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Artificial Intelligence in Oral Surgery: A Review

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Abstract

This review examines the role of artificial intelligence (AI) in oral surgery, highlighting its applications in diagnosis, treatment planning, and predictive analytics. AI enhances precision in surgical procedures, reduces human error, and improves patient outcomes. By analyzing large datasets, AI facilitates personalized treatment strategies and offers innovative solutions to complex cases, ultimately advancing the field of oral surgery.

Introduction

The integration of artificial intelligence (AI) in dentistry marks a significant shift in the field and offers the potential to enhance various aspects of dental practice and patient care. AI transforms how dental professionals diagnose, treat, and manage oral health by employing advanced algorithms and machine learning techniques to

analyze data and make informed decisions.[1]

The term "AI" was introduced by mathematician John McCarthy in 1955 to describe a machine's ability to perform intelligent tasks. Today, AI refers to any technology or device that can imitate human cognitive functions, like problem-solving. Key subcategories of AI include machine learning, deep learning, cognitive computing, natural language processing, and robotics, among others.[2]

A popular type of AI is machine learning, which allows computers to learn how to perform tasks by analyzing numerous examples. An advanced form of this technology is deep learning, where the computer employs multiple layers of "thinking steps," known as neural networks, to comprehend complex data like images or patterns. For instance, deep learning can assist a computer in detecting signs of tooth decay in X-ray images. These neural networks focus on processing intricate images by extracting features through various layers of filters.[3,4]

AI-powered tools are increasingly being used to detect abnormalities like cavities, bone loss, or malignancies with greater accuracy and at earlier stages than traditional methods. By analyzing historical data and patient-specific factors, AI can also predict the likelihood of future oral diseases, enabling timely interventions and preventive care.[5]

A clinical decision support system (CDSS) utilizes a comprehensive database of medical knowledge and algorithms to assist in decision-making and forecast outcomes. This system allows healthcare professionals to work more effectively, save time, and deliver care at a lower cost, thanks to its voice-activated controls and user-friendly interface. AI is transforming dentistry by improving diagnostic capabilities, personalizing treatment plans, predicting future dental issues, and boosting operational efficiency. We expect that AI technology will keep evolving, further revolutionizing dental practices and enhancing patient care.[6]

Present review article aims to discuss various application of artificial intelligence in oral and maxillofacial surgery **(Table 1)**.

Artificial intelligence in Oral and Maxillofacial Surgery: The use of AI in oral and maxillofacial surgery (OMFS) has become increasingly popular in recent decades, enhancing various aspects of the specialty. AI applications include tasks such as diagnosis, cephalometrics, preoperative planning, intraoperative measurements, outcome evaluation, and postoperative follow-up. One promising area for AI algorithms is in managing impacted teeth. For example, an AI-based model can help determine whether tooth extraction is necessary by predicting the risks associated with tooth eruption. Additionally, AI tools have been employed to evaluate the surgical complexity of planned procedures before surgery. By utilizing clinical input data, AI algorithms can also forecast the success of osteointegration and dental implants, along with optimizing the design of dental implants prior to the procedure.[6]

AI has also made its mark in robotic surgery

within the realm of oral and maxillofacial surgery (OMFS). AI-assisted cranial surgical procedures—including dental implants, tumor resections, biopsies, and temporomandibular joint surgeries—have shown positive outcomes. Research indicates that AI-assisted surgery enhances the accuracy and safety of oral implant procedures compared to traditional freehand methods. In particular, using AI has led to fewer instances of revision surgeries and implant repositioning in certain cases. Additionally, AI-driven techniques have allowed for more precise surgical removal of tumors and cysts, reducing the need for further procedures.[7]

Table 1: Various Application AI in Oral and Maxillofacial Surgery[7-9]

Utility of AI	Description
Diagnosis and Treatment Planning	In Oral and Maxillofacial Surgery, Artificial Intelligence supports various aspects including diagnosis, cephalometric analysis, surgical planning, intraoperative measurements, outcome assessment, and postoperative monitoring. Additionally, AI aids in managing impacted teeth, forecasting tooth eruption risks, evaluating surgical complexities, predicting the success of osteointegration, and designing dental implants.
Robotic Surgery in OMFS	Robotic surgery in oral and maxillofacial surgery uses AI to support various cranial surgical activities, including dental implants, tumor removal, biopsies, and surgeries related to the temporomandibular joint. The application of AI increases precision, minimizes the need for revisions, and guarantees accurate surgical resections
Radiographic Image Enhancement	AI and deep learning technologies enhance the quality of radiographic images by minimizing noise and deblocking, particularly in low-dose CT scans. They also help decrease motion and metal artifacts in dental CT and cone beam CT images.
Surgical Planning	Surgical planning currently relies on standard programs that do not use AI; however, improvements in 3D imaging have led to enhanced surgical simulations. Computer-assisted planning makes the surgical planning process easier and offers better visualization. There is room for future growth of AI in this field.
Efficiency and Safety in OMFS	In oral and maxillofacial surgery, AI can enhance efficiency for surgeons by assisting with automated diagnoses from radiological data and ensuring patient

	records are up to date. Additionally, AI contributes to patient safety by identifying drug interactions and addressing potential prescribing mistakes.
Smartphones with embedded biosensors	Continuous monitoring of physiological metrics for health prognostication.
Advanced AI algorithms	Analyze complex medical imaging data like CT scans and 3D models for preoperative assessments, surgical simulations, and personalized treatment plans.
Deep Learning Models	Identification of tumors, especially in oncology-oriented image analysis.
AI Assistants	Provide around-the-clock clinical support, bridging the gap between patients and healthcare providers, assisting in clinical decision-making.

Discussion: The integration of Artificial Intelligence into oral surgery marks a significant advancement in the field, enhancing various aspects from diagnosis to surgical planning and postoperative care. A notable study by Zhang et al. illustrates this potential through their implementation of an optimized backpropagation neural network for predicting postoperative swelling after third molar extractions. Achieving a remarkable classification accuracy of 98%, their findings underscore AI's capability to accurately forecast complications that may arise post-surgery. This predictive ability not only enhances the safety and quality of patient care but also equips surgeons with important insights that facilitate pre-emptive measures, potentially reducing the incidence and severity of postoperative issues.[10]

In the realm of orthognathic surgery, AI's diagnostic capabilities have consistently demonstrated high levels of accuracy, exceeding 90% in differentiating between surgical and orthodontic cases. The work conducted by Shin et al. highlights a significant leap in diagnostic precision, where the fusion of lateral and posteroanterior cephalograms achieved a specificity rate of 99.3% alongside a 95.4% accuracy rate. These results indicate that AI can play a critical role in refining treatment planning, ensuring that patients receive the most appropriate interventions based on accurate diagnostic information. This precision aids clinicians in making timely decisions, thus enhancing the overall efficacy of the treatment process.[11]

Furthermore, AI's contributions to surgical planning, particularly in soft-tissue prediction, are noteworthy. The study by Tanikawa et al. showcases AI's ability to predict three-dimensional facial changes with sub-millimeter accuracy. This level of precision is invaluable, as it allows surgeons to anticipate postoperative

outcomes more effectively, optimizing not only aesthetic results but also functional recovery. The near-linear relationship established in their research for mandibular setback procedures exemplifies the potential for tailored approaches that enhance patient satisfaction and minimize complications.[12]

However, the widespread application of AI in oral surgery is not without challenges. One significant limitation is the reliance on large, high-quality datasets for training AI systems. Inconsistent data availability can hinder the effectiveness of AI models, making it crucial for the field to prioritize data collection and standardization. Additionally, the interpretability of AI algorithms poses a challenge, as complex models can lead to resistance from practitioners who might struggle to understand or trust automated predictions. Integrating AI tools into existing clinical workflows also presents logistical hurdles and can require substantial investment in both technology and training.[13,14]

Looking toward the future, the potential of AI in oral surgery is immense. As machine learning and data analytics continue to improve, we can expect enhanced diagnostic accuracy and predictive capabilities. The ongoing convergence of AI with clinical expertise is likely to usher in a new era of personalized treatment, where approaches are even more finely tuned to meet the specific needs of individual patients. Additionally, collaborative research efforts can focus on overcoming current limitations, as the development of more advanced AI models tailored for oral surgery can further refine treatment strategies and outcomes. In conclusion, while challenges exist, the ongoing evolution of AI in oral surgery suggests a trajectory toward improved patient care and surgical effectiveness, fostering a collaborative environment where technology complements clinical skills.[13,14]

Advantages of AI in Oral Surgery

1. **Enhanced Accuracy:** AI systems can provide precise predictions and diagnostics, which can lead to improved surgical outcomes.
2. **Efficiency:** AI applications reduce the time required for diagnostics and treatment planning, enabling faster patient management.
3. **Personalized Treatment:** AI allows for tailored treatment approaches based on individual patient data, enhancing care.
4. **Predictive Capabilities:** As demonstrated in third molar surgery, AI can effectively predict postoperative complications, aiding in better patient preparation and care.

Limitations of AI in Oral Surgery

1. **Data Dependency:** AI systems require large and high-quality datasets for training,

which may not always be available.

2. **Interpretability:** The complex nature of AI algorithms can make it difficult for practitioners to understand and trust the outcomes.

3. **Integration Issues:** The adoption of AI tools may face resistance due to the need for changes in existing clinical workflows.

4. **Cost:** Implementation of advanced AI systems may involve substantial financial investment in technology and training.

Conclusion and Future Prospective: Looking ahead, the future of AI in oral surgery appears promising. Advancements in machine learning and data analytics will likely continue to enhance diagnostic and predictive accuracy. As AI becomes more integrated into clinical workflows, it may lead to improved surgical techniques and patient outcomes. Furthermore, ongoing research and collaboration across disciplines will facilitate the development of more robust AI models tailored to different aspects of oral surgery.

In conclusion, while AI presents transformative potential in oral surgery, addressing its limitations and ensuring seamless integration into practice will play a crucial role in realizing its full benefits. As technologies evolve, the synergy between AI and clinical expertise is expected to yield even greater advancements in patient care.

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