhance accuracy and efficiency, though some respondents showed ambiguity in identifying its specific advantages. In orthodontics, the predominant view emphasized AI’s role in predicting treatment outcomes and progress, with a smaller group recognizing its broader functionalities in the field.

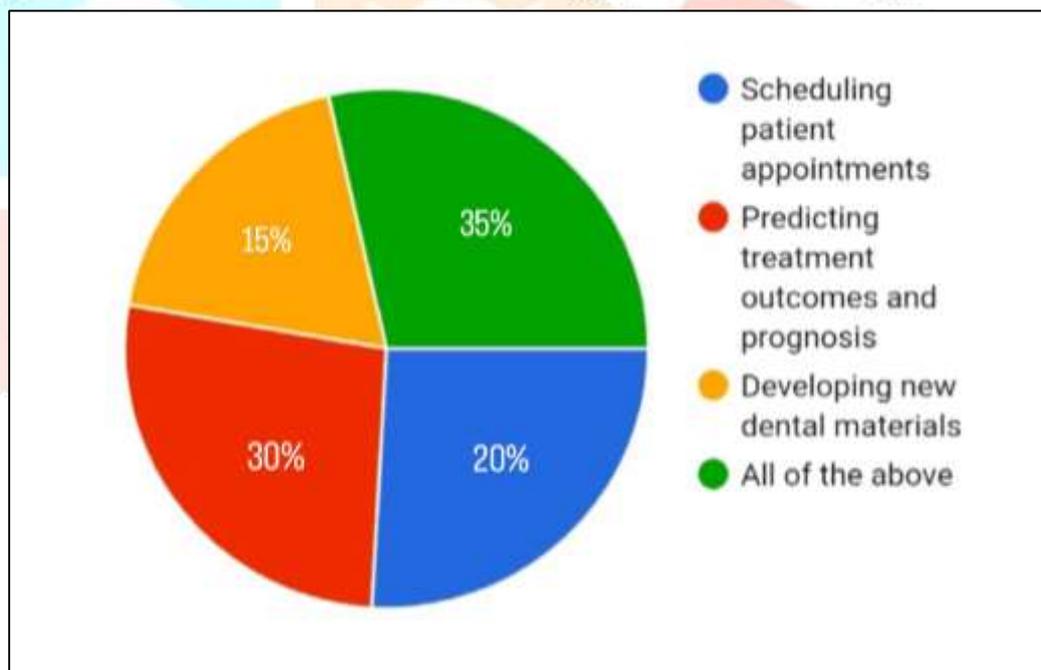


Fig. 2- Question- “AI-based predictive analytics in dentistry is mainly used for?”

As depicted in Fig. 2, the survey findings underscore varying perceptions regarding the primary application of artificial intelligence in dentistry. A commanding 35% of respondents endorsed "all of the above," denoting AI’s versatile applicability across multiple domains. Conversely, 15% identified its role in "developing new dental materials," reflecting a more specialized, albeit narrower, recognition of its potential. The survey revealed a recognition of AI’s multifaceted applications, with many respondents selecting options that highlighted its broad potential. Regarding AI in digital smile design, the majority acknowledged its role in creating simulations and designs, while others recognized its contributions to automating procedures and streamlining workflows. Only a small group viewed AI as completely replacing dentist input. When identifying the prevalent type of AI in dental practice, most respondents pointed to “Weak AI” for specific tasks, with minimal divergence from established AI paradigms.

Survey data elucidates pivotal impediments and ethical quandaries encumbering the integration of artificial intelligence (AI) within clinical dental practices, particularly in developing nations. The preponderance of

respondents, 72%, identified the exorbitant costs of AI technologies as the paramount obstacle. Conversely, a lesser 32% underscored the paucity of bespoke algorithms tailored to dental-specific applications, reflecting a nuanced challenge to its adoption. Among ethical apprehensions, the predominant concern, cited by 67% of participants, pertained to safeguarding data privacy and upholding patient confidentiality as an imperative issue. In contrast, a comparatively minimal 38% expressed trepidation regarding the prospective displacement of dental practitioners by AI tools within clinical environments.

Table. 3- Question- “Why is the integration of AI in dental practices often limited in developing countries?”	
Limitations	Percentage of respondents
In adequate infrastructure	70%
High cost of AI implementation	62%
Lack of skilled personnel	49%

As illustrated in Table 3, the survey underscores that in developing nations, the adoption of AI in dental practices is predominantly hindered by financial and infrastructural constraints. A significant 70% of respondents highlighted inadequate infrastructure as a major impediment, while a lesser 49% identified the scarcity of proficient personnel as a critical challenge. The survey highlights key reservations among dental professionals regarding AI integration in dentistry, with many attributing their hesitation to limited exposure to AI education and training. Fear of job displacement emerged as the least significant concern. Integration challenges were identified across multiple areas, including oral surgeries, orthodontic treatment planning, and radiographic analysis, with complex oral surgeries being the most frequently noted challenge.

Discussion: -

The findings of this survey reveal a varied awareness of AI's role in dental practices. While a substantial proportion of respondents demonstrated some understanding, there remains a significant gap in knowledge, underscoring the need for targeted educational initiatives. This aligns with the findings of Gnanambigai Kalaimani et al., who reported similar awareness levels among dental surgeons and students, emphasizing the necessity of integrating AI education into dental training programs to bridge this gap [11].

Regarding AI technologies for early oral cancer detection, the survey highlighted limited awareness among participants, paralleling the recommendations of S. Murali et al., who advocated for lectures, curricular inclusion, and scientific meetings to promote AI knowledge and adoption in dentistry [12].

The analysis also revealed that while many dental professionals were confident in AI's potential to enhance diagnostics, a notable portion expressed interest in further education through workshops. This mirrors the study by Mahmood Dashti et al., which demonstrated higher AI knowledge among dentists than students, though students were more optimistic about its future applications. These findings underscore the importance of ongoing training for practitioners and AI integration in dental curricula to foster innovation and improve patient outcomes [13].

Trust in AI-generated treatment recommendations was mixed, with some respondents fully relying on AI, while others preferred to prioritize clinicians' expertise. Similar trends were observed in a study by Mingyang Chen et al., which concluded that AI should function as a supportive tool rather than replace clinical decision-making entirely [14].

Ethical and privacy concerns were prominent among respondents, with many emphasizing the lack of regulatory frameworks as a key issue. This aligns with the findings of Jelena Roganović et al., who highlighted the necessity of clear regulations and educational initiatives to address ethical apprehensions and ensure AI's responsible implementation in dental practice [15].

In orthodontics, AI's primary role was identified as predicting treatment outcomes, followed by manufacturing appliances and aiding in diagnosis and planning. These findings align with Seema Gupta et al., who noted similar barriers to AI adoption, including high costs and lack of technical knowledge. Their

study also emphasized the importance of targeted education to address these challenges and improve AI utilization across specialties [16].

In the realm of digital smile design, most respondents recognized AI's utility in creating simulations and automating tasks. However, only a small percentage perceived AI as capable of fully replacing dentists. This observation is consistent with the study by N. Kurian et al., which highlighted AI's efficiency in streamlining workflows but emphasized the irreplaceable value of human expertise in complex procedures and ethical patient care [17].

Conclusion: -

The survey underscores the evolving landscape of artificial intelligence within dentistry, highlighting a dichotomy between its recognized transformative potential and the prevailing barriers to its widespread integration. While a substantial proportion of respondents acknowledge AI's capacity to enhance diagnostic accuracy, streamline workflows, and predict treatment outcomes, the data reveal persistent impediments such as infrastructural deficiencies, financial constraints, and ethical apprehensions. Furthermore, the findings delineate a conspicuous need for targeted educational initiatives to bridge knowledge gaps, foster confidence, and cultivate a nuanced understanding of AI's multifaceted applications.

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