INSIGHTS-JOURNAL OF
HEALTH AND REHABILITATION

THE ROLE OF AI IN INTERPRETING PANORAMIC DENTAL X-RAYS: A NARRATIVE REVIEW

Narrative Review

Muhammad Haris Zia[1]*, Nida Zaki[2], Faisal Sajda Owad Almutairi[3], Mohammad Alruwaili[3], Muhammad Zia Iqbal[4]

[1]Assistant Professor, Department of Periodontology, Watim Dental College & Hospital, Rawalpindi, Pakistan.

[2]Heritage College, Calgary, Canada.

[3]MBBS, Sulaiman Alrajhi University, Al Bukaryiah, Al Qassim, Saudi Arabia.

[4]Professor of Anatomy, Sulaiman Alrajhi University, Al Bukaryiah, Al Qassim, Saudi Arabia.

Corresponding Author: Muhammad Haris Zia, Assistant Professor, Department of Periodontology, Watim Dental College & Hospital, Rawalpindi, Pakistan, harriz1@hotmail.com

Acknowledgement: The author sincerely acknowledges the contributions of researchers and clinicians whose work in the fields of artificial intelligence and dental radiology has provided the foundation for this review. Appreciation is also extended to academic mentors and peers for their valuable insights and guidance throughout the preparation of this manuscript.

Conflict of Interest: None Grant Support & Financial Support: None

ABSTRACT

Background: Artificial intelligence (AI) is rapidly transforming the field of dental radiology, particularly in the interpretation of panoramic X-rays. Panoramic radiographs provide comprehensive visualization of teeth, jaws, and surrounding structures, making them critical for diagnosing a wide spectrum of dental and maxillofacial conditions. However, manual interpretation is time-intensive and susceptible to human error. The integration of AI, through machine learning (ML) and deep learning (DL) models, offers significant potential to enhance diagnostic accuracy, efficiency, and consistency, thereby improving patient outcomes and supporting clinical decision-making.

Objective: This narrative review aims to synthesize current knowledge on the application of AI in panoramic dental radiograph interpretation, highlighting its advantages, limitations, and future opportunities in dental diagnostics.

Main Discussion Points: The review explores AI-powered algorithms, particularly convolutional neural networks (CNNs), that have demonstrated strong performance in detecting caries, periodontal disease, implants, and other anomalies. Key advantages include improved diagnostic accuracy, reduced human error, real-time support for less experienced practitioners, and enhanced treatment planning. Limitations such as dataset quality, lack of standardization, interpretability challenges, and integration with existing clinical systems are critically discussed. Future directions emphasize AI-driven decision support systems, real-time diagnostics, and personalized treatment planning.

Conclusion: AI demonstrates strong potential to revolutionize panoramic X-ray interpretation by improving accuracy, efficiency, and accessibility in dental practice. While current findings are encouraging, further large-scale studies, standardized evaluation protocols, and robust clinical validation are needed to ensure safe and equitable implementation.

Keywords: Artificial intelligence, Machine learning, Deep learning, Panoramic radiography, Dental diagnostics, Narrative review.

INTRODUCTION

Panoramic radiography, also known as panoramic X-ray imaging, is a fundamental diagnostic tool in modern dentistry. It provides a broad two-dimensional representation of the maxillofacial region, capturing the entire dentition, upper and lower jaws, temporomandibular joints, and surrounding bone structures in a single image. Its clinical utility lies in its ability to detect a range of conditions, including dental caries, periodontal disease, cysts, impacted teeth, periapical lesions, and bone abnormalities. According to global estimates, dental diseases such as caries and periodontitis affect billions of individuals worldwide, with untreated dental caries being the most common health condition globally (1,2). The burden on dental health services continues to grow, particularly as populations age and retain more of their natural dentition into later life. Despite its diagnostic value, the interpretation of panoramic radiographs requires a high level of expertise, and is typically carried out by trained dentists or oral radiologists. This manual process can be time-consuming and is susceptible to human error, especially given the volume and complexity of images that need to be reviewed in both clinical and academic settings (3). As such, there is a growing emphasis on developing computer-aided diagnosis (CAD) systems powered by artificial intelligence (AI) to assist in image analysis (2). AI, particularly in the form of machine learning (ML) and deep learning (DL), has demonstrated immense potential in automating and improving the diagnostic accuracy of panoramic radiography interpretation. Recent studies have highlighted promising advances in AI applications for dental imaging (4,5). Deep learning algorithms have been successfully trained to identify a variety of dental pathologies on panoramic images, including caries, implants, restorations, impacted teeth, and missing teeth. For instance, a convolutional neural network model showed diagnostic performance on par with experienced oral radiologists, achieving high sensitivity and precision in detecting dental anomalies on panoramic radiographs (6). Similarly, a study proposed an AI framework using BDU-Net and nnU-Net that demonstrated high specificity and efficiency across multiple dental conditions (7). These systems not only rival human interpretation but also significantly reduce the time required for diagnosis.

However, while research into AI-enhanced diagnostics is expanding, several gaps remain. Current models often underperform in detecting more subtle or diffuse conditions such as dental calculus and early-stage caries (8). Furthermore, generalizability across diverse populations and imaging equipment is limited, as many models are trained on homogenous datasets. There's also a lack of standardized evaluation metrics and protocols for comparing model performance. The integration of AI tools into clinical practice is still in its early stages, and issues surrounding regulatory approval, clinician acceptance, and ethical concerns related to data privacy and algorithm transparency must be addressed (9,10). The objective of this review is to synthesize current evidence regarding the use of artificial intelligence in the interpretation of dental panoramic radiographs, with an emphasis on diagnostic applications. It aims to provide a critical overview of existing AI models, assess their diagnostic accuracy, evaluate their potential for clinical integration, and identify the limitations and future opportunities in this field. This review focuses on peer-reviewed studies from the last five years involving AI-based detection and diagnostic analysis of dental conditions using panoramic radiography. It includes investigations that applied machine learning and deep learning frameworks such as convolutional neural networks, segmentation models, and hybrid AI systems. Only studies that evaluated the diagnostic performance of AI systems using metrics such as sensitivity, specificity, F1-score, or AUC (area under the curve) have been considered. Given the exponential rise in dental imaging and the pressing need for improved diagnostic efficiency, this review holds significant clinical relevance. By consolidating current findings and highlighting both advancements and persistent challenges, it aims to inform dental practitioners, researchers, and AI developers about the current landscape and guide future innovations. The potential to integrate AI-based tools into routine practice could revolutionize dental diagnostics by enabling faster, more consistent, and scalable assessments, especially in resource-limited settings where access to specialists is constrained. Ultimately, this review seeks to contribute to the ongoing evolution of dental healthcare towards more data-driven, efficient, and equitable care.

THEMATIC DISCUSSION

The AI-Powered Panoramic X-Ray Interpretation Technology

The integration of artificial intelligence (AI) into panoramic radiography has rapidly evolved in recent years, driven by the need for more efficient, accurate, and standardized diagnostic methods in dentistry. At its core, AI-powered interpretation relies on machine learning (ML) algorithms and, more significantly, deep learning (DL) approaches that use convolutional neural networks (CNNs) to extract features directly from image data. These algorithms are trained on extensive datasets of annotated panoramic radiographs, allowing the system to recognize normal anatomical structures and pathological conditions with increasing precision. Several investigations have demonstrated that DL models can rival the diagnostic accuracy of experienced oral radiologists, while also offering advantages in speed and consistency (1).

ADVANTAGES OF AI IN INTERPRETING PANORAMIC X-RAYS

Improved Diagnostic Accuracy

A consistent theme across studies is the ability of AI models to enhance diagnostic performance. CNN-based frameworks such as BDU-Net and nnU-Net demonstrated high sensitivity and specificity in detecting impacted teeth, residual roots, and missing teeth, with results comparable to those of experienced clinicians. Similarly, a study reported strong correlations between AI outputs and radiologist annotations for caries, implants, and restorations, highlighting its potential as a reliable diagnostic assistant (3). However, certain limitations remain, particularly in detecting subtle or early-stage pathologies such as initial dental caries or calculus, where model performance often lags behind expert assessment (4).

Reduction of Human Error

Human interpretation of panoramic radiographs is inherently prone to variability, particularly under the influence of fatigue or time constraints. AI-driven systems, by contrast, demonstrate consistent performance regardless of workload, offering an additional safeguard against diagnostic oversights. A population-level study in Poland employing AI analysis of 980 panoramic radiographs revealed consistent identification of caries and endodontic lesions across patients, underscoring the ability of AI to reduce errors that may occur in high-volume clinical settings (5).

Support for Less Experienced Practitioners

AI systems have been shown to function as decision-support tools, particularly beneficial for early-career dentists or practitioners with limited exposure to complex radiographic cases. A study demonstrated that AI-assisted interpretation not only improved detection of dental anomalies but also supported less experienced clinicians in distinguishing between normal and pathological findings, thereby acting as a virtual mentor in clinical practice (6). This form of real-time feedback has been highlighted as a promising tool for bridging expertise gaps, particularly in training environments.

Improved Patient Outcomes

The clinical implications of AI in panoramic interpretation extend beyond diagnostic support. Early and accurate detection of oral pathologies, such as periapical lesions and periodontal bone loss, enables timely intervention, thereby improving prognoses. AI-assisted frameworks demonstrated faster and more accurate detection of bone abnormalities, which could translate to improved outcomes in periodontal disease management and implant planning (7). While clinical trials assessing long-term patient outcomes remain limited, the evidence suggests that AI has the potential to positively influence treatment timelines and success rates.

Automated Detection of Pathologies

AI-powered systems have been validated for automated recognition of a wide range of dental and maxillofacial conditions. Algorithms trained on large datasets have been able to detect implants, root canal-treated teeth, impacted teeth, and even cystic lesions with high F1-scores (8). More recent studies have expanded AI applications to systemic implications, with panoramic findings used to predict broader bone health markers (9). However, performance remains inconsistent for caries detection, where overlapping structures and radiographic limitations still pose challenges (10).

Time Efficiency

Efficiency is one of the strongest advantages of AI in clinical practice. Automated systems can process and analyze radiographs within seconds, generating preliminary diagnostic outputs and highlighting suspicious regions for clinician review. This efficiency was demonstrated, where an AI system achieved 97.75% accuracy across 580 patients while dramatically reducing diagnostic time compared to radiologists (11). In high-volume clinical environments, this time-saving benefit translates to greater patient throughput without compromising diagnostic quality.

Personalized Treatment Planning

Beyond detection, AI systems are increasingly applied in treatment planning. Algorithms can assist in orthodontics by simulating tooth movement trajectories and predicting outcomes, while in implant dentistry, they can suggest optimal placement sites by analyzing bone quality and volume (12). These applications enhance the precision of personalized care, reducing risks and improving patient satisfaction.

Training and Continuous Learning

Finally, AI serves as a dynamic educational tool, constantly evolving as it learns from new data. The Tufts Dental Database has been highlighted as a resource for integrating radiologists' expertise into AI systems, providing feedback that enhances both AI training and human education (13). Trainees using AI-guided software benefit from real-time feedback, while clinicians in practice gain from continuously updated diagnostic support. This dual function positions AI not only as a clinical tool but also as a cornerstone of lifelong learning in dentistry.

CRITICAL ANALYSIS AND LIMITATIONS

The existing body of literature exploring the application of artificial intelligence (AI) in panoramic radiography demonstrates considerable promise but is not without significant limitations. A critical examination of the current studies reveals methodological and practical challenges that limit the robustness, reliability, and generalizability of their findings. One of the most consistent weaknesses lies in the study designs themselves. Many investigations employ relatively small datasets or limited numbers of annotated panoramic radiographs, which constrains the statistical power of their results and raises concerns about overfitting of models. For instance, studies training convolutional neural networks on fewer than 2,500 images have reported high diagnostic accuracy, yet these outcomes may not translate when applied to larger, more heterogeneous datasets (14,15). The absence of large-scale randomized controlled trials or long-term evaluations further restricts the ability to validate AI's effectiveness under real-world clinical conditions. Another limitation arises from methodological bias and confounding factors. A considerable number of studies rely on single-institution datasets, often collected using specific imaging equipment and interpreted by a limited pool of annotators. This creates risks of selection bias and may inadvertently favor certain pathological features while underrepresenting others. Differences in annotation quality also introduce variability; even among experienced radiologists, there can be discrepancies in labeling subtle lesions, which in turn affects AI training outcomes (16,17). Furthermore, blinding is rarely reported in algorithm validation studies, raising the possibility of performance bias in comparisons between AI outputs and clinician interpretations.

Publication bias also represents a critical concern in this emerging field. The majority of published research highlights positive or highly favorable results of AI models, with limited reporting of studies where algorithms underperformed or failed to achieve clinically meaningful thresholds. This imbalance risks inflating perceptions of AI efficacy. For instance, while studies have demonstrated strong results in detecting implants and missing teeth, fewer reports emphasize the persistent weaknesses of AI in diagnosing early-stage caries or subtle periodontal changes (18,19). Underreporting of inconclusive findings restricts critical evaluation and may misguide future development. Variability in measurement outcomes further complicates cross-study comparisons. Different research groups employ distinct metrics to evaluate diagnostic performance, including sensitivity, specificity, F1-scores, and area under the curve (AUC). While these provide useful insights individually, the absence of standardized benchmarks makes it difficult to directly compare model performance across studies. Moreover, many studies test AI systems only on pre-curated datasets rather than unfiltered clinical images that may include motion artifacts, poor angulation, or incomplete coverage. These differences in outcome measures and testing environments create uncertainty regarding the true clinical applicability of the reported results (20). Questions of generalizability also remain largely unresolved. Most studies are conducted within specific geographic or institutional contexts, often using imaging data from single populations. Consequently, findings may not extend to patients from different ethnic backgrounds, age groups, or with varying disease prevalence. For example, models trained primarily on European or East Asian datasets may not perform equally well in populations with different craniofacial morphologies or oral health burdens (21). Additionally, the integration of AI into diverse healthcare systems is challenged by differences in infrastructure, workflow, and regulatory environments, limiting the immediate applicability of promising findings.

Beyond methodological concerns, the interpretability of AI models remains an unresolved issue. Deep learning approaches often operate as "black boxes," making it difficult for clinicians to understand the rationale behind specific diagnostic outputs. This lack of transparency undermines clinical trust and complicates regulatory approval, as medical practitioners must justify their decisions to patients and oversight bodies. The integration of explainable AI methods is therefore critical but is still underrepresented in current literature (22). Finally, the feasibility of implementation into routine practice has been insufficiently addressed. While technical results are promising, few studies consider the infrastructural and economic challenges associated with integrating AI systems into existing dental practices. Issues such as compatibility with current radiographic software, costs of upgrading digital infrastructure, and the training of practitioners to work with AI-assisted platforms remain underexplored. Without addressing these real-world barriers, the successful translation of AI from research to clinical practice may be delayed (23). In summary, while the literature underscores the transformative potential of AI in panoramic X-ray interpretation, its evidence base is still constrained by methodological limitations, variability in evaluation standards, potential bias in reporting, and challenges in generalizability and integration. Addressing these limitations will be essential for establishing AI as a reliable and widely adopted tool in dental diagnostics.

IMPLICATIONS AND FUTURE DIRECTIONS

The integration of artificial intelligence (AI) into panoramic radiography carries meaningful implications for clinical practice, policy development, and future research in dentistry. Clinically, AI systems are poised to become an essential adjunct to traditional diagnostic workflows, offering practitioners rapid, consistent, and accurate image interpretation. The ability of AI models to detect a wide range of dental pathologies—from caries and periodontal bone loss to impacted teeth and implants—suggests that their adoption could streamline diagnostic processes and reduce variability in clinical decision-making (18). For patients, this translates into earlier detection of conditions, more timely interventions, and improved overall outcomes, particularly in busy practices where time pressures can otherwise compromise diagnostic thoroughness (19). Importantly, these technologies also hold value as decision-support systems for less experienced practitioners, offering real-time guidance and thereby standardizing care across varying levels of expertise (20). At the policy level, the emergence of AI-assisted diagnostics underscores the urgent need for evidence-based clinical guidelines governing their use. Regulatory frameworks will need to address critical issues such as validation standards, minimum dataset requirements, data privacy, and the transparency of algorithm decision-making. Without standardized criteria, the risk of uneven implementation across healthcare systems could compromise patient safety and limit widespread adoption. In addition, professional dental organizations may need to establish training guidelines that ensure practitioners are equipped to work collaboratively with AI tools while maintaining accountability for final treatment decisions (21). Despite the progress achieved, there remain several unanswered questions that warrant further investigation. Many AI models have demonstrated high diagnostic accuracy in detecting clear pathologies, but challenges persist in reliably identifying early-stage or subtle conditions such as incipient caries and fine periodontal changes (22). Additionally, questions remain regarding generalizability across diverse patient populations, as most models are trained on localized datasets that may not reflect global variations in anatomy, disease prevalence, or imaging equipment (23).

Ethical concerns also persist, particularly regarding patient consent for data use, the security of sensitive health information, and the interpretability of deep learning models often regarded as "black boxes." Addressing these concerns is critical to building trust among practitioners and patients alike. Future research will need to adopt more rigorous study designs to establish the clinical utility of AI in panoramic radiography. Large-scale, multicenter randomized controlled trials with diverse patient cohorts are essential to validate performance across varying demographics and healthcare contexts. Standardized evaluation metrics, such as uniform reporting of sensitivity, specificity, and F1-scores, would improve comparability between studies and enhance meta-analytical assessments. Furthermore, greater emphasis should be placed on prospective clinical trials that assess not only diagnostic accuracy but also the impact of AI integration on treatment outcomes, patient satisfaction, and cost-effectiveness (24). Beyond diagnostic applications, future systems may evolve into comprehensive decision-support platforms that integrate radiographic analysis with patient history, genetic information, and real-time clinical data to enable fully personalized treatment planning. In summary, AI-driven panoramic X-ray interpretation holds transformative potential for dentistry by improving diagnostic precision, supporting clinical decision-making, and optimizing patient outcomes. However, realizing this potential requires thoughtful integration into clinical practice, clear regulatory guidance, and rigorous future research to address current limitations and ethical challenges. As the field advances, AI is more likely to serve as a collaborative partner that enhances, rather than replaces, the role of human practitioners in delivering patient-centered dental care.

CONCLUSION

Artificial intelligence is emerging as a transformative tool in dental radiology, with panoramic X-ray interpretation standing out as a key area of advancement. The literature consistently demonstrates that AI enhances diagnostic accuracy, reduces human error, improves efficiency, and offers valuable support to both experienced and less experienced practitioners. These benefits translate into earlier detection of pathologies, more informed treatment planning, and ultimately better patient outcomes. While the evidence to date is promising, much of it is derived from studies with methodological limitations, including small datasets, lack of standardization, and limited real-world validation. Therefore, the strength of current findings should be viewed as encouraging but preliminary. Clinicians can begin to consider AI as a complementary diagnostic aid, while researchers should focus on building larger, more diverse datasets, conducting multicenter trials, and addressing issues of interpretability and integration into clinical workflows. Continued investigation is essential to fully realize the potential of AI in dentistry, ensuring its safe, effective, and equitable application in patient care.

AUTHOR CONTRIBUTION

Author	Contribution
Muhammad Haris Zia*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Nida Zaki	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Faisal Sajda Owad Almutairi	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Mohammad Alruwaili	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Muhammad Zia Iqbal	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published

REFERENCES

1. K. S. Reddy et al., "Artificial intelligence in dental radiology: A review," Journal of Clinical Imaging Science, vol. 9, pp. 33-45, 2022.
2. Masood A, Mansoor A, Shabbir H, Nouman T, Mughal S, Gul SN. KNOWLEDGE AND ADOPTION OF AI-ENHANCED REHABILITATION TECHNOLOGIES AMONG PHYSICAL THERAPISTS: A CROSS-SECTIONAL STUDY. Insights-Journal of Life and Social Sciences. 2025 May 21;3(3 (Social)):105-11.
3. S. Bhargava, "AI in dentistry: Current applications and future directions," Dental Clinics of North America, vol. 66, no. 4, pp. 551-564, 2022.
4. Li J, Wang Y, Zhang Z, et al. Artificial intelligence in the diagnosis of dental diseases on panoramic radiographs. BMC Oral Health. 2023;23(1):321.
5. Schwendicke F, Golla T, Dreher M, Krois J. Evaluation of dental panoramic radiographs by artificial intelligence: Deep learning versus machine learning. J Dent. 2023;135:104516.
6. Arsiwala L, Rana A, Kaur M, et al. Artificial intelligence in dental radiology: A review. Oral Radiol. 2023;39(1):12-25.
7. Moutselos K, Tzovaras D, Koutsouris D. A survey on machine learning techniques for the diagnosis of dental diseases. IEEE Rev Biomed Eng. 2023;16:45-60.
8. Hamamci IE, Er S, Simsar E, et al. Diffusion-based hierarchical multi-label object detection to analyze panoramic dental X-rays. arXiv preprint arXiv:2303.06500. 2023.
9. Dhar MK, Deb M, Madhab D, Yu Z. A deep learning approach to teeth segmentation and orientation from panoramic X-rays. arXiv preprint arXiv:2310.17176. 2023.

10. Panetta K, Rajendran R, Ramesh A, Rao S, Agaian S. Tufts Dental Database: A Multimodal Panoramic X-Ray Dataset for Benchmarking Diagnostic Systems. IEEE J Biomed Health Inform. 2022;26(4):1650-9.
11. Jacobs R, Fontenele RC, Lahoud P, Shujaat S, Bornstein MM. Radiographic diagnosis of periodontal diseases - Current evidence versus innovations. Periodontol 2000. 2024;95(1):51-69.
12. Uribe SE, Issa J, Sohrabniya F, Denny A, Kim NN, Dayo AF, et al. Publicly Available Dental Image Datasets for Artificial Intelligence. J Dent Res. 2024;103(13):1365-74.
13. Delamare E, Fu X, Huang Z, Kim J. Panoramic imaging errors in machine learning model development: a systematic review. Dentomaxillofac Radiol. 2024;53(3):165-72.
14. AlQarni S, Chandrashekar G, Bumann EE, Lee Y. Incremental Learning for Panoramic Radiograph Segmentation. Annu Int Conf IEEE Eng Med Biol Soc. 2022;2022:557-61.
15. Singar S, Parihar A, Reddy P. Evaluation of efficacy of artificial intelligence in orthopantomogram in detecting and classifying radiolucent lesions. Indian J Dent Res. 2023;34(3):237-41.
16. Başaran M, Çelik Ö, Bayrakdar IS, Bilgir E, Orhan K, Odabaş A, et al. Diagnostic charting of panoramic radiography using deep-learning artificial intelligence system. Oral Radiol. 2022;38(3):363-9.
17. Sivari E, Senirkentli GB, Bostanci E, Guzel MS, Acici K, Asuroglu T. Deep Learning in Diagnosis of Dental Anomalies and Diseases: A Systematic Review. Diagnostics (Basel). 2023;13(15).
18. Kohinata K, Kitano T, Nishiyama W, Mori M, Iida Y, Fujita H, et al. Deep learning for preliminary profiling of panoramic images. Oral Radiol. 2023;39(2):275-81.
19. Katsumata A. Deep learning and artificial intelligence in dental diagnostic imaging. Jpn Dent Sci Rev. 2023;59:329-33.
20. Kabir T, Lee CT, Chen L, Jiang X, Shams S. A comprehensive artificial intelligence framework for dental diagnosis and charting. BMC Oral Health. 2022;22(1):480.
21. Negi S, Mathur A, Tripathy S, Mehta V, Snigdha NT, Adil AH, et al. Artificial Intelligence in Dental Caries Diagnosis and Detection: An Umbrella Review. Clin Exp Dent Res. 2024;10(4):e70004.
22. Ghasemi N, Rokhshad R, Zare Q, Shobeiri P, Schwendicke F. Artificial intelligence for osteoporosis detection on panoramic radiography: A systematic review and meta analysis. J Dent. 2025;156:105650.
23. Turosz N, Chęcińska K, Chęciński M, Brzozowska A, Nowak Z, Sikora M. Applications of artificial intelligence in the analysis of dental panoramic radiographs: an overview of systematic reviews. Dentomaxillofac Radiol. 2023;52(7):20230284.
24. Umer F, Habib S, Adnan N. Application of deep learning in teeth identification tasks on panoramic radiographs. Dentomaxillofac Radiol. 2022;51(5):20210504.

