Saudi Journal of Medicine and Public Health

https://saudijmph.com/index.php/pub

https://doi.org/10.64483/202412255

Artificial Intelligence in Oral and Maxillofacial Diseases: Enhancing Early Detection, Advancing Treatment Methods, and Accelerating the Prevention and Management Process.

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Abstract

Background: Oral and Maxillofacial (OMF) diseases are a significant global health challenge. The conventional approach to diagnosis, which bears subjectivity from the clinical and radiographic aspects, can delay treatment stratification. Artificial Intelligence (AI), specifically deep learning, could solve these problems by providing new levels of precision and personalization to OMF medicine.

Aim: The purpose of this review is to summarize and describe the current uses of AI in detecting, treating, and managing OMF diseases, including how machine learning can provide deeper diagnostics, personalized treatment, and predictive analyses.

Methods: A narrative review was conducted using peer-reviewed literature documenting AI in OMF medicine from PubMed, Scopus, IEEE Xplore, and Google Scholar (2018-2024).

Results: Convolutional neural networks continue to exhibit strong performance in the detection and classification of oral and maxillofacial pathologies from images, consistently performing equal to or better than clinicians in these classifications. AI-based systems provide a new level of precision in surgical treatment planning, implantology, and orthodontics. Predictive analytics provide a level of risk stratification and prognosis creation that facilitates the shift from reactionary health management to proactive health management.

Conclusion: AI has begun to reshape the practice of OMF medicine, whether it be through earlier detection, a more precise intervention, or better overall patient outcomes. Challenges do exist, as in all fields, such as real-world data standardization and clinical validation. However, the opportunities for AI to establish a standard of care based on proactive, predictive, and personalized capabilities in conjunction with human capabilities is significant.

Keywords: Artificial Intelligence, Oral Cancer Detection, Precision Dentistry, Predictive Analytics, Deep Learning. .

1. Introduction

Oral health is fundamental to general health and well-being. However, diseases of the oral cavity and maxillofacial complex affect about 3.5 billion people worldwide, with untreated dental caries being the most common condition (Tonetti et al., 2017; James et al., 2018). The traditional diagnostic workflow in dental and OMF surgery has traditionally relied mostly on the expertise of the clinician in interpreting visible signs and radiographs in two dimensions, and it can be subjective with great variability. Early signs related to insidious diseases such as OSCC or periodontitis are not readily detectable and are usually overlooked in routine examinations, leading to late diagnosis and poor prognostic outcomes (Warnakulasuriya, 2018).

The digital transformation of healthcare, characterized by the proliferation of electronic health records, three-dimensional imaging, and genomic data, has provided fertile ground for the application of AI. In medicine, AI has already accomplished outstanding feats in areas like radiology and dermatology (Alabi et al., 2021). With its rich store of visual and radiographic data, OMF medicine is uniquely positioned to benefit from this technological revolution. AI, particularly a subset called ML and its deeper cousin, DL, can learn complex patterns from large datasets. CNNs are a class of DL models that

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Receive Date: 3 December 2024, Revise Date: 29 December 2024, Accept Date: 31 December 2024

are specifically adept at image analysis, which makes them perfect for applications like detecting caries on bitewings or periapical lesions on panoramic radiographs and segmenting tumors from CBCT scans.

This review serves as an overview of both the current and emerging applications of AI across the spectrum of OMF diseases. It is organized into three key sections: the role played by AI in the enhancement of early detection and diagnosis, the effect it exerts on the development and personalization of treatment approaches, and its prospects for accelerating prevention and long-term management. By synthesizing the latest evidence, this article will outline a pathway toward a future wherein AI-assisted clinicians can provide care that is not only more accurate and efficient but fundamentally more preventive and patient-centric.

Improving Early Detection and Diagnosis

Diagnostic applications represent the first and most prolific area of application of AI in OMF medicine; thus, AI systems are being used to assist in the automation and enhancement of analysis of clinical and radiographic data, helping to minimize diagnostic errors and allow for earlier interventions (Table 1 & Figure 1).

AI in Dental Caries and Periodontal Disease Detection

The two most common oral diseases are dental caries and periodontitis. Traditionally, diagnosis depends on visual-tactile examination and radiographic interpretation. To automate this process, thousands of annotated periapical, bitewing, and panoramic radiographs have been used to train various AI models, mostly CNNs. In the case of the detection of caries, proximal, occlusal, and root surface lesions can be shown with high sensitivity and specificity. Generally, their performance was better than that of dental students and, in some studies, showed performances equal to those of expert radiologists. According to Musri et al. (2021), importantly, AI can standardize detection and eliminate the variability introduced by human fatigue or experience level.

Meanwhile, the diagnostic criteria involved in periodontitis are somewhat more complicated, mostly related to bone loss, calculus, and clinical attachment level. AI systems have been developed that are capable of automatically measuring, on panoramic radiographs, bone loss as a percentage of root length to provide a quantifiable and reproducible metric for diagnosing and staging the disease (Krois et al., 2019). More advanced systems are beginning to integrate radiographic analysis with clinical data to offer a comprehensive periodontal diagnosis. Moreover, AI applied to intraoral photographs has the ability to detect early gingival inflammation, calculus, and even subgingival tartar, thus triggering preventive measures before significant bone loss has taken place (Li et al., 2021; Hsiao et al., 2021). This capability for mass screening could revolutionize public dental health initiatives.

Revolutionizing Oral Cancer Screening

The 5-year survival rate of oral cancer, especially OSCC, relies heavily on the stage at which the disease is diagnosed. While early-stage detection increases survival to more than 80%, late-stage diagnosis decreases to less than 30% (Morgan et al., 2022). AI has emerged as a strong method to enhance the visual examination performed by dentists. Currently, deep learning models trained on enormous datasets of clinical photographs of oral lesions, including leukoplakia, erythroplakia, and OSCC, can classify such lesions as benign, potentially malignant, or malignant with high accuracy.

For instance, a CNN system developed by Welikala et al. (2020) demonstrated 98% sensitivity and 92% specificity in differentiating oral potentially malignant disorders and OSCC from clinical images, thereby outperforming a group of general dental practitioners. These systems can be deployed on smartphones and could provide a low-cost screening tool for primary care providers in remote or underserved areas who could refer high-risk cases to specialists (Uthoff et al., 2018). Beyond visual inspection, AI is also being used to analyze histopathological slides, where it identifies micrometastases, grades tumors, and even predicts molecular markers from the tissue morphology to aid pathologists in providing more accurate and timely reports.

1.3 Advanced Interpretation of Maxillofacial Imaging

CBCT and MRI have become standard for complex OMF surgical planning. The interpretation of these 3D volumes is time-consuming and requires specialized training. AI is dramatically accelerating this process through automated segmentation and detection. CNNs can automatically segment critical anatomical structures from CBCT scans, including the mandibular canal, maxillary sinuses, and individual teeth, in a matter of seconds—a task that can take a human operator 30 minutes or more (Jaskari et al., 2020). This not only saves time but also increases precision.

AI algorithms are also being trained to detect a wide range of pathologies from these scans. They can identify not only periapical lesions but also cysts, such as radicular cysts and dentigerous cysts, and fibro-osseous lesions with high reliability. Regarding TMDs, this may involve AI analysis of MRI studies for automatic disc position, effusion detection, and quantification of condylar degeneration by providing objective data to support a clinical diagnosis. This is according to Lin et al. (2022). Automated analysis ensures subtle radiographic signs are not missed and offers a consistent baseline against which disease progression is monitored over time.

Advancing Treatment Methods

Beyond diagnostics, AI is presently actively reshaping treatment protocols across OMF surgery, implantology, and orthodontics, driving them toward highly personalized and precision-based interventions.

Table 1: AI Applications in the Detection and Diagnosis of OMF Diseases

Disease/Application	AI Input Data	AI Function/Task	Reported Performance & Impact
Dental Caries	Bitewing, Periapical Radiographs	Automated detection and classification of lesion severity.	>90% sensitivity/specificity; reduces missed diagnoses (Musri et al., 2021).
Periodontal Disease	Panoramic Radiographs, Intraoral Photos	Automated bone loss measurement, calculus detection, and disease staging.	Bone loss measurement accuracy >92%; enables mass screening (Krois et al., 2019; Li et al., 2023).
Oral Potentially Malignant Disorders (OPMD) & OSCC	Clinical Photographs, Histopathology Slides	Classification of lesions (benign/malignant), tumor grading, and biomarker prediction.	Sensitivity/Specificity >95% for OSCC detection; aids pathologists (Welikala et al., 2020).
Anatomical Segmentation	CBCT Scans	Automatic delineation of mandibular canal, teeth, and sinuses.	Dice similarity coefficient >0.9; reduces planning time by >80% (Jaskari et al., 2020).
Cysts & Tumors	Panoramic, CBCT Scans	Detection and differential diagnosis of radiolucent/radiopaque lesions.	High accuracy in distinguishing ameloblastoma from odontogenic keratocyst (Poedjiastoeti & Suebnukarn, 2018).
Temporomandibular Joint (TMJ) Disorders	MRI, CBCT Scans	Assessment of disc displacement, condylar morphology, and osseous changes.	High concordance with expert radiologists; provides quantitative data (Lin et al., 2022).

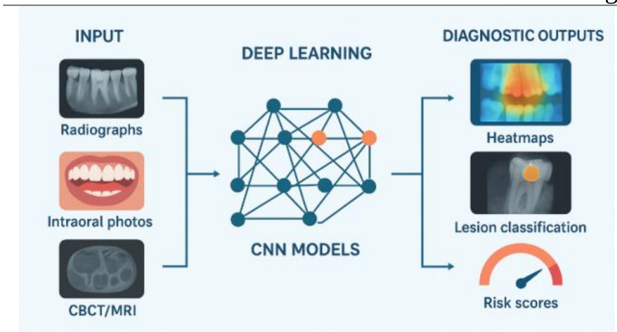

Figure 1: AI Integration in Early Detection of Oral and Maxillofacial Diseases

AI in Surgical Planning and Execution

AI is now revolutionizing the planning of complex OMF surgeries, such as orthognathic surgery for dentofacial deformities or reconstruction after oncological resection. Traditional planning involves manual, time-consuming cephalometric tracing and model surgery. AI-driven software is able to perform landmark identification and cephalometric analysis autonomously on lateral cephalograms with accuracy to the sub-millimeter level, providing a comprehensive diagnostic assessment instantly (Yoon et al., 2022; Junaid et al., 2022). In orthognathic surgery, predictive AI models are able to simulate the postoperative soft-tissue appearance based on the planned bony movements, thereby enabling surgeons to optimize the surgical plan for functional and aesthetic outcomes and manage patient expectations effectively (Suh et al., 2019).

In oncology, AI is helping in tumor margin delineation. AI algorithms may define the extension of tumor infiltration from preoperative CT/CBCT and MRI scans more precisely than the human eye can and suggest optimal resection margins to balance oncological safety with tissue preservation (Santer et al., 2022). Further, in reconstructive surgery, AI automates the design of patient-specific implants and surgical guides for fibula free flap reconstruction with a perfect fit and reduces operating time.

Optimizing Dental Implantology

Dental implant success hinges on precise planning based on bone quality, quantity, and vital anatomy. AI systems integrate CBCT data with digital surface scans to create a virtual patient. They can then automatically propose the ideal implant size, position, and angulation by considering the bone density, proximity to the mandibular canal and mental foramen, and the planned prosthetic outcome (Shujaat et al., 2023). This goes beyond static guides; AI can simulate bone remodeling and long-term biomechanical stress, predicting the risk of future peri-implant bone loss and informing pre-emptive design modifications.

AI is also being used in the prediction of implant success rates. ML models, based on patient-specific factors such as age, medical history, including diabetes or smoking habits, bone quality, and implant characteristics, can make a personalized risk assessment for early failure or peri-implantitis, thus permitting a tailored treatment protocol and follow-up schedule by the clinician (Yadalam et al., 2022; Alharbi & Almutiq, 2022).

Personalization of Orthodontic-Orthopedic Treatment

Orthodontics is another field ripe for AI disruption. AI algorithms can automatically analyze dental casts and intraoral scans to identify tooth-size discrepancies, arch form, and malocclusion classification. They can also predict treatment difficulty and the likelihood of requiring tooth extractions (Ozsari et al., 2023). Probably the biggest advance, however, is in the prediction of tooth movement. ML models, which have been trained on thousands of sequential scans of patients undergoing treatment, are now able to predict the individual tooth response to different forces and appliances. For the first time, truly personalized and optimized clear aligner treatment plans can now be created with the potential of reducing overall treatment time and improving the final occlusal outcomes (Ren et al., 2022). For growing patients, AI can forecast the mandibular growth pattern from serial cephalograms, guiding the timing and type of orthopaedic intervention for class II and III malocclusions.

Accelerating Prevention and Management

The ultimate promise of AI in healthcare is to shift from treatment to prevention and from generic care to personalized long-term management. In OMF medicine, this is starting to take shape through predictive analytics and intelligent monitoring systems (Table 2 & Figure 2).

Predictive Analytics for Risk Assessment

A major frontier for AI involves the development of comprehensive risk assessment tools. By integrating data from a patient's medical history, genetic predispositions, lifestyle factors (diet, smoking, alcohol use), salivary biomarkers, and microbiome analysis, ML models can yield personalized risk profiles about the development of major oral diseases. For instance, a model might estimate a patient's 5-year risk of developing new caries lesions or the progression of periodontitis. This lets dentists move away from a one-size-fits-all recall system-for instance, check-ups every 6 months, to a risk-based recall system, where high-risk patients are monitored more frequently and with greater intensity, while low-risk patients avoid unnecessary appointments.

Table 2: AI in Prevention, Prognostics, and Personalized Management

Application Area	Data Sources	AI Function	Clinical Impact
Personalized Caries Risk Assessment	Diet history, microbiome, salivary tests, and clinical data.	Generates individualized risk scores and predicts future lesion development.	Enables targeted, risk-based preventive care; optimizes recall intervals (Schwendicke et al., 2020; Schwendicke & Krois, 2022).
Remote Oral Hygiene Coaching	Data from AI-powered toothbrushes (motion, pressure, coverage).	Real-time feedback and personalized coaching on brushing technique.	Improves patient adherence and plaque removal efficacy (Shen et al., 2022).
Chronic Disease Monitoring (Teledentistry)	Serial intraoral scans or smartphone photos of the oral mucosa.	Tracks disease progression (e.g., gingival recession, oral lichen planus).	Facilitates early intervention and remote patient management (Homsi et al., 2023).
Oral Cancer Prognostication	Histopathology, genomic data, and clinical stage.	Predicts risk of recurrence, metastasis, and treatment response.	Informs adjuvant therapy choices and follow-up intensity (Yang et al., 2022).
Periodontal Treatment Response	Baseline clinical data, microbiome composition.	Identifies patients likely to be "non-responders" to standard therapy.	Guides the initial treatment strategy towards more effective protocols.

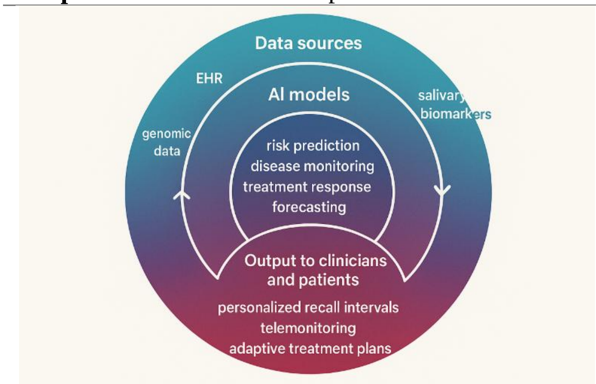

Figure 2: Predictive and Personalized AI Framework for Oral Health Management

Remote Monitoring and Teledentistry

By combining AI with wearable sensors and smartphone technology, a new model of continuous remote oral health monitoring is possible. AI-powered smart toothbrushes can analyze brushing patterns in real time and offer feedback to enhance oral hygiene efficacy and consistency (Shajari et al., 2023). Smart brushes can provide real-time feedback during brushing on areas requiring increased brushing time and pressure to improve cleaning efficacy. Intraoral scanners are becoming increasingly affordable and portable, which enables patients to take intraoral scans at home. Changes, like gingival recession, tooth wear, or white spot lesion development over time, can then be flagged by AI monitoring these scans, prompting early intervention by the dentist. For patients with oral lichen planus, AI analysis of regular smartphone photographs of the oral mucosa can track lesion activity and response to treatment, facilitating remote disease management (Rybinski et al., 2021).

Prognostication and Outcome Prediction

AI further predicts the probable course and outcome after a disease is diagnosed or treatment is initiated. In oral cancer, AI models are being developed by integrating histopathological features with genomic and clinical data for predicting tumor aggressiveness, likelihood of metastasis, and response to chemotherapy or radiotherapy, thus guiding the selection of the most effective therapeutic regimen (Yang et al., 2022). Similarly, in periodontitis, AI has the capability of analyzing baseline clinical and microbiological data to predict which patients will most likely be "non-responders" to conventional therapy, thus encouraging a more aggressive or alternative initial treatment approach.

Challenges and Future Directions

Despite the outstanding progress, several hurdles are yet to be overcome before AI is widely used in a clinical manner in OMF medicine. One major issue pertains to data quality and heterogeneity. AI algorithms require immense datasets that are diverse in content and well-annotated. Lack of standardization in data formats, together with biased datasets, can prevent model generalizability (Hamid, 2023). There are also regulatory and ethical considerations. The "black box" nature of some complex DL models-in which at least some aspect of the reasoning leading to a decision is not clear-raises concerns about accountability and trust (Pierce et al., 2022; Benzinger et al., 2023). Strong clinical trials that prospectively validate AI tools are required before being routinely used in care pathways.

The future development of integrated "AI clinical assistants" holds promise. These systems will not work in a vacuum but will be integral to the clinical workflow, evaluating seamlessly all the data coming from everywhere—EHRs, radiographs, genomic tests, and real-time sensor data—to give one unified diagnostic, treatment, and prognostic summary to the clinician. Moreover, integration of AI with other emerging technologies, such as augmented reality for surgical navigation and 3D printing for instant fabrication of guides and implants, will result in a fully digital OMF workflow (Zoabi et al., 2022; Miragall et al., 2023).

Conclusion

The integration of artificial intelligence into the practice of Oral and Maxillofacial medicine is not a prospect for the distant future; it forms one continuum of revolution. From enhancing the detection of caries and cancer with superhuman accuracy to personalizing surgical and orthodontic plans, from predicting disease risk to enabling remote management, AI is fundamentally increasing the capability of clinicians. While there are considerable challenges yet to overcome in terms of data governance, model validation, and clinical integration, the trajectory is clear. By embracing this technology responsibly, the specialty of OMF medicine can transition toward a more efficient, precise, and ultimately preventive paradigm that ensures better health outcomes for patients worldwide.

References

1. Alabi, R. O., Bello, I. O., Youssef, O., Elmusrati, M., Mäkitie, A. A., & Almangush, A. (2021). Utilizing deep machine learning for prognostication of oral squamous cell carcinoma—a systematic review. *Frontiers in oral health*, *2*, 686863. https://doi.org/10.3389/froh.2021.686863
2. Alharbi, M. T., & Almutiq, M. M. (2022). Prediction of dental implants using machine learning algorithms. *Journal of Healthcare Engineering*, *2022*(1), 7307675. https://doi.org/10.1155/2022/7307675
3. Benzinger, L., Ursin, F., Balke, W. T., Kacprowski, T., & Salloch, S. (2023). Should Artificial Intelligence be used to support clinical ethical decision-making? A systematic review of reasons. *BMC medical ethics*, *24*(1), 48. https://doi.org/10.1186/s12910-023-00929-6
4. Hamid, O. H. (2023). Data-centric and model-centric AI: Twin drivers of compact and robust industry 4.0 solutions. *Applied Sciences*, *13*(5), 2753. https://doi.org/10.3390/app13052753
5. Homsi, K., Snider, V., Kusnoto, B., Atsawasuwan, P., Viana, G., Allareddy, V., ... & Elnagar, M. H. (2023). In-vivo evaluation of artificial intelligence driven remote monitoring technology for tracking tooth movement and reconstruction of 3-dimensional digital models during orthodontic treatment. *American Journal of Orthodontics and Dentofacial Orthopedics*, *164*(5), 690-699 https://doi.org/10.1016/j.ajodo.2023.04.019
6. Hsiao, T. Y., Ho, Y. C., Chen, M. R., Lee, S. Y., & Sun, C. W. (2021). Disease activation maps for subgingival dental calculus identification based on intelligent dental optical coherence tomography. *Translational Biophotonics*, *3*(3), e202100001. https://doi.org/10.1002/tbio.202100001

7. James, S. L., Abate, D., Abate, K. H., Abay, S. M., Abbafati, C., Abbasi, N., ... & Briggs, A. M. (2018). Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *The lancet*, *392*(10159), 1789-1858. https://doi.org/10.1016/S0140-6736(18)32279-7
8. Jaskari, J., Sahlsten, J., Järnstedt, J., Mehtonen, H., Karhu, K., Sundqvist, O., ... & Kaski, K. (2020). Deep learning method for mandibular canal segmentation in dental cone beam computed tomography volumes. *Scientific reports*, *10*(1), 5842. https://doi.org/10.1038/s41598-020-62321-3
9. Junaid, N., Khan, N., Ahmed, N., Abbasi, M. S., Das, G., Maqsood, A., ... & Heboyan, A. (2022, December). Development, application, and performance of artificial intelligence in cephalometric landmark identification and diagnosis: a systematic review. In *Healthcare* (Vol. 10, No. 12, p. 2454). MDPI. https://doi.org/10.3390/healthcare10122454
10. Krois, J., Ekert, T., Meinhold, L., Golla, T., Kharbot, B., Wittemeier, A., ... & Schwendicke, F. (2019). Deep learning for the radiographic detection of periodontal bone loss. *Scientific reports*, *9*(1), 8495. https://doi.org/10.1038/s41598-019-44839-3
11. Lin, B., Cheng, M., Wang, S., Li, F., & Zhou, Q. (2022). Automatic detection of anteriorly displaced temporomandibular joint discs on magnetic resonance images using a deep learning algorithm. *Dentomaxillofacial Radiology*, *51*(3), 20210341. https://doi.org/10.1259/dmfr.20210341
12. Li, W., Liang, Y., Zhang, X., Liu, C., He, L., Miao, L., & Sun, W. (2021). A deep learning approach to automatic gingivitis screening based on classification and localization in RGB photos. *Scientific Reports*, *11*(1), 16831. https://doi.org/10.1038/s41598-021-96091-3
13. Miragall, M. F., Knoedler, S., Kauke-Navarro, M., Saadoun, R., Grabenhorst, A., Grill, F. D., ... & Knoedler, L. (2023). Face the future—artificial intelligence in oral and maxillofacial surgery. *Journal of clinical medicine*, *12*(21), 6843. https://doi.org/10.3390/jcm12216843
14. Morgan, E., Soerjomataram, I., Rumgay, H., Coleman, H. G., Thrift, A. P., Vignat, J., ... & Arnold, M. (2022). The global landscape of esophageal squamous cell carcinoma and esophageal adenocarcinoma incidence and mortality in 2020 and projections to 2040: new estimates from GLOBOCAN 2020. *Gastroenterology*, *163*(3), 649-658. https://doi.org/10.1053/j.gastro.2022.05.054
15. Musri, N., Christie, B., Ichwan, S. J. A., & Cahyanto, A. (2021). Deep learning convolutional neural network algorithms for the early detection and diagnosis of dental caries on periapical radiographs: A systematic review. *Imaging science in dentistry*, *51*(3), 237. https://doi.org/10.5624/isd.20210074
16. Ozsari, S., Güzel, M. S., Yılmaz, D., & Kamburoğlu, K. (2023). A comprehensive review of artificial intelligence based algorithms regarding temporomandibular joint related diseases. *Diagnostics*, *13*(16), 2700. https://doi.org/10.3390/diagnostics13162700
17. Pierce, R. L., Van Biesen, W., Van Cauwenberge, D., Decruyenaere, J., & Sterckx, S. (2022). Explainability in medicine in an era of AI-based clinical decision support systems. *Frontiers in genetics*, *13*, 903600. https://doi.org/10.3389/fgene.2022.903600
18. Poedjiastoeti, W., & Suebnukarn, S. (2018). Application of convolutional neural network in the diagnosis of jaw tumors. *Healthcare informatics research*, *24*(3), 236-241. https://doi.org/10.4258/hir.2018.24.3.236
19. Ren, L., Liu, L., Wu, Z., Shan, D., Pu, L., Gao, Y., ... & Lai, W. (2022). The predictability of orthodontic tooth movements through clear aligner among first-premolar extraction patients: a multivariate analysis. *Progress in Orthodontics*, *23*(1), 52. https://doi.org/10.1186/s40510-022-00447-y
20. Rybinski, M., Dai, X., Singh, S., Karimi, S., & Nguyen, A. (2021). Extracting family history information from electronic health records: natural language processing analysis. *JMIR Medical Informatics*, *9*(4), e24020. https://doi.org/10.2196/24020
21. Santer, M., Kloppenburg, M., Gottfried, T. M., Runge, A., Schmutzhard, J., Vorbach, S. M., ... & Freysinger, W. (2022). Current applications of artificial intelligence to classify cervical lymph nodes in patients with head and neck squamous cell carcinoma—a systematic review. *Cancers*, *14*(21), 5397. https://doi.org/10.3390/cancers14215397
22. Schwendicke, F., & Krois, J. (2022). Data dentistry: how data are changing clinical care and research. *Journal of dental research*, *101*(1), 21-29. https://doi.org/10.1177/00220345211020265
23. Schwendicke, F. A., Samek, W., & Krois, J. (2020). Artificial intelligence in dentistry: chances and challenges. *Journal of dental research*, *99*(7), 769-774. https://doi.org/10.1177/0022034520915714
24. Shajari, S., Kuruvinashetti, K., Komeili, A., & Sundararaj, U. (2023). The emergence of AI-based wearable sensors for digital health technology: a review. *Sensors*, *23*(23), 9498. https://doi.org/10.3390/s23239498
25. Shen, K. L., Huang, C. L., Lin, Y. C., Du, J. K., Chen, F. L., Kabasawa, Y., ... & Huang, H. L.

(2022). Effects of artificial intelligence-assisted dental monitoring intervention in patients with periodontitis: a randomized controlled trial. *Journal of clinical periodontology*, *49*(10), 988-998. https://doi.org/10.1111/jcpe.13675

26. Shujaat, S., Riaz, M., & Jacobs, R. (2023). Synergy between artificial intelligence and precision medicine for computer-assisted oral and maxillofacial surgical planning. *Clinical oral investigations*, *27*(3), 897-906. https://doi.org/10.1007/s00784-022-04706-4
27. Suh, H. Y., Lee, H. J., Lee, Y. S., Eo, S. H., Donatelli, R. E., & Lee, S. J. (2019). Predicting soft tissue changes after orthognathic surgery: the sparse partial least squares method. *The Angle Orthodontist*, *89*(6), 910-916. https://doi.org/10.2319/120518-851.1
28. Tonetti, M. S., Bottenberg, P., Conrads, G., Eickholz, P., Heasman, P., Huysmans, M. C., ... & Paris, S. (2017). Dental caries and periodontal diseases in the ageing population: call to action to protect and enhance oral health and well-being as an essential component of healthy ageing–Consensus report of group 4 of the joint EFP/ORCA workshop on the boundaries between caries and periodontal diseases. *Journal of clinical periodontology*, *44*, S135-S144. https://doi.org/10.1111/jcpe.12681
29. Uthoff, R. D., Song, B., Sunny, S., Patrick, S., Suresh, A., Kolur, T., ... & Liang, R. (2018). Point-of-care, smartphone-based, dual-modality, dual-view, oral cancer screening device with neural network classification for low-resource communities. *PloS one*, *13*(12), e0207493. https://doi.org/10.1371/journal.pone.0207493
30. Warnakulasuriya, S. (2018). Clinical features and presentation of oral potentially malignant disorders. *Oral surgery, oral medicine, oral pathology and oral radiology*, *125*(6), 582-590. https://doi.org/10.1016/j.oooo.2018.03.011
31. Welikala, R. A., Remagnino, P., Lim, J. H., Chan, C. S., Rajendran, S., Kallarakkal, T. G., ... & Barman, S. A. (2020). Automated detection and classification of oral lesions using deep learning for early detection of oral cancer. *Ieee Access*, *8*, 132677-132693. https://doi.org/10.1109/ACCESS.2020.3010180
32. Yadalam, P. K., Trivedi, S. S., Krishnamurthi, I., Anegundi, R. V., Mathew, A., Al Shayeb, M., ... & Rajkumar, R. (2022). Machine learning predicts patient tangible outcomes after dental implant surgery. *IEEE Access*, *10*, 131481-131488. https://doi.org/10.1109/ACCESS.2022.3228793
33. Yang, S. Y., Li, S. H., Liu, J. L., Sun, X. Q., Cen, Y. Y., Ren, R. Y., ... & Liao, W. (2022). Histopathology-based diagnosis of oral squamous cell carcinoma using deep learning. *Journal of Dental Research*, *101*(11), 1321-1327. https://doi.org/10.1177/00220345221089858
34. Yoon, H. J., Kim, D. R., Gwon, E., Kim, N., Baek, S. H., Ahn, H. W., ... & Kim, S. J. (2022). Fully automated identification of cephalometric landmarks for upper airway assessment using cascaded convolutional neural networks. *European Journal of Orthodontics*, *44*(1), 66-77. https://doi.org/10.1093/ejo/cjab054
35. Zoabi, A., Redenski, I., Oren, D., Kasem, A., Zigron, A., Daoud, S., ... & Srouji, S. (2022). 3D printing and virtual surgical planning in oral and maxillofacial surgery. *Journal of Clinical Medicine*, *11*(9), 2385. https://doi.org/10.3390/jcm11092385