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Global Journal of Medical, Pharmaceutical, and Biomedical Update

Mini-Review

The Utility of Artificial Intelligence in Dentistry: Advancing Frontiers

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Received: 23 March 2024
Accepted: 30 May 2024
Published: 26 July 2024

DOI
10.25259/GJMPBU_9_2024

Quick Response Code:

ABSTRACT

Computer power continues to grow along with the ease of access to worldwide information and the accessibility of enormous amounts of data that are ready for processing with artificial intelligence (AI) applications in the health sector. A substantial amount of data requires meticulous analysis to improve accuracy in generating datasets from AI. Soon, AI will play a crucial role in the field of dentistry in diagnosis, prediction models, restorative procedures, endodontic procedures, and orthodontic procedures. The advancements in AI technology are causing a revolution in the field of dentistry, making it easier for dentists to provide expert opinions and work with greater precision. There are numerous benefits of the use of AI discussed in this article.

Keywords: Artificial intelligence, Dentistry, Prosthodontics, Endodontics, Orthodontics

INTRODUCTION

The advancements in artificial intelligence (AI) technology are causing a revolution in the field of dentistry, making it easier for dentists to provide expert opinions and work with greater precision.[1] The emerging field of AI research continues to expand at an impressive rate, and the results will undoubtedly influence dentistry. AI is defined as "the ability of a device to perform functions normally associated with human intelligence, such as reasoning, learning, and self-development." It currently occupies a significant position in our lives and is getting progressively larger on an AI basis.[2] John McCarthy, a mathematician, coined the term AI in 1956.[3] As studies on AI continue to develop at an ever-increasing pace, there is no doubt that dentistry, along with many other disciplines, is set to change and advance.

The use of AI has the potential to improve our knowledge of illnesses in different communities. By analyzing and extrapolating vast amounts of data, AI can provide a computerized analysis that could lead to a better understanding of various health conditions. It is appropriate to expect the use of terminologies such as "digital transformations," "digitalized workflows," and "technical developments" because of the technological advances in computer power, the accessibility of global information, and the widespread availability of large data that are currently ready for AI assessment. Datasets for AI demand thorough analysis to improve their accuracy. The experts are required to invest time and effort to prepare the data to be used for successful learning. Machine

learning is an algorithm that refers to the study of computer models that improve their performance by learning from experience without explicit instruction.It requires sample data to make predictions or decisions.

On the other hand, deep learning and statistical learning are sub-branches of machine learning, which is a science under Computer Science or Computer Engineering.[2] AI in dentistry is revolutionizing the discipline by enabling more precision, fewer errors, and a reduction in staffing needs. In dental clinics, AI is capable of performing an array of duties, including appointment scheduling, clinical diagnosis support, and treatment planning. General algorithms are a powerful tool for searching through large amounts of data efficiently; they work using the principle of survival of the fittest in natural selection, allowing them to find the best possible solutions to problems.[4]

The integration of AI into various dental diagnostic and treatment procedures has also been initiated. AI has already been proven to be highly proficient in identifying and categorizing orthodontic malocclusion with high degrees of sensitivity, accuracy, specificity, and precision. AI also has the capability of automatically identifying dental restorations on panoramic radiographs and identifying anomalies related to the teeth and maxillofacial region, including bone lesions, periodontal illnesses, root caries, and face deformities.[4] In the event of a dental emergency where direct communication with the dentist is not possible, the patient has a constant assurance that access to emergency telemedicine services is available. Hence, AI can enable obtaining prompt and effective care from qualified medical professionals in times of need. Through these opportunities, AI provides a sense of safety and security to the patients.

AI will likely not replace dentists, but it will improve their expertise and assist them in accomplishing new heights in precision, patient satisfaction, and treatment outcomes.[5]

The present review aims to provide insights into the potential utility of AI in various branches of dentistry.

APPLICATION OF AI IN DENTISTRY

Diagnosis

When it comes to dental diagnosis, it is all about gathering patient information, formulating a diagnosis, and coming up with an effective treatment plan. Through AI, this process has become much more organized and systematic. AI technology makes it easier to collect patient data, reduce routine tasks, and even facilitate research and development. The great thing about AI is that it helps dental professionals to extract the right data from medical records and make informed decisions. Diagnosis in dentistry involves gathering patient data in a systematic manner by meticulous clinical examination and thorough elicitation of history. AI is making it easier to collect patient data in a more systematic and organized way, reducing routine tasks and facilitating research and development. It is also promotes greater participation in the healthcare system. AI is focused on establishing an effective framework for every procedure by combining appropriate data from an enormous array of medical records to assist dentists in making recommendations. To manage an increasing amount of information regarding patients over time and process it with the aid of an integrated clinical database, clinical decision support systems were created. The systems assist dentists in making assessments about the disease's diagnosis, prognosis, therapy, and prevention. Clinical Decision Support Systems help diagnose a patient based on their caries risk assessment and generate a recommended treatment plan. This reduces treatment time and improves efficiency for both the patient and the dentist.[6] For instance, a Clinical Decision Support System might classify a patient with a toothache based on a short questionnaire that includes information about their last visit to the dentist, past restoration history, sugar exposure history, and fluoride exposure history. With this information, a suggested treatment plan is AI-generated, providing valuable information to both the dentist and the patient. Overall, AI technology is helping to improve efficiency, save time, and provide better care for dental patients.[5]

Prediction model

Studies have shown that genetic algorithms and Artificial Neural Networks can be used to predict and interpret biological activities such as dental caries. Artificial neural network essentially makes use of interlinked computer processors to process ambiguous data, examine non-linear information, interpret and learn from existing data, and interpret. Thus,artificial neural networks have proven to be an exceptionally valuable analytic tool in the field of medicine. These systems possess a unique ability to solve complex problems that traditional methods cannot. They are particularly advantageous in the fields of disease diagnosis, biomedical identification, image analysis, and data analysis. The remarkable versatility and potency of these systems make them an appealing option for medical professionals seeking to improve their analytical capabilities.[7] With a proper training database, these technologies can predict the sizes of unerupted teeth. Kim *et al*. conducted a study where a model was developed using an artificial neural network that could predict toothache. The model was based on an association between toothache and daily brushing duration and frequency if dental floss was used, frequency of toothbrush replacement, scaling, and other additional variables such as exercise and diet. The study concluded that reduction in stress, proper dietary habits, and proper oral hygiene are key factors in reducing toothache.[8]

Restorative dentistry

Augmented reality is a technology that overlays a real-world environment with a computer-generated one, enhancing the user's experience and shifting their perspective. This technology can be utilized in conjunction with AI to create even more impressive outcomes in restorative dentistry. Photon emission tomography, near-infrared spectroscopy, dyes, haptic force feedback, and robotics can all be used in combination with augmented reality to further enhance the sensory perception of reality. Technology is advancing and improving our AI lives. Algorithms engineer a network of artificial neurons connected in assembled layers. They can solve complex tasks such as image classification. This technology can be applied in radiographic imaging, which can help dentists determine the extent of decay in a tooth. AI-powered technology is revolutionizing the healthcare industry for its betterment.[9] When examining dental procedures such as conservative caries excavation and tooth preparation for accommodating restorations, it is important to consider the role that deep learning can play in the process. This technology allows for the visualization of simple features such as lines, edges, and corners, as well as macroscopic patterns, all of which are arranged in a hierarchical structure that can be incredibly useful in these applications. By leveraging these insights, dental professionals can more effectively plan and execute these procedures, resulting in better outcomes for their patients.[5]

Endodontics

When it comes to dentistry, having access to accurate AI information is crucial for ensuring successful outcomes. Hence, the data acquired from diagnostic imaging, such as periapical radiographs, computed tomography scans, and magnetic resonance imaging scans, can be valuable sources of input for augmented reality information.[9] However, a meta-analysis conducted by Dutra *et al*. concluded that the accuracy score for a periapical region by cone beam computed tomography imaging is 0.9, traditional intraoral periapical (IOPA) is 0.73, and digital IOPA is 0.72.[10] Hence, dentists can utilize augmented reality to obtain vital information in real-time about the complex anatomy of root canals without diverting their concentration from the operation field. This three-dimensional presentation of information on the patient's body is much more efficient and less confusing than having to look at a separate screen. It is just one way that technology is helping to improve the practice of dentistry.[9] AI-based networks are capable of detecting a minor variation in the resolution of a single pixel that the human eye could miss.[11] AI is also beneficial in determining the working length during an endodontic procedure. The most commonly used methods for working length are radiography and electronic apex locators. However, several other variables may impact the radiographic interpretation, which might result in a misdiagnosis, therefore making it desirable to use AI.[12] A study was conducted by Saghiri *et al*. and concluded that artificial neural networks might be recognized as an effective approach for determining the working length.[13]

Orthodontics

AI algorithms have shown tremendous potential in detecting and diagnosing conditions within the oral cavity that are undetectable to the human eye, thereby making it helpful in the use of planning orthodontic treatment.[14] When doctors make use of AI, their diagnosis, treatment plan, growth and development evaluation, treatment progress and result assessment, maintenance phase, monitoring from afar, and long-term follow-up all get better.[15] AI serves an integral part in several domains, including segmenting teeth and skeletal structures, enabling skeletal evaluation and growth projections, and precisely positioning Cephalometric Points in 3D cephalometric analysis.[16] Machine learning has become a part of orthodontic practice for classification and categorization of malocclusions. The automated detection of anatomical landmarks in radiographs has become possible because of technological advancements in medical imaging.[17] AI-based software for "automatic" cephalometric analysis is reasonably accurate with added advantages of efficiency and rapidity of the procedure.

AI may also be employed for generating a realistic replica of a patient's smile following possible orthodontic treatment, offering the patient an overview of exactly what they can anticipate. Choi *et al.,* (2019) conducted a study with the help of an AI model, where the model achieved an 88% to 97% accuracy in predicting the requirement for surgery and providing an extraction plan for surgical patients.[18] An AI-based smartphone application-based simulation has also proven an effective instrument for emotionally immersing the patient in the decision-making process.[19,20] An artificial neural network model was developed by Xie *et al*. in 2010 to determine if extractions are to be performed before orthodontic intervention for dental malocclusion.[21] The software, which is dedicated to designing orthognathic cases, makes use of AI as well as machine learning.[17] AI has also enabled the morphology of the joints in conjunction with various imaging options.[22] Ezhov *et al*., in their study, found that AI was able to enhance the ability of dentists to diagnose patients with increased sensitivity and specificity scores when analyzing cone-beam computed tomography (CBCT).[23]

Periodontology and implantology

AI-assisted imaging devices can differentiate between healthy and inflamed gingiva through machine learning.[24] Chang

et al. developed an AI system utilizing deep learning along with conventional computer-aided design (CAD) processing to detect bone loss and staging of periodontitis. The system demonstrated good precision and reliability in evaluating the periodontal parameters.[25] A similar study demonstrated the ability of machine learning to accurately predict marginal bone loss.[26] AI-based models have achieved almost a 37% reduction in stress when compared to the finite element analysis models.[27]

Oral pathology

Another AI-based automated, computer-aided oral cancer detection has demonstrated a 91.4% accuracy in the classification of hyperspectral pictures of oral cancer patients with sensitivity and specificity of 0.94 and 0.91, respectively.[28] An integrated strategy combining feature selection and machine learning techniques, has been demonstrated to improve the prognostication in the presence of clinicopathologic and genetic indicators are present.[29]

Recent studies have aimed at developing AI models that are able to differentiate normal, precancerous, and cancerous tissues. AI Models used in a study by Song *et al.* could differentiate lesions into normal, precancerous, or cancerous with or without stating the various stages of oral cancer.[30] An AI-based neural network developed by Schwarz *et al*. was also able to distinguish samples of different grades of dysplasia (mild, moderate, and severe) and neoplastic tissues.[31]

A decision tree classifier provides the highest accuracy in classification, and such software may be incorporated within the microscope imaging systems. This would enable the pathologists to record and evaluate numerical parameters across various fields in the slide, including the number and size of cells and nuclei.[32]

PROSTHODONTICS

CAD/computer-aided manufacturing (CAM) procedures have made their way into routine clinical and laboratory practice. AI has been used in the field of prosthodontics to improve CAD/CAM systems, implant prosthetics, tooth preservation, and orofacial anatomy. AI is capable of creating removable partial dentures (RPDs) using 3D printing technology. 3D printing technology facilitates improved production improved production, efficiency, accuracy and cost-effectiveness of RPDs compared to older approaches. Computer-aided analysis of RPD fit can provide accurate measurements and assessments of prosthesis performance, fit, occlusion, and general functionality. This can help diagnose and fix faults with the prosthesis, thereby improving patient happiness and outcomes.[33] In addition, it improves the accuracy and efficiency of tooth preparation. AI can assist in tooth margin preparation by automating the precise excision of marginal lines. Initially, advanced technical expertise and manual effort were necessary. AI contributes to improving implant placement and planning by assessing CBCT pictures and producing a 3D model of the patient's jawbone. Identifying the optimal position and angle for implant insertion improves the procedure's success rate.[34] Digital software enables more precise planning for grin designs. It has improved patient outcomes by ensuring predictability and esthetic appeal. Dental professionals can personalize their patients' smiles using virtual smile design software, including tooth shape, size, color, and location. This personalization creates a personalized smile that complements the patient's facial traits and personality.[35]

COMMUNITY DENTISTRY

AI can play a pivotal role in oral cancer and pre-cancer screening within communities, offering innovative solutions for early detection and intervention.[36] By analyzing patient data, including medical history and oral examination findings, AI algorithms identify high-risk individuals and accurately differentiate between benign and potentially malignant lesions. This facilitates timely referrals for further evaluation and personalized management plans, empowering communities to implement proactive strategies for prevention and early intervention, thus improving patient outcomes.

In addition, AI can serve as a powerful tool for identifying populations in need of dental treatment, enabling efficient resource mobilization.[37] Through large-scale data analysis, AI algorithms pinpoint regions with high oral health needs and limited access to care. If funding is available, this would allow dental professionals to strategically allocate resources such as mobile clinics and outreach programs, while AI-driven population health management systems facilitate targeted interventions for individuals at high risk of oral diseases.

Moreover, AI contributes to generating awareness in media for oral health by analyzing trends and sentiments to tailor content to public interests. AI-powered content creation tools produce engaging materials catering to diverse audiences and demographics.[38] Personalized content delivery ensures that individuals receive relevant oral health information through preferred media channels, amplifying awareness campaigns and promoting oral health literacy for healthier communities.[39]

ORAL SURGERY

AI applications in oral and maxillofacial surgery (OMFS) have been increasing in prominence in recent decades,

benefiting several elements of the field. AI has been used for activities such as diagnosis, cephalometrics, pre-operative planning, intraoperative measurements, outcome evaluation, and postoperative follow-up in OMFS.[40] An AI-based algorithm can help establish the surgical rationale for tooth extraction by predicting the likelihood of dental eruption-related risks.[41] AI algorithms trained on clinical input data could predict the effectiveness of osseointegration treatments and dental implants, as well as optimize the design of dental implants before surgery.[42] Automated landmark detection using machine learning algorithms on lateral cephalometric radiographs has emerged as a promising method.[43]

Wang *et al.* conducted a study where he used multiscale decision tree regression voting with scale-invariant patch features for landmark detection, allowing for the calculation of specific clinical parameters.[44] Computer-aided planning using 3D imaging simplifies cephalometric analysis, splint fabrication, and operation simulation. It enables clearer visibility of dental anomalies such as yaw rotations, occlusal plane canting, and variable length of the body/ramus of the mandible.[45]

The utility of AI across various branches of dentistry is collectively summarized in [Figure 1].

BENEFITS

The use of advanced technology in dentistry could significantly improve patient care. With AI-based tools, dentists tend to be fast in assessing medical and dental history data, which is crucial for patient-centered care. This is particularly important for individuals with complex medical histories.[46,47] Furthermore, AI-based technology can lessen gaps in access to oral and dental health services.[48] For instance, applications for oral cancer, periodontitis, or caries detection can be used in resource-limited settings. From a sustainable AI ability perspective, AI can help prevent oral/dental diseases and reduce the costs associated with treatments. By identifying the earliest signs of disease, we can prevent further damage and minimize the use of resources. AI can entirely alter the interaction between patients and companies. We may establish a database of techniques and practices that can be evaluated against AI. This can facilitate knowledge sharing and aid in improving patient outcomes.[49]

LIMITATIONS AND CHALLENGES

Due to regulatory hurdles and data privacy considerations, dental data are not as publicly available and accessible as other data. There are numerous methods of verifying or

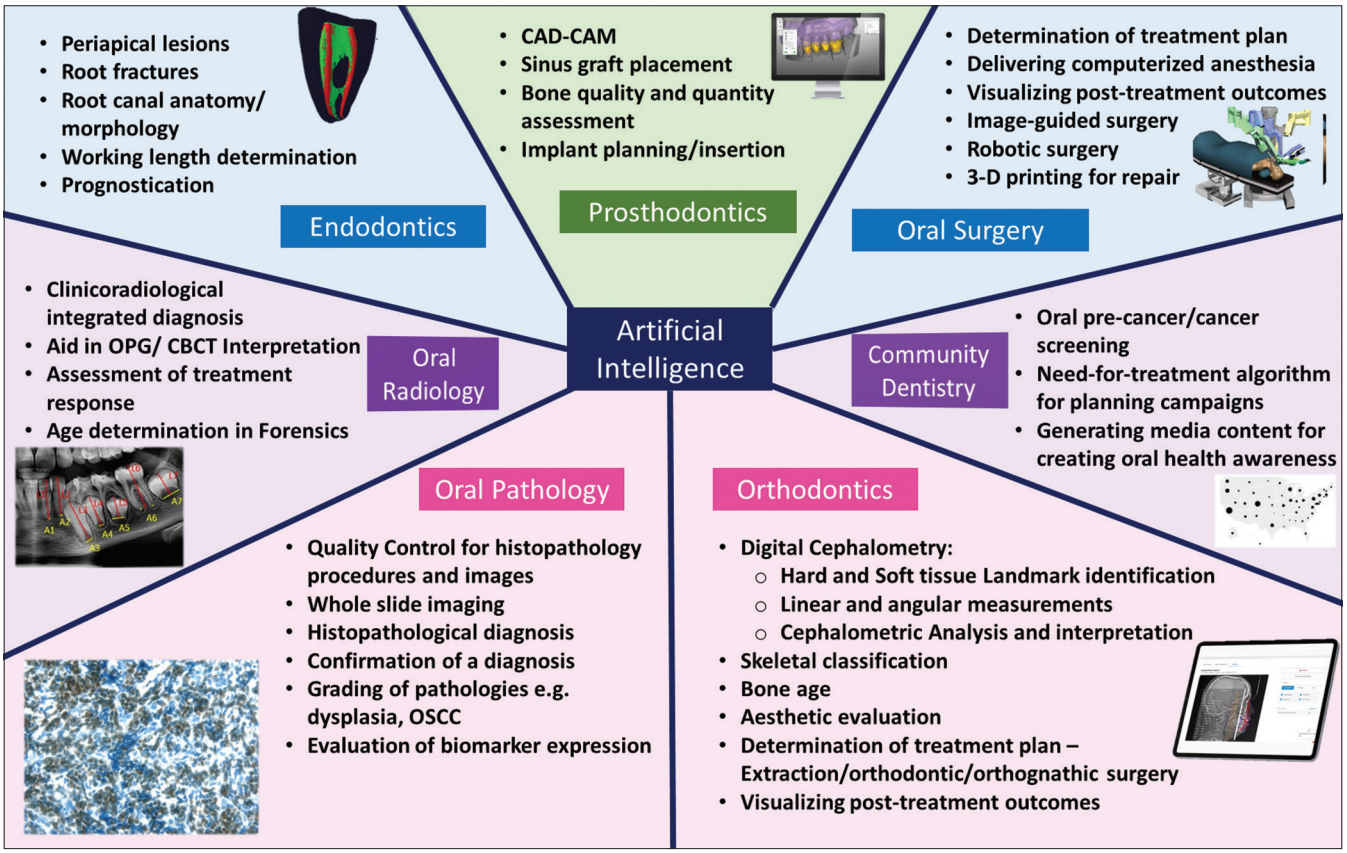

Figure 1: Utility of AI across various branches of dentistry. CAD-CAM: Computer-Aided Design and Computer-Aided Manufacturing, OPG: Orthopantomogram, CBCT: Cone Beam Computed Tomography, OSCC: Oral Squamous Cell Carcinoma.

triangulating the sensitive, multifaceted, and sophisticated data on each patient. Selection bias is the result of sampling when extremely affluent persons, overly sick, overly healthy, or both are overrepresented. Applications of AI built with such data will inevitably be pre-judiced.[50] Errors can still occur, thus oversight by humans is still essential. As a model system primarily focuses on machines and software, it is oblivious to human connections, including empathy toward patients. Because all of the information is stored in the system, there may be security problems.[51] There are legal issues with intellectual property, and some factors must be considered to make sure that the algorithms are transparent and non-proprietary.[52]

Evaluating the reproducibility of deep learning research poses difficulties due to the constrained availability of codes and datasets.[53] A significant number of legal discussions around AI have centered on the concern of algorithmic transparency limitations. The use of AI in high-risk scenarios has raised the need for transparent, fair, and responsible AI design and governance.[54] Another reason for caution is that it poses a danger to "both the moral framework of society and the foundation of the liability idea in law."[55] Data reveal that AI models are capable of large-scale deployment and embedding of social and human biases. Still, the underlying data should bear more of the blame than the algorithm itself.[56] AI systems have safety risks, and hence, strategies should be implemented to control the quality of the algorithms and systems utilized in AI.[57]

AI utilized in health care needs to adjust to a constantly evolving environment with frequent disruptions while preserving moral standards to protect patients' interests.[58]

FUTURE PROSPECTS

The future prospects of AI in dentistry are promising, with emerging technologies and potential new applications poised to reshape the field. One area of advancement is in the development of AI-powered robotic systems for dental procedures.[5] These systems can enhance precision, reduce procedural errors, and improve patient outcomes, particularly in complex surgeries and dental implant placements. In addition, advancements in 3D imaging and virtual reality technology are enabling the creation of immersive training simulations for dental students and professionals, allowing for more realistic and effective learning experiences.

Furthermore, AI holds the potential to revolutionize patient care through personalized treatment planning and predictive analytics. By analyzing vast amounts of patient data, including genetic information, medical history, and treatment outcomes, AI algorithms can tailor treatment plans to individual patient needs, optimizing outcomes and minimizing risks.[59] Moreover, AI-driven virtual assistants and chatbots are being developed to enhance patient engagement, providing real-time support, appointment reminders, and post-treatment guidance, thereby improving patient satisfaction and adherence to treatment regimens.

Looking ahead, AI is expected to play a crucial role in preventive dentistry through early disease detection and monitoring. With advancements in wearable technology and remote monitoring devices, AI algorithms can analyze real-time oral health data, such as saliva pH levels and bacterial composition, to detect signs of disease onset and provide timely interventions.[60] In addition, AI-powered image analysis tools can enhance dental screenings in underserved communities, enabling early identification of oral health issues and facilitating access to timely treatment.

Overall, the future of AI in dentistry holds immense potential for improving patient care, enhancing treatment outcomes, and advancing preventive measures. By embracing emerging technologies and exploring new applications, the field is poised to undergo transformative changes, ultimately leading to more efficient, accessible, and personalized dental care for patients worldwide.

CONCLUSION

As technology continues to advance, we are seeing more and more AI-based software being integrated into various industries, including dentistry. Moreover, while some may be hesitant about this shift, there are many potential benefits to be gained from utilizing these tools. For instance, introducing AI-based software could help to reduce disparities in dental care by providing more standardized and consistent treatment options. Furthermore, it could enhance the dental practice's operational efficiency, allowing dentists to see more patients and provide higher-quality care. Perhaps most importantly, AI-based software could facilitate the sharing of information between medical and dental providers. This is especially crucial for medically compromised dental patients, who may require specialized care and attention from both types of professionals. Overall, while there are certainly some concerns to be addressed when it comes to implementing AI-based software in dentistry, it is clear that there is great potential for positive change and improved patient outcomes.

AI is currently being studied in dentistry for several purposes, including the identification of normal and abnormal structures, diagnosis of diseases, and prediction of treatment outcomes. In addition, machine learning has been used in various ways in dentistry, with different methodologies and reporting metrics. Using AI as an additional tool, dental professionals can reduce their workload and improve the accuracy of diagnosis, decision-making, treatment planning, disease prognosis, and treatment outcome prediction.

Ethical approval

Institutional Review Board approval is not required.

Declaration of patient consent

Patient consent is not required as there are no patients in this study.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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How to cite this article: Tafti F, Thorat R, Mhatre S, Srichand R, Savant SC, Sachdev SS. The Utility of Artificial Intelligence in Dentistry: Advancing Frontiers. Glob J Med Pharm Biomed Update. 2024;19:8. doi: 10.25259/GJMPBU_9_2024