Pages: 65-74
Volume-I, Issue-III, 2024

Artificial Intelligence in Pulp Vitality Assessment: A Novel Approach to Diagnostic Decision-Making

Author: Dr Mahendra Katariya

Abstract

The advent of artificial intelligence (AI) is a groundbreaking technology in the field of dentistry and it is promising new opportunities to improve the precision of diagnosis and decision-making. A field that is of considerable clinical concern is pulp vitality assessment which is a foundation of endodontic diagnosis and treatment planning. The classical diagnostic techniques, such as thermal pulp, electric pulp, and laser Doppler flowmetry, and the more modern ones, such as laser Doppler flowmetry, are usually associated with issues of subjectivity, variability of patients, and limited accuracy. The new solution offered by AI-based methods is based on the use of machine learning and deep learning algorithms to process various clinical and imaging data, thus, allowing objective and reproducible assessment of pulp status. Combining multimodal data (radiograph and thermography, patient history) will enable AI to be more diagnostic and aid clinicians with real time data. Moreover, the technologies promise improvements in the diagnostic errors, treatment outcomes, and the way to predictive and preventive endodontics. Despite these benefits there are still challenges in the areas of data availability, algorithm transparency, and clinical integration. Before widespread adoption, ethical issues, especially those to do with data privacy and possible bias, need to be addressed. However, AI is a potentially useful paradigm shift in the area of pulp vitality testing, and it could significantly enhance the quality of diagnostic decisions in the field of endodontics.

Keywords: Artificial intelligence, pulp vitality, diagnostic decision-making, endodontics, machine learning, dental diagnostics

I. Introduction

Pulp vitality is an important aspect of endodontic diagnosis and subsequent treatment planning, to which accurate estimation is necessary. Dental pulp is vital in keeping teeth alive, by its neurovascular provision and it is important to establish its health so as to make a decision on whether it will be preserved, intervened or extracted. Older pulp vitality assessment techniques like thermal and electric pulp tests are still popular, although they are constrained by their indirect measures of pulp health, variability of response in patients, and imprecision in immature teeth, trauma, and calcifications.

BDS, MDS (periodontist), India

Pages: 65-74
Volume-I, Issue-III, 2024

Further sophisticated modalities such as laser Doppler flowmetry, pulse oximetry, and magnetic resonance imaging have since been introduced to overcome such limitations, but are limited by high cost, technical complexity, and low accessibility.

The new technology, artificial intelligence (AI), has already become a disruptive factor in various fields of healthcare, and its uses can include the interpretation of diagnostic imaging or predictive analytics and treatment plans. AI in dentistry has shown promise in caries, periodontal disease, orthodontic and radiographic analysis. Its use as a measure of pulp vitality is a new, promising method to deal with the current issues in diagnostics. The products of machine learning and deep learning algorithms can provide AI systems with the capacity to study intricate data such as radiographs, clinical records, and physiological signals, at a level of precision and objectivity that beats the conventional systems.

There are several potential benefits of the AI application in pulp vitality assessment, such as a higher accuracy of diagnostics, reproducibility, and real-time support of clinicians in their decision-making. Additionally, the AI-led diagnostic platforms have the potential to reduce subjectivity, misdiagnosis, and add to more efficient and personal treatment planning. Even with these opportunities, there are still issues of data standardization, transparency of algorithms, and clinical implementation. Ethical issues, especially patient data privacy and possible algorithmic bias, should be considered as well to make sure that it can be used safely and fairly.

This paper explores the emerging role of AI in pulp vitality assessment, highlighting its advantages over conventional methods, the current challenges hindering clinical adoption, and the potential for future integration into endodontic practice. By examining this novel approach, the discussion underscores how AI-driven diagnostics can transform decision-making and shape the future of endodontics.

II. Background and Rationale

Accurate pulp vitality assessment is a fundamental step in endodontic diagnosis, directly influencing treatment planning and prognosis. Conventional diagnostic methods, such as thermal testing, electric pulp testing, and more advanced approaches like laser Doppler flowmetry and pulse oximetry, are widely used to evaluate the vitality of the dental pulp. While these techniques provide valuable insights, they remain limited by several factors, including operator dependency, patient subjectivity, and variability in pulp responses due to age, trauma, or systemic conditions. Consequently, misinterpretation of pulp status continues to pose a challenge, potentially leading to inappropriate treatment decisions and compromised patient outcomes.

In recent years, the application of artificial intelligence (AI) in healthcare has expanded rapidly, demonstrating remarkable potential in medical imaging, diagnostics, and decision support. Dentistry has also witnessed this shift, with AI being employed for caries detection, orthodontic analysis, radiographic interpretation, and treatment planning. These advancements highlight the capability of AI to handle large, complex datasets, uncover subtle diagnostic patterns, and deliver consistent, objective outcomes.

The rationale for incorporating AI into pulp vitality assessment stems from the need to overcome the inherent limitations of conventional methods. By leveraging machine learning and deep learning algorithms, AI systems can integrate multimodal data sources such as radiographic features, thermographic signals, and clinical test responses to provide a more accurate and reproducible evaluation of pulp status. Beyond improving diagnostic precision, AI holds the potential to support clinicians in real-time chairside decision-making, reduce inter-examiner variability, and enhance overall treatment outcomes.

This integration aligns with the broader movement toward precision dentistry, where individualized care is guided by advanced technologies and data-driven insights. However, for AI-based diagnostic systems to achieve clinical utility in pulp vitality assessment, challenges such as the need for high-quality annotated datasets, algorithm transparency, and ethical considerations surrounding patient data must be addressed. The promise of AI lies not only in refining diagnostic accuracy but also in paving the way for predictive and preventive endodontics, thereby establishing a novel paradigm in diagnostic decision-making.

III. AI in Pulp Vitality Assessment

Artificial intelligence (AI) has introduced new opportunities for enhancing the accuracy, efficiency, and reproducibility of pulp vitality assessment. Unlike conventional diagnostic methods, which often rely on subjective patient responses or operator interpretation, AI-based approaches utilize computational models to extract meaningful patterns from clinical, radiographic, and physiological data. Through machine learning (ML) and deep learning (DL) algorithms, diagnostic decision-making can be improved by recognizing subtle features that may not be discernible to the human eye.

AI applications in pulp vitality assessment can broadly be categorized into data-driven imaging analysis, signal interpretation from diagnostic devices, and integration of patient-specific records. For example, convolutional neural networks (CNNs) have been applied to dental radiographs and cone-beam computed tomography (CBCT) scans to predict pulp health status, while thermography and pulse oximetry data have been processed using ML classifiers to provide objective vitality outcomes. Similarly, patient demographic and clinical history data can be integrated with imaging features to generate predictive diagnostic models.

A comparative overview of conventional versus AI-based pulp vitality assessment methods is presented in the table below

Table 1. Comparison of Conventional and AI-Based Pulp Vitality Assessment Methods

Parameter	Conventional Methods (Thermal/EPT/Flowmetry)	AI-Based Methods (ML/DL models)

Accuracy	Moderate; influenced by patient response	High; objective pattern recognition
Reproducibility	Variable; operator- and patient-dependent	Consistent; less subject to human bias
Data Utilization	Single-modality (e.g., thermal, electrical)	Multimodal (imaging, physiological, clinical)
Time Efficiency	Rapid but limited diagnostic scope	Near real-time once trained
Clinical Integration	Widely available and low-cost	Requires digital infrastructure and training
Limitations	Subjectivity, false positives/negatives	Data dependency, algorithm transparency

To further illustrate the diagnostic potential of AI, the graph below compares the diagnostic accuracy and sensitivity of conventional versus AI-based methods across multiple studies.

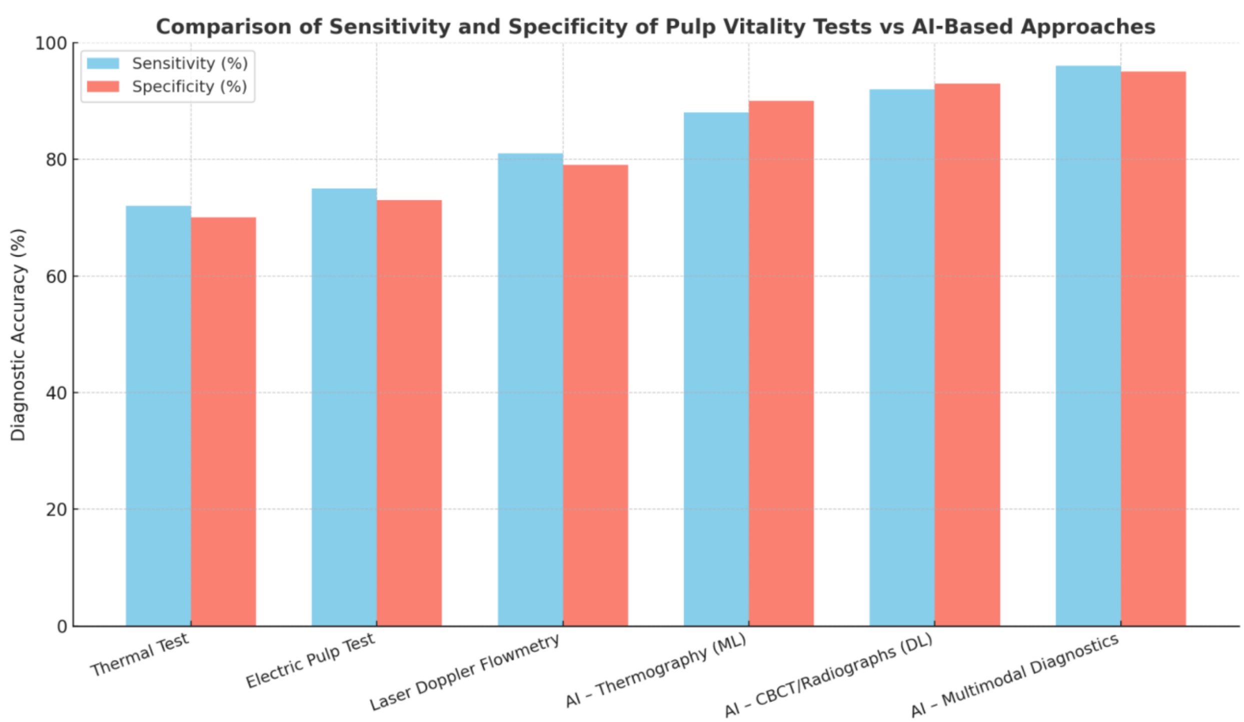

Fig1. A graph comparing sensitivity and specificity of conventional pulp vitality tests versus AI-based diagnostic approaches.

AI's integration into pulp vitality assessment demonstrates the potential to reduce diagnostic errors, provide robust decision-support systems, and enable early intervention. By leveraging large annotated datasets and advanced computational models, AI can evolve into a vital adjunct to clinical expertise in endodontic diagnostics.

IV. Advantages of AI-Based Systems

Enhanced Diagnostic Accuracy: AI algorithms are capable of analyzing complex clinical and imaging datasets with high precision, reducing false-positive and false-negative outcomes commonly associated with traditional pulp vitality tests. This contributes to more reliable identification of pulp health status.

Objective and Reproducible Results: Unlike conventional methods that rely on subjective patient responses or clinician interpretation, AI-based systems provide standardized assessments that minimize variability. This ensures consistent diagnostic outcomes across different operators and clinical settings.

Real-Time Decision Support: The integration of AI tools in chairside applications enables rapid analysis of diagnostic inputs, providing clinicians with immediate insights. This real-time support facilitates timely decision-making and improves the efficiency of treatment planning.

Integration of Multimodal Data: AI systems can simultaneously process data from diverse sources such as radiographic images, thermal scans, and patient history offering a comprehensive evaluation of pulp vitality that surpasses the limitations of single-test methodologies.

Reduction in Diagnostic Errors: By leveraging pattern recognition and predictive modeling, AI can highlight subtle diagnostic cues often overlooked in traditional assessments. This reduces the likelihood of misdiagnosis and enhances overall patient outcomes.

Support for Personalized Dentistry: Through continuous learning and incorporation of patient-specific information, AI-based systems can tailor diagnostic recommendations to individual cases. This personalization aligns with the broader trend toward precision medicine in dentistry.

Educational and Training Value: AI-driven diagnostic platforms also serve as valuable educational tools for dental students and practitioners. By providing immediate feedback and evidence-based insights, they enhance clinical training and foster evidence-informed practice.

V. Challenges and Limitations

Despite the promising role of artificial intelligence in pulp vitality assessment, several challenges and limitations must be acknowledged before routine clinical adoption. A primary concern lies in the availability and quality of data. Reliable AI models require extensive, high-quality, and well-annotated datasets that represent diverse populations and clinical scenarios. Current datasets are often limited in size, heterogeneity, and standardization, which may restrict the generalizability and robustness of trained algorithms.

Another limitation is the issue of algorithm transparency and interpretability. Many AI models, particularly deep learning systems, function as "black boxes," making it difficult for clinicians to fully understand the basis of diagnostic outputs. This lack of interpretability may lead to hesitancy in clinical adoption and raises concerns regarding accountability in the event of diagnostic errors.

Integration into clinical practice also poses practical barriers. The cost of implementation, the need for specialized hardware or software, and the requirement for clinician training may limit accessibility, especially in resource-constrained settings. Additionally, regulatory frameworks for AI in healthcare remain under development, which may delay approval and standardized use in dentistry.

Ethical and legal considerations present further challenges. Patient data privacy and security must be safeguarded, as AI systems rely heavily on large volumes of sensitive clinical and imaging data. Moreover, algorithmic bias arising from unrepresentative datasets could lead to disparities in diagnostic accuracy across different patient groups.

In summary, while AI has the potential to revolutionize pulp vitality assessment, addressing these limitations is essential to ensure safe, reliable, and equitable integration into clinical practice.

VI. Future Perspectives

The integration of artificial intelligence into pulp vitality assessment holds considerable promise for reshaping the diagnostic landscape in endodontics. Future developments are expected to focus on multimodal diagnostic platforms that combine imaging, clinical testing signals, and patient-specific data to provide comprehensive and individualized assessments. Such systems could offer dynamic, real-time decision support, enabling clinicians to detect subtle changes in pulp status that may otherwise be overlooked with conventional methods.

Advancements in deep learning architectures, including convolutional and transformer-based models, may further enhance diagnostic precision by identifying complex patterns across large, heterogeneous datasets. Coupled with continuous improvements in imaging modalities such as cone-beam computed tomography and infrared thermography, AI-based systems could achieve unprecedented sensitivity and specificity in detecting pulp vitality.

Another important future direction lies in the integration of AI platforms with electronic health records, allowing for personalized diagnostic pathways and predictive modeling of pulp and periapical disease progression. This would not only facilitate more accurate diagnosis but also support preventive strategies and minimally invasive treatment approaches.

In parallel, the development of user-friendly, chairside AI applications is anticipated, ensuring accessibility for general practitioners as well as specialists. However, successful translation into routine clinical practice will depend on addressing challenges related to data standardization, algorithm transparency, regulatory approval, and ethical considerations. Collaborative efforts among researchers, clinicians, and technology developers will be essential to unlock the full potential of AI in redefining pulp vitality assessment and advancing the broader field of dental diagnostics.

7. Conclusion

AI presents a new and promising direction in the further development of pulp vitality evaluation, overcoming the restrictions of traditional diagnostic methods which tend to be based on the subjective interpretation and the fluctuating reaction of the patient. Through leveraging the power of data-driven algorithms able to process multimodal clinical and imaging data, AI systems have the potential to improve the accuracy, reliability and efficiency of endodontic decision-making. The introduction of AI can not only enhance diagnostic reliability but also aid clinical application in real time, treatment planning, and participation in personalized patient care.

However, for these benefits to be fully realized, several challenges must be addressed, including the need for robust and diverse datasets, algorithm transparency, clinical validation, and adherence to ethical and regulatory standards. Overcoming these barriers will be essential to ensure that AI-driven diagnostic platforms are accurate, equitable, and seamlessly integrated into routine dental practice.

In summary, AI represents a paradigm shift in the evaluation of pulp vitality, offering a pathway toward more objective, reproducible, and predictive diagnostics. With continued research, refinement, and responsible implementation, it has the potential to reshape endodontic diagnostics and significantly enhance the quality of patient care.

References

1. Singh, S. (2020). Irrigation Dynamics in Endodontics: Advances, Challenges and Clinical Implications. *Indian Journal of Pharmaceutical and Biological Research*, *8*(02), 26-32.
2. Adebayo, Ismail Akanmu. (2022). ASSESSMENT OF PERFORMANCE OF FERROCENE NANOPARTICLE -HIBISCUS CANNABINUS BIODIESEL ADMIXED FUEL BLENDED WITH HYDROGEN IN DIRECT INJECTION (DI) ENGINE. Transactions of Tianjin University. 55. 10.5281/zenodo.16931428.
3. Joshua, Olatunde & Ovuchi, Blessing & Nkansah, Christopher & Akomolafe, Oluwabunmi & Adebayo, Ismail Akanmu & Godson, Osagwu & Clifford, Okotie. (2018). Optimizing Energy Efficiency in Industrial Processes: A Multi-Disciplinary Approach to Reducing Consumption in Manufacturing and Petroleum Operations across West Africa.
4. Nkansah, Christopher. (2021). Geomechanical Modeling and Wellbore Stability Analysis for Challenging Formations in the Tano Basin, Ghana.
5. Adebayo, Ismail Akanmu. (2022). ASSESSMENT OF PERFORMANCE OF FERROCENE NANOPARTICLE -HIBISCUS CANNABINUS BIODIESEL

ADMIXED FUEL BLENDED WITH HYDROGEN IN DIRECT INJECTION (DI) ENGINE. Transactions of Tianjin University. 55. 10.5281/zenodo.16931428.

6. Adebayo, I. A., Olagunju, O. J., Nkansah, C., Akomolafe, O., Godson, O., Blessing, O., & Clifford, O. (2019). Water-Energy-Food Nexus in Sub-Saharan Africa: Engineering Solutions for Sustainable Resource Management in Densely Populated Regions of West Africa.
7. Nkansah, Christopher. (2022). Evaluation of Sustainable Solutions for Associated Gas Flaring Reduction in Ghana's Offshore Operations. 10.13140/RG.2.2.20853.49122.
8. Asamoah, A. N. (2023). The Cost of Ignoring Pharmacogenomics: A US Health Economic Analysis of Preventable Statin and Antihypertensive Induced Adverse Drug Reactions. *SRMS JOURNAL OF MEDICAL SCIENCE*, *8*(01), 55-61.
9. Karamchand, G., & Aramide, O. O. (2023). AI Deep Fakes: Technological Foundations, Applications, and Security Risks. *Well Testing Journal*, *32*(2), 165-176.
10. Karamchand, G., & Aramide, O. O. (2023). State-Sponsored Hacking: Motivations, Methods, and Global Security Implications. *Well Testing Journal*, *32*(2), 177-194.
11. Adebayo, Ismail Akanmu. (2024). A COMPREHENSIVE REVIEW ON THE INTEGRATION OF GEOTHERMAL-SOLAR HYBRID ENERGY SYSTEMS FOR HYDROGEN PRODUCTION. 10.5281/zenodo.16901970.
12. Aramide, Oluwatosin. (2024). CYBERSECURITY AND THE RISING THREAT OF RANSOMWARE. Journal of Tianjin University Science and Technology. 57. 10.5281/zenodo.16948440.
13. Shaik, Kamal Mohammed Najeeb. (2024). Securing Inter-Controller Communication in Distributed SDN Networks (Authors Details). International Journal of Social Sciences & Humanities (IJSSH). 10. 2454-566. 10.21590/ijtmh.10.04.06.
14. Sanusi, B. Design and Construction of Hospitals: Integrating Civil Engineering with Healthcare Facility Requirements.
15. Olagunju, O. J., Adebayo, I. A., Blessing, O., & Godson, O. (2024). Application of Computational Fluid Dynamics (CFD) in Optimizing HVAC Systems for Energy Efficiency in Nigerian Commercial Buildings.
16. Vethachalam, S. (2024). Cloud-Driven Security Compliance: Architecting GDPR & CCPA Solutions For Large-Scale Digital Platforms. *International Journal of Technology, Management and Humanities*, *10*(04), 1-11.
17. Hasan, N., Riad, M. J. A., Das, S., Roy, P., Shuvo, M. R., & Rahman, M. (2024, January). Advanced retinal image segmentation using u-net architecture: A leap forward in ophthalmological diagnostics. In *2024 Fourth International Conference on Advances in Electrical, Computing, Communication and Sustainable Technologies (ICAECT)* (pp. 1-6). IEEE.
18. Onoja, M. O., Onyenze, C. C., & Akintoye, A. A. (2024). DevOps and Sustainable Software Engineering: Bridging Speed, Reliability, and Environmental Responsibility. *International Journal of Technology, Management and Humanities*, *10*(04).

19. Arefin, S., & Zannat, N. T. (2024). The ROI of Data Security: How Hospitals and Health Systems Can Turn Compliance into Competitive Advantage. *Multidisciplinary Journal of Healthcare (MJH)*, *1*(2), 139-160.
20. Riad, M. J. A., Debnath, R., Shuvo, M. R., Ayrin, F. J., Hasan, N., Tamanna, A. A., & Roy, P. (2024, December). Fine-Tuning Large Language Models for Sentiment Classification of AI-Related Tweets. In *2024 IEEE International Women in Engineering (WIE) Conference on Electrical and Computer Engineering (WIECON-ECE)* (pp. 186-191). IEEE.
21. Shaik, Kamal Mohammed Najeeb. (2024). SDN-BASED TRAFFIC ENGINEERING FOR DATA CENTER NETWORKS: OPTIMIZING PERFORMANCE AND EFFICIENCY. International Journal of Engineering and Technical Research (IJETR). 08. 10.5281/zenodo.15800046.
22. Sanusi, B. O. (2024). The Role of Data-Driven Decision-Making in Reducing Project Delays and Cost Overruns in Civil Engineering Projects. *SAMRIDDHI: A Journal of Physical Sciences, Engineering and Technology*, *16*(04), 182-192.
23. Roy, P., Riad, M. J. A., Akter, L., Hasan, N., Shuvo, M. R., Quader, M. A., ... & Anwar, A. S. (2024, May). Bilstm models with and without pretrained embeddings and bert on german patient reviews. In *2024 International Conference on Advances in Modern Age Technologies for Health and Engineering Science (AMATHE)* (pp. 1-5). IEEE.
24. Singh, S. (2020). Deep Margin Elevation: A Conservative Alternative in Restorative Dentistry. *SRMS JOURNAL OF MEDICAL SCIENCE*, *5*(02), 1-9.
25. Heng, A. S. Y. (2009). *Intelligent prognostics of machinery health utilising suspended condition monitoring data* (Doctoral dissertation, Queensland University of Technology).
26. Zheng, L., Wang, H., Mei, L., Chen, Q., Zhang, Y., & Zhang, H. (2021). Artificial intelligence in digital cariology: a new tool for the diagnosis of deep caries and pulpitis using convolutional neural networks. *Annals of Translational Medicine*, *9*(9), 763.
27. Bindal, P., Bindal, U., Kazemipoor, M., Kazemipoor, M., & Jha, S. K. (2019). Hybrid machine learning approaches in viability assessment of dental pulp stem cells treated with platelet-rich concentrates on different periods. *Applied Medical Informatics*, *41*(3), 93-101.
28. Odunaike, A. DESIGNING ADAPTIVE COMPLIANCE FRAMEWORKS USING TIME SERIES FRAUD DETECTION MODELS FOR DYNAMIC REGULATORY AND RISK MANAGEMENT ENVIRONMENTS.
29. Shan, T., Tay, F. R., & Gu, L. (2021). Application of artificial intelligence in dentistry. *Journal of dental research*, *100*(3), 232-244.
30. Aminoshariae, A., Kulild, J., & Nagendrababu, V. (2021). Artificial intelligence in endodontics: current applications and future directions. *Journal of endodontics*, *47*(9), 1352-1357.
31. Bhatia, A., & Singh, R. (2013). Using Bayesian Network as Decision making system tool for deciding Treatment plan for Dental caries. *Journal of Academia and Industrial Research (JAIR)*, *2*(2), 93.

32. Singh, S. (2019). Vital pulp therapy: A Bio ceramic-Based Approach. *Indian Journal of Pharmaceutical and Biological Research*, *7*(04), 10-18.
33. Pethani, F. (2021). Promises and perils of artificial intelligence in dentistry. *Australian Dental Journal*, *66*(2), 124-135.
34. Lahoud, P., EzEldeen, M., Beznik, T., Willems, H., Leite, A., Van Gerven, A., & Jacobs, R. (2021). Artificial intelligence for fast and accurate 3-dimensional tooth segmentation on cone-beam computed tomography. *Journal of Endodontics*, *47*(5), 827-835.
35. Ren, R., Luo, H., Su, C., Yao, Y., & Liao, W. (2021). Machine learning in dental, oral and craniofacial imaging: a review of recent progress. *PeerJ*, *9*, e11451.
36. Heo, M. S., Kim, J. E., Hwang, J. J., Han, S. S., Kim, J. S., Yi, W. J., & Park, I. W. (2021). Artificial intelligence in oral and maxillofacial radiology: what is currently possible?. *Dentomaxillofacial Radiology*, *50*(3), 20200375.