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A Review on Artificial Intelligence in Oral and Maxillofacial Surgery

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ABSTRACT

Artificial Intelligence (AI) has emerged as a transformative force in Oral and Maxillofacial Surgery (OMFS), leveraging machine learning and deep learning techniques to revolutionize diagnostics, treatment planning, and surgical outcomes. This comprehensive review explores the multifaceted applications of AI in OMFS, spanning from 3D imaging analysis and cephalometrics to pre-surgical planning and implantology. Convolutional Neural Networks (CNNs) and Generative Adversarial Networks (GANs) form the backbone of AI algorithms, enhancing accuracy in tasks such as disease classification, lesion detection, and anatomical segmentation. The integration of AI in OMFS is driven by technological advancements and the growing adoption of digitisation. While challenges persist, including refining radiology-based diagnoses, the potential for precision, efficiency, and improved patient care positions AI as a transformative tool in shaping the future of OMFS.

Keywords: Artificial Intelligence, convolutional neural networks, deep learning, machine learning, Oral and Maxillofacial Surgery

INTRODUCTION

Artificial intelligence (AI) stands out as a versatile health technology tool, bringing about a transformative impact on medical services by incorporating predictive, preventive, personalised, and participatory approaches. Within the dynamics of AI, various computational concepts, including machine learning, deep learning techniques, and neural networks, play a pivotal role in reshaping the landscape of healthcare. Furthermore, applications powered by artificial intelligence play a pivotal role in fostering optimal adherence to therapeutic regimens, ensuring that patients follow prescribed treatment plans and attain improved health outcomes.[1] These advancements can also be extended to particular specialties within the medical field. In the 2000s, the introduction of three-dimensional models marked a significant development for pre-surgical planning. In maxillofacial surgery, various AI applications leverage digital imaging, 3D photography, intraoral scans, and 3D photographs to anticipate outcomes and strategise surgeries, particularly in cases of skeletal trauma.[2] Convolutional neural networks form a robust foundation for algorithms within machine learning, supporting diagnoses, predictions, and outcome assessments. Additionally, algorithms contribute to treatment decisions and preoperative procedures. Machine learning techniques find application in orthognathic surgery, oral cancerology, and oral surgery within the realm of maxillofacial surgery. The increasing prevalence of AI in Oral and Maxillofacial Surgery (OMFS) is attributed to technological advancements and the widespread adoption of digitisation. Across various domains, computers are now capable of providing secondary opinions, enhancing the accuracy, speed, and efficiency of diagnoses through the integration of AI in OMFS.[3] With its multidisciplinary nature, OMFS plays a pivotal role in addressing a wide spectrum of pathologies, ranging from dental and facial trauma to complex craniofacial deformities. In recent decades, the utilisation of artificial intelligence (AI) in Oral and Maxillofacial Surgery (OMFS) has experienced substantial growth, making notable contributions to different facets of this specialty. AI has found application in tasks including but not limited to diagnosis, cephalometrics, preoperative planning, intraoperative measurements, outcome evaluation, and postoperative follow-up in OMFS.[4] The dynamic evolution of medical technology has witnessed the integration of artificial intelligence (AI) into various healthcare domains, offering innovative solutions to enhance diagnostic accuracy, treatment planning, and surgical outcomes. The advent of AI in healthcare has been particularly transformative, and its applications are progressively permeating diverse medical specialties. In the context of OMFS, AI holds immense promise for revolutionizing traditional practices, presenting opportunities to augment clinical decision-making, streamline surgical procedures, and ultimately elevate patient care.[5] This comprehensive review aims to elucidate the current landscape of AI in OMFS, exploring its applications across diagnostic imaging, treatment planning, surgical simulation, robotics, and data processing.

AI ALGORITHMS

AI algorithms and technologies encompass machine learning, a subset of artificial intelligence dedicated to creating computer models capable of enhancing their performance through experiential learning, eliminating the need for explicit programming. Machine learning algorithms utilise sample data to construct models for making predictions or decisions, with classifications into supervised learning (using labeled data for tasks like classification and regression), unsupervised learning (employing unlabelled data for tasks like clustering), and reinforcement learning (where algorithms learn from dynamic environment feedback, commonly applied in robotics and gaming).[6] Deep learning, a branch of machine learning rooted in neural network research from the 1980s, shares the foundational concept of learning from data but distinguishes itself through its capacity to derive high-level abstractions and complex features from extensive datasets using artificial neural networks.[7] The evolution of deep learning is propelled by advancements addressing overfitting, the availability of high-performance hardware like GPUs, and the abundance of big data.[8] Convolutional Neural Networks (CNNs), a notable architecture in deep learning, significantly contribute to AI progress, particularly in image analysis, finding applications in oral and maxillofacial (OMF) radiology, such as dental caries segmentation in periapical radiographs.[9] Generative Adversarial Networks (GANs), a recent class of deep learning models, comprise two networks competing to generate data resembling the original dataset. In the context of radiographic images, enhanced GAN models using CNNs have been deployed. In OMF radiology, CNNs serve diverse purposes, including classification, detection, and segmentation. Classification determines disease presence, absence, or type, with the development of complex CNN models for solving classification tasks in radiographic image analysis. Detection locates regions with lesions or specific anatomical structures, incorporating additional layers for functions like region proposals or regression. Segmentation delineates anatomical structures or lesions in images from various modalities, including plain radiography, CT, MR, and ultrasound.[10]

ARTIFICIAL INTELLIGENCE AND CBCT ANALYSIS

Artificial intelligence (AI) has gained prominence in dentistry, particularly in the analysis of Cone Beam Computed Tomography (CBCT) scans. CBCT, a valuable 3D imaging tool, has significantly improved diagnostics and treatment planning in dentistry. However, interpreting CBCT images can be intricate, necessitating AI-driven solutions. Preprocessing techniques, including noise reduction, Region of Interest (ROI) cropping, and image alignment, are employed to prepare CBCT data for AI analysis. AI-driven tasks for CBCT include segmentation, detection, and classification, benefiting from various AI architectures to enhance accuracy and efficiency. AI applications in dentistry span diverse areas such as tooth classification and segmentation, alveolar bone detection, mandible segmentation, landmark detection, contour detection, lesion identification, malocclusion classification, and buccal bone thickness measurement.[11] Despite notable progress, challenges persist, particularly in the scarcity of high-quality annotated datasets and the absence of standardised data acquisition protocols. Nevertheless, the integration of AI into dentistry holds substantial promise, evident in its potential to improve diagnosis, treatment planning, and overall patient care. As AI continues to evolve, dentistry is poised for further innovations, ushering in an era of precision and efficiency in dental healthcare. Addressing concerns in diagnostic imaging, the presence of motion artifacts resulting from patient or organ movements is significant. AI has been effectively utilised in dental CT and cone beam CT (CBCT) images to reduce metal artifacts. High-attenuation coefficients of dental crowns and implants can cause scattering, photon starvation, and beam hardening phenomena, leading to the formation of dark and bright streak artifacts that impact diagnostic accuracy. Leveraging AI techniques, including advanced image reconstruction algorithms and deep learning approaches, can mitigate the presence of metal artifacts in dental CT and CBCT images, thereby improving the precision of diagnostic outcomes.[12]

ARTIFICIAL INTELLIGENCE IN DETECTION OF CYSTS AND TUMOURS

One significant application of AI in OMFS is the diagnosis of maxillofacial cysts and tumours, especially in the context of oral cancer. Early detection of pre-malignant lesions is crucial, and machine learning tools utilising autofluorescence measurement or photography have shown promise in this regard. Convolutional Neural Networks (CNNs) dedicated to detecting oral cavity carcinomas have demonstrated comparable performance to experts. Moreover, AI algorithms have been utilised for the detection of metastatic lymph nodes through radiomic analysis, providing valuable radiological biomarkers for tumour lesions' phenotype and microenvironment.[13] The management of cancer patients involves predicting the pathology's evolution, and AI algorithms have been developed to predict survival, risk of recurrence, and postoperative complications. These algorithms are trained on clinicobiological data from medical records, emphasising the importance of maintaining prospective registers and utilising text mining tools for data extraction. In the scope of maxillofacial cysts and tumours, the integration of AI into automated diagnosis has shown promise.[14] Commercial programs and models, such as dentalXr and Dentomo, are available for diagnosing various maxillofacial conditions. AI models utilising asymmetry analysis, surgical navigation programs, and 2D/3D image classification have demonstrated efficacy in segmenting and diagnosing maxillofacial cysts and tumours. While challenges remain, including the need for manual input in the initial phase of lesion detection, AI holds substantial potential for improving accuracy and efficiency in diagnosing maxillofacial conditions. Furthermore, in the context of oral cancer, ML techniques have been applied for early screening, accurate diagnosis, treatment prediction, and prognosis evaluation. ML classifiers have been effective in distinguishing different types of odontogenic cysts, while deep learning algorithms have shown high accuracy in detecting oral cancer in photographic images. ML has also been utilised to predict cancer outcomes based on various prognostic variables, such as histological grade and lymph node metastases. Additionally, ML contributes to the evaluation of treatment complications, with models predicting xerostomia and extra-nodal extension in head and neck cancer patients.[15]

ARTIFICIAL INTELLIGENCE IN ORTHOGNATHIC SURGERY

The integration of new technologies, particularly Artificial Intelligence (AI), has significantly improved the entire orthodontic-surgical management process for patients with dentofacial deformities (DFD). From initial diagnosis to postoperative follow-up, these technologies have enhanced various aspects of the treatment journey. Many articles focus on tools for automating the annotation of tele-radiographs and aiding in cephalometric diagnosis.[16] Automating this task, known for its time-consuming nature and high inter-operator variability, allows for better allocation of medical time, increased reproducibility of measurements, and improved comparability of results. Algorithms are now considered as efficient as experts, with numerous commercial solutions emerging. 3D imaging analysis tools, powered by machine learning, have been proposed to optimise the description of complex

DFD characteristics. Machine learning facilitates rapid and reproducible identification and interpretation of numerous bone and skin landmarks, outperforming other computational techniques.[17] For patients with DFD, the decision for surgery requires experience from both orthodontists and surgeons. Training algorithms on cephalometric values or unannotated imaging studies enables the development of treatment decision support tools, predicting the need for surgery during orthodontic treatment. These algorithms assist practitioners in confirming or reconsidering their decisions, limiting unfavourable aesthetic and functional results. To address the concerns of patients regarding post-operative appearance modifications, planning software now offers simulations of profile changes. AI-assisted analysis of 3D images provides realistic preoperative simulations based on previous treatment outcomes, aiding in surgical planning and communication with patients. Looking ahead, there is a vision for a fully AI-assisted digital workflow capable of diagnosing DFD based on automatic 3D cephalometrics, proposing highly personalised treatment plans, performing realistic surgical simulations, and evaluating surgical outcomes. The realisation of such a comprehensive set of algorithms would require a substantial database of operated patients for training and validation purposes. In orthognathic surgery, AI has proven beneficial for precise preoperative planning. Traditional 2D surgical planning methods have limitations, especially for patients with extensive facial asymmetry. AI concepts, including deep learning networks, have shown promise in accurately diagnosing the need for orthognathic surgery based on various inputs, such as cephalograms and facial photographs. Additionally, AI has been applied to predict treatment outcomes, complications, and the need for future orthognathic surgery.[18]

DISCUSSION AND OTHER APPLICATIONS

AI has demonstrated its potential to enhance efficiency among surgeons and address potential errors in the field of Oral and Maxillofacial Surgery (OMFS). It plays a role in automating diagnosis based on radiology and updating patient records automatically, offering potential improvements in efficiency for surgeons. However, challenges in accuracy for automated radiology-based diagnosis may require further research and refinement. AI also holds promise in improving patient safety by identifying drug interactions and rectifying potential prescribing errors. While current AI tools may not perform complex surgical procedures, there is optimism that they may become capable of handling more intricate tasks in the future. Technological advancements powered by AI could enhance OMF cosmetic surgeries, reducing the time spent anaesthetizing patients and decreasing post-surgery recovery time. AI applications extend to pre-surgical orthopaedics, speech pathology detection, and predicting the need for Cleft Lip and Palate (CLP) surgery, with models demonstrating high accuracy rates ranging from 85% to 95.6%.[19] In the context of impacted third molar extraction, a common procedure in OMFS, algorithms have been proposed to optimise various stages of management. Predictive models assessing the eruption potential of third molars through automatic measurement of their angulation on panoramic radiographs (PR) can aid in the decision-making process for surgical indications.[20] In implantology, AI has been utilised to recognise implant types on radiographs, predict osteointegration success or implant survival, and enhance dental implant design by optimising parameters like porosity, length, and diameter to minimise stress at the implant-bone interface. Studies have evaluated the performance of deep convolutional neural networks (DCNN) for detecting and classifying fractured dental implants using different radiographic images, highlighting the potential of automated DCNN architectures.[21] Machine learning methods, such as random forest (RF), have shown effectiveness in predicting peri-implantitis, with implant functional time identified as a significant influencing factor.[22] Additionally, ML models have been successfully applied for implant type recognition using radiographic images. In the realm of implant design optimisation, artificial neural networks (ANN) combined with genetic algorithms have been employed for predicting the optimum implant dimensions, showcasing the versatility of AI in advancing implantology.[23]

CONCLUSION

In conclusion, the integration of Artificial Intelligence (AI) in Oral and Maxillofacial Surgery (OMFS) marks a transformative phase, streamlining tasks from diagnosis to treatment planning. AI, employing machine learning and deep learning, demonstrates notable success in automating radiographic annotation, predicting surgical needs, and enhancing patient outcomes. Applications range from impacted molar extractions to implantology, with AI models achieving high accuracy in tasks like implant recognition and peri-implantitis prediction. While AI doesn't perform complex surgeries, its potential in orthognathic surgery and facial symmetry assessment is promising. Despite successes, challenges persist, particularly in refining radiology-based diagnoses. Collaboration and data sharing between developers, surgeons, and researchers are critical for ongoing improvement. Overall, the integration of AI in OMFS holds great promise, offering precision in diagnostics, streamlined processes, and a potential revolution in patient care. As technology advances, AI's role in shaping the future of OMFS is set to expand.

REFERENCES

1. Ossowska A, Kusiak A, Świetlik D. Artificial intelligence in dentistry—narrative review. *Int J Environ Res Public Health.* 2022;19:3449. doi: 10.3390/ijerph19063449.

2. Topol E.J. A decade of digital medicine innovation. *Sci. Transl. Med.* 2019;11:eaaw7610.

3. Rasteau S., Ernenwein D., Savoldelli C., Bouletreau P. Artificial intelligence for oral and maxillofacial surgery: A narrative review. *J. Stomatol. Oral. Maxillofac. Surg.* 2022;123:276–282. doi: 10.1016/j.jormas.2022.01.010.

4. Mehrabanian, M. Emerging technologies in oral and maxillofacial surgery. *Br Dent J* **235**, 856 (2023). https://doi.org/10.1038/s41415-023-6611-1

5. Rokhshad R., Keyhan S.O., Yousefi P. Artificial intelligence applications and ethical challenges in oral and maxillofacial cosmetic surgery: A narrative review. *Maxillofac. Plast. Reconstr. Surg.* 2023;45:14. doi: 10.1186/s40902-023-00382-w.

6. Miragall MF, Knoedler S, Kauke-Navarro M, Saadoun R, Grabenhorst A, Grill FD, Ritschl LM, Fichter AM, Safi AF, Knoedler L. Face the Future-Artificial Intelligence in Oral and Maxillofacial Surgery. J Clin Med. 2023 Oct 30;12(21):6843. doi: 10.3390/jcm12216843. PMID: 37959310; PMCID: PMC10649053.

7. Hesamian MH, Jia W, He X, Kennedy P. Deep learning techniques for medical image segmentation: achievements and challenges. J Digit Imaging 2019; 32: 582–96. doi: 10.1007/s10278-019-00227-x

8. Schwendicke F, Golla T, Dreher M, Krois J. Convolutional neural networks for dental image diagnostics: a scoping review. J Dent 2019; 91: 103226.

9. Balaji, S. M.. Maxillofacial Surgery and Artificial Intelligence. Annals of Maxillofacial Surgery 13(1):p 1-2, Jan–Jun 2023. | DOI: 10.4103/ams.ams_86_23

10. Yan KX, Liu L, Li H. Application of machine learning in oral and maxillofacial surgery. Artif Intell Med Imaging 2021; 2(6): 104-114 [DOI: 10.35711/aimi.v2.i6.104]

11. Park J., Hwang D., Kim K.Y., Kang S.K., Kim Y.K., Lee J.S. Computed tomography super-resolution using deep convolutional neural network. *Phys. Med. Biol.* 2018;63:145011.

12. Hyun C.M., Bayaraa T., Yun H.S., Jang T.J., Park H.S., Seo J.K. Deep learning method for reducing metal artifacts in dental cone-beam CT using supplementary information from intra-oral scan. *Phys. Med. Biol.* 2022;67:175007.

13. Abdolali F., Zoroofi R.A., Otake Y., Sato Y. Automatic segmentation of maxillofacial cysts in cone beam CT images. *Comput. Biol. Med.* 2016;72:108–119.

14. Rana M., Modrow D., Keuchel J., Chui C., Rana M., Wagner M., Gellrich N.C. Development and evaluation of an automatic tumour segmentation tool: A comparison between automatic, semi-automatic and manual segmentation of mandibular odontogenic cysts and tumours. *J. Craniomaxillofac. Surg.* 2015;43:355–359.

15. Yilmaz E., Kayikcioglu T., Kayipmaz S. Computer-aided diagnosis of periapical cyst and keratocystic odontogenic tumour on cone beam computed tomography. Comput. Methods Programs Biomed. 2017;146:91–100. doi: 10.1016/j.cmpb.2017.05.012.

16. Lin H.H., Lonic D., Lo L.J. 3D printing in orthognathic surgery—A literature review. *J. Formos. Med. Assoc.* 2018;117:547–558. doi: 10.1016/j.jfma.2018.01.008.

17. Alkhayer A., Piffkó J., Lippold C., Segatto E. Accuracy of virtual planning in orthognathic surgery: A systematic review. *Head. Face Med.* 2020;16:34.

18. Mohaideen K, Negi A, Verma DK, Kumar N, Sennimalai K, Negi A. Applications of artificial intelligence and machine learning in orthognathic surgery: a scoping review. *J Stomatol Oral Maxillofac Surg.* 2022;123:962–972. doi: 10.1016/j.jormas.2022.06.027.

19. Huqh MZU, Abdullah JY, Wong LS, Jamayet NB, Alam MK, Rashid QF, et al. Clinical applications of artificial intelligence and machine learning in children with cleft lip and palate—a systematic review. *Int J Environ Res Public Health.* 2022;19:10860.

20. Kurt Bayrakdar S, Orhan K, Bayrakdar IS, Bilgir E, Ezhov M, Gusarev M, Shumilov E. A deep learning approach for dental implant planning in cone-beam computed tomography images. BMC Med Imaging. 2021;21:86.

21. Lee DW, Kim SY, Jeong SN, Lee JH. Artificial Intelligence in Fractured Dental Implant Detection and Classification: Evaluation Using Dataset from Two Dental Hospitals. Diagnostics (Basel). 2021;11:233.

22. Hadj Saïd M, Le Roux MK, Catherine JH, Lan R. Development of an Artificial Intelligence Model to Identify a Dental Implant from a Radiograph. Int J Oral Maxillofac Implants. 2020;36:1077-1082.

23. Dalvit Carvalho da Silva R, Jenkyn TR, Carranza VA. Convolutional neural networks and geometric moments to identify the bilateral symmetric mid-plane in facial skeletons from CT scans. Biology (Basel). 2021;10:182.