Study of Leveraging Artificial Intelligence for Solutions in Dentistry

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Abstract: One potential solution for resolving various issues in dentistry is the incorporation of artificial intelligence (AI) tools. To find practical answers, this work explores the use of AI approaches to dental problems. Artificial intelligence (AI) techniques, including computer vision, deep learning, and machine learning, have revolutionized many areas of dentistry, from patient management and preventive care to diagnosis and treatment planning. One prominent application is in the field of diagnosis, where AI-enabled systems evaluate radiographic images, such as CT and X-rays, to accurately and efficiently identify anomalies, dental caries, and periodontal illnesses. Furthermore, by synthesizing enormous volumes of patient data, such as medical history, imaging results, and clinical observations, AI-driven decision support systems help dentists design the best possible course of action for each patient. The analysis of related research conducted over the past four years has demonstrated that dentistry can advance toward more accurate, patient-centered, and efficient procedures by utilizing AI.

Keywords: Artificial Intelligence, CNN, Healthcare, Dentistry, LLMs, Decision support.

1. INTRODUCTION

Artificial intelligence has also revolutionized dental technology. Artificial intelligence (AI) in dentistry refers to a range of tools designed to mimic human cognitive processes and assist in clinical decision-making. Dental care is becoming more accurate and efficient thanks to artificial intelligence (AI) technologies, which range from smart patient appointment scheduling systems to diagnostic algorithms that examine radiology images.

AI has several uses in dentistry, including patient management, diagnosis, and treatment planning, and even teaching. AI-powered devices, for example, are able to analyze dental photos with amazing accuracy, detecting problems early on, such as oral cancer, periodontal disorders, and cavities. This greatly shortens the time needed for diagnosis while also increasing the likelihood that the treatment will be successful.

Furthermore, artificial intelligence plays an important role in tailored treatment planning. By analyzing massive amounts of data, AI systems can predict treatment outcomes, allowing dentists to adapt therapies to each patient's unique needs. This tailored approach is at the heart of modern dental care, ensuring that patients receive the most effective treatments based on their specific needs.

In the field of patient administration, AI streamlines administrative chores such as scheduling and billing, allowing dental professionals to concentrate on patient care. Furthermore, AI-powered teaching tools are changing dentistry education by delivering interactive and adaptable learning experiences to students.

While AI has significant benefits in the field of dentistry, it is vital to highlight that it supplements rather than replaces the expertise of dental experts. The human touch is still important, and AI can help dental practitioners improve their skills, resulting in better oral health outcomes for patients.

The future of AI in dentistry seems bright, with ongoing research and development promising even more novel uses. As AI advances, it will play a more important role in determining the future of dental care.

1.1 Outcome

This work opens the door for future research on the use of artificial intelligence methods for dental problems and perhaps facilitates the discovery of answers. Scholars can investigate this more by working on it.

1.2 Scope and Limitations

Only dental specialties that can benefit from the application of AI-based technologies are covered in this survey.

2. LITERATURE REVIEW

To improve the resolution of 2D cone beam dental images, Janka Hatvani et al. [10] looked into the use of U-net CNN topologies and Subpixel Networks. Based on large-scale datasets, their study showed that deep learning can effectively improve dental imaging quality and analysis by providing better detection performance when compared to reconstruction-based methods.

With an accuracy of 94.18%, Anuradha Laishram et al. [1] developed a method that uses the Faster R-CNN model to identify various dental problems in panoramic radiographs. The utilization of base models like Alex Net and Google Net in their methodology highlights the effectiveness of deep learning in the identification and categorization of dental pathologies.

Using X-ray pictures, V. Geetha et al. [20] investigated a number of techniques for diagnosing dental caries, including back-propagation neural networks and Laplacian filtering. Their work demonstrated the efficacy of BPNN in dental imaging analysis with a high accuracy of 97.1%.

Using panoramic radiographs, Chiaki Kuwada et al.'s study [4] examined three deep learning (DL) systems for classifying impacted supernumerary teeth (ISTs) in the maxillary incisor region: Alex Net, VGG-16, and Detect Net. VGG-16 performed worse than both Detect Net and Alex Net, but Detect Net demonstrated greater diagnostic efficacy.

Haitham Askar et al. [9] employed Squeeze Net models to categorize various dental lesions, including carious, hypomineralized, and fluorotic types, with a focus on white spot, fluorotic, and non-fluorotic lesions. Important regions were identified with the help of feature visualization, which had a significant effect on the upper incisors.

In their investigation into the diagnostic efficacy of artificial intelligence in identifying impacted third molars on cone-beam computed tomography scans, Kaan Orhan et al. [11] found some encouraging results. Their study demonstrates how accurately AI can detect impacted third molars, signifying important developments in dental image analysis.

An SVM model with 99.7% classification accuracy was created by Shaikh, K. et al. [12] to treat dental caries.

An AI-based dental implant operating system that can identify the type of implant, determine its precise location, and operate on missing teeth was proposed by Rushikesh Bodhe et al. [18].

A Mixed-scale dense CNN and RCNN model developed by Chenxi Huang et al. [3] may identify problems in teeth from photos and segment tooth images for dental caries, periodontitis, orthodontics, and implants.

A unique artificial intelligence (AI) method was created by Pierre Lahoud et al. [17] that can precisely segment the mandibular canal (MC) on cone beam computed tomography. This would assist in preventing neurovascular problems both before and after surgery by relieving practitioners of the laborious and delicate work of manually tracing and segmenting this structure.

In-depth research on Deep Learning in orthodontics was done by Niama Assia El Joudi et al. [14], who addressed periodontics for bone loss detection, forecasts for orthognathic surgery, and decisions on tooth extraction. A CNN model was used to achieve an amazing 99.7% accuracy in their review, which also highlighted applications like cancer diagnosis, lesion categorization, gender prediction, and maxillary sinus detection.

In a thorough evaluation of clinical decision support in diagnostic dentistry, Amara Swapna Lingam et al. [2] placed a strong emphasis on using ANN models to treat patients promptly. They used CBCT and other machine learning models (ANN, PCA, Regression algorithm, Naive Bayes, and Decision Forest) to detect oral cancer and optimize endodontic outcomes.

The extensive analysis of dentistry by Paridhi Agarwal et al. [16] included synthetic data applications for the detection of root fractures and periapical diseases. Their study covered a wide range of topics, including oral surgery, dental radiography, root morphology, stem cell viability prediction, and novel applications including bioprinting and forensic odontology.

Martha Büttner et al.'s [13] proposal for using natural language processing (NLP) in dentistry included speech recognition, text categorization, clinical chatbots, and EHR data extraction. NLG algorithms and LLMs linked to EHRs enabled efficient interaction with medical data, as demonstrated by the 57% accuracy they achieved when using ChatGPT to respond to 60 inquiries in the field of endodontics.

Using the Faster R-CNN model, Shih-Lun Chen et al. [19] demonstrated a technique for classifying various dental problems in dental panoramic radiography. With an accuracy of 94.18%, they classified and identified seven different kinds of dental diseases using base models like Alex Net and Google Net.

A three-step method for automating teeth detection and classification in panoramic X-rays using the YOLOv7 and Mask-RCNN models was presented by Rashidi Ranjbar et al. [6] and achieved high accuracy. The Mask-RCNN model is in charge of multiclass labeling, giving each type of tooth a unique class name.

Verma et al.'s hybrid approach [5] greatly enhanced the detection of dental caries, periapical infection, altered bone height, and third molar impactions in panoramic radiographs by combining a Convolutional Neural Network (CNN) as a feature extractor and a Support Vector Machine (SVM) for classification. By automatically learning features and effectively extracting local and global information, the CNN-SVM model beat previous techniques.

Digital technologies, such as intraoral scanners and smartphone applications, are transforming oral health monitoring and treatment planning. Oliver Schierz et al. [15] explore this role. In order to improve patient experience and diagnostic accuracy, this study shows how integrating cutting-edge software and mobile devices can have a substantial impact on oral healthcare delivery in a variety of settings.

An innovative preventive system named Tooth.AI, conceptually designed, was presented by Hossam A. Gabbar et al. [8] with the goal of intelligently identifying and diagnosing bone and dental problems.

To optimize fatigue fracture resistance and minimize microstrain in the surrounding bone tissue, Griggs et al. [7] proposed optimizing implant design.

3. DISCUSSIONS

In the realm of dentistry, the integration of artificial intelligence (AI) has manifested diverse applications across specialized domains. These applications are tailored to enhance diagnostics, treatment planning, and patient care within distinct branches of dentistry. The following section delves into how AI is making significant strides in specific dental specialties.

3.1 Prosthodontics

CAD/CAM technologies thrive in enhancing the customization of dental prostheses through the integration of AI models like generative adversarial networks (GANs). This approach allows practitioners to fabricate crowns and bridges with exceptional precision, achieving an ideal mix of beauty and practicality. Addressing the challenge of making precise dental restorations while minimizing errors and time consumption, AI solutions in computer-aided design have prevailed over these obstacles by streamlining workflows, augmenting accuracy, and replacing usual casting methods with advanced digital approaches [2]. To tackle the challenges of identifying numerous restorative materials, a deep learning model [3] efficiently distinguishes between 11 types, ensuring more thorough dental examinations.

3.2 Endodontics

Deep learning models, namely convolutional neural networks (CNNs), have revolutionized endodontic diagnostics by offering a new perspective on early detection by recognizing root canal defects from X-rays. Using these state-of-the-art algorithms, endodontists may confidently navigate complex diagnoses and take a proactive approach to patient care that is consistent with contemporary precision medicine principles. However, high radiation dosage poses challenges to optimizing clinical results in cone beam CT imaging [2]. These challenges are addressed by applying deep learning techniques to morphological classification. Manual picture segmentation is still a time-consuming technique that lengthens processing times despite these limitations.

3.3 Orthodontics

Decision support systems, driven by machine learning algorithms such as decision trees, simplify the orthodontic treatment planning process by integrating patient records and empowering orthodontists to offer customized interventions [14]. To diagnose cephalometric landmarks, forecast when tooth extraction is necessary, and evaluate cervical maturation for age estimate, advanced deep learning models like CNNs and ANNs are essential. Furthermore, the stages of cervical vertebrae maturation can be identified by machine Learning classifiers using cephalometric radiographs, and customized treatment planning can be facilitated by 3D scans that improve accuracy in evaluating dental anomalies [3].

3.4 Periodontics

The early diagnosis of periodontal disease has been improved with the use of deep learning techniques, particularly recurrent neural networks (RNNs) [14]. Periodontists in preventive dentistry are empowered by the integration of RNNs with deep clinical data, which enables robust disease identification and tailored therapy based on individual risk profiles. Radiographic bone loss (RBL) in panoramic radiographs is a demanding task that convolutional neural networks (CNNs) efficiently handle [14]. Because of CNNs' exceptional accuracy in identifying boundaries, teeth, and implants, periodontal bone loss phases can be precisely classified. While CNNs increase diagnostic accuracy by accurately identifying alveolar bone loss, ANNs are utilized to detect periodontitis [3].

3.5 Oral and Maxillofacial Surgery

The utilization of reinforcement learning models is revolutionizing surgical planning techniques in the field of oral and maxillofacial surgery. A surgical era centered on accuracy is being ushered in by the seamless integration of these models to determine the best locations for incisions and surgical techniques. The combination of surgical experience and reinforcement learning holds the potential to yield more predictable results, enabling oral and maxillofacial surgeons to handle complex cases with unmatched precision and leading the field into a new era of surgical brilliance. The development of robotic surgical procedures is the primary use of artificial intelligence in oral surgery [18].

3.6 Pediatric Dentistry

Sentiment analysis algorithms and natural language processing (NLP) models working together are a big step forward in understanding and anticipating the behavioral quirks of pediatric patients. Pediatric dentists use sentiment analysis and natural language processing (NLP) to glean insightful information from patient feedback. This all-encompassing method not only makes behavioral analysis possible but also fosters a patient-centered environment, honing communication tactics to ensure that young dental patients receive a good, individualized experience

3.7 Diagnostic Dentistry

3.7.1 Oral Cavity Issues

To automate the detection and classification of caries in third molars, researchers used a pre-trained CNN model called MobileNet V2 on 400 panoramic radiographs. With cropped images, they achieved an accuracy of 87%, while R-CNN and GoogleNet produced the highest accuracy for the conditions of healthy (92%), decayed (88%), and restored (82%), teeth [14].

3.7.2 Tooth Impaction Detection

The three DL systems, Detect-Net, VGG-16, and AlexNet, were verified and compared to classify patients with maxillary impacted supernumerary teeth (ISTs) who have completely erupted incisors [4]. Overall, the results for DetectNet's diagnostic effectiveness were the best. In contrast, VGG-16 yielded significantly fewer values than both DetectNet and AlexNet. To employ panoramic dental radiographs to detect third molar impactions, altered periodontal bone height, and evident dental caries/periapical infection, a hybrid deep learning and machine learning technique [5] was proposed. AI applications showed good accuracy values in recognizing impacted third molar teeth and the link between anatomical structure [11].

3.7.3 Periapical Lesions Detection

In routine clinical practice, apical periodontitis is identified by conventional techniques such as IOPA and OPG, whereas periapical lesions are precisely assessed using 3D imaging provided by CBCT. But when it comes to identifying apical periodontitis in teeth with filled roots, CBCT's precision decreases [18]. Artificial intelligence algorithms are being created to detect loss of alveolar bone and forecast periodontally challenged teeth with a high degree of accuracy that is on par with skilled oral surgeons. Furthermore, AI algorithms show great promise in periapical lesion detection and differentiation, identifying 142 out of 153 lesions on panoramic radiographs with an accuracy of 92.8% [18].

Using SqueezeNet modeling, deep learning was utilized to identify white spot lesions on dental photos and classify them as either carious, fluorotic, or other hypomineralized lesions. For improved accuracy and generalizability, further study is advised to expand to larger datasets and broader multi-class detection, emphasizing that light reflections are the main source of false positive detections, especially impacting upper incisors [9].

3.7.4 Root Fractures Detection

Vertical Root Fractures (VRFs) can be obtained via cone beam computed tomography (CBCT) imaging and radiography; CNN is particularly useful for locating VRFs on panoramic radiographs. To identify VRFs in teeth that are both intact and filled with roots, a neural network was created using CBCT images and periapical radiographs. When it comes to specificity, accuracy, and sensitivity for identifying fractures in roots—especially in second molars—CBCT performs better than 2-D radiography. Wavelet analysis can be utilized to assess breaks using synthetic data [18].

3.7.5 Dental Caries

A back-propagation neural network outperforms other techniques like Electrical Caries Monitor and Direct Image Fibre Optic Trans-illumination in terms of diagnostic accuracy when it comes to predicting dental caries. It does this by utilizing Laplacian filtering, window-based adaptive thresholding, morphological operations, and statistical feature extraction [20]. This approach works well in the identification of dental caries on X-ray images, showing accuracy, precision-recall curve area, and ROC area.CariesNet addresses the difficulty mild case identification presents for AI-driven dental caries detection systems. They improve accuracy by segmenting dental structures and detecting cavities, incorporating speckle detection for feature extraction, and using transfer learning, active contour techniques, and M-CNN [3].

3.7.6 Oral Cancer

AI-driven methods for identifying and forecasting oral cancer have greatly increased accuracy rates and efficient data collecting is made possible by methods like cytology, CT, and fluorescence imaging [2]. Artificial intelligence (AI) attains an accuracy of 80–85% in comparison to traditional approaches; this increases to 93% with artificial neural networks (ANN) and 95% with regression algorithms. These developments not only enhance diagnosis but also help forecast the likelihood of malignancy, where boosted decision trees (BDT) are particularly effective with an accuracy of 90%–96%.

3.8 Dental Radiology

In Image Interpretation, RNNs and hybrid models have revolutionized dental radiology, significantly enhancing image interpretation. Efficient diagnosis leverages patient data accessibility through digital intraoral periapical (IOPA) X-rays, scans, and other digital imaging modalities [2]. Dental classification, featuring three classes ("cavity," "filling," "implant"), employs a

Gaussian filter and convolution entropy-based feature map extension, achieving exceptional accuracy of 99.7% with support fusion matching [12].

Shih-lun Chen et al. proposed dental condition detection using Faster R-CNN on panoramic radiographs, achieving an initial accuracy of 94.18% and exceeding 95% through transfer learning and image preprocessing, further enhanced with five distinct CNNs, including Alex Net and Google Net, potentially reaching up to 99.81% after image enhancement processes [19]. Advanced object detection methods like YOLOv7 have enhanced both accuracy and speed in panoramic dental imaging, yet challenges still need to be solved, such as detecting tooth roots and implants, limiting effectiveness in routine dental procedures.

Addressing issues like class imbalances through techniques like Visual Recognition with Deep Nearest Centroids and CLUSTSEG offers avenues for further improving these models [6]. Comparing DL systems for classifying maxillary impacted supernumerary teeth (ISTs) in panoramic radiographs revealed Detect Net's superior diagnostic efficacy, while VGG-16 showed significantly lower performance. Detect Net's automatic detection capabilities make it suitable for efficiently identifying ISTs, addressing the challenge of accurate classification in dental imaging [4].

3.9 Geriatric Dentistry

There has been a notable trend towards a more customized approach in the treatment planning of older patients with the use of rule-based models and expert systems. Through the use of these intelligent systems, which include variables such as age, medical history, and oral health status, dentists may provide proactive and individualized dental care. This use of expert systems in geriatric dentistry highlights a compassionate and individualized approach to dental care for the elderly and represents a significant advancement in promoting oral health among the aging population.

3.10 Forensic Odontology

It involves the examination of dental records, dental remains, and bite marks to identify individuals, establish their age, determine possible causes of death or injury, and provide expert testimony in court cases. Using pre-trained DenseNet121 [14], a deep transfer learning technique was utilized to predict the gender of the deceased or unaccounted for. Using 24,000 panoramic dental X-rays with various image resolutions, it could identify gender. With 97.25% accuracy, the 224x224 resolution produced the best results. A filter is used in a new automated method based on the ResNet20 model to eliminate noise from dental X-ray pictures during the pre-processing stage. As opposed to the ResNet20 model, the histogram equalization method was employed. However, the ResNet20 model's accuracy of 98.17% was higher. In addition to being ineffective at interpreting bite marks and forecasting mandibular morphology, CBCT imaging [18] has shown remarkable efficacy in ascertaining the biological age and gender of the healthy.

3.11 Clinical Decision Support System

AI analyzes patient data [2] using prior clinical expertise to help medical practitioners identify and treat patients. It facilitates decision-making. Based on sugar consumption and fluoride exposure, AI helps determine a patient's risk assessment and recommends a course of therapy. It has significant value for both professionals and patients.

3.12 Implant Dentistry

R.Bodhe et al [18] proposed that an artificial intelligence (AI) system be used to identify the type and location of implants, pinpoint the specific location of the mandibular canal—a canal that runs along both sides of the lower jaw and houses the alveolar nerve—and determine the precise number of missing teeth. Additionally, it can replace lost teeth. A deep neural network [3] showed good accuracy in identifying implants using faster R-CNN before detecting alveolar bone loss at the edge of implants. Findings from the investigation of a new AI-powered instrument [17] for precise mandibular canal segmentation on CBCT may contribute to the enhancement of pre-operative planning processes for implant implantation, bone grafting, orthognathic surgery, and tooth extraction. The construction of a basic feed-forward neural network (ANN) and the method for training an ANN utilizing backpropagation of error on the output of finite element simulations were demonstrated [7]. It was suggested that dental implants be designed with the least amount of microstrain in the surrounding bone and the greatest fatigue fracture resistance. Good accuracy was attained by using basic ANNs with only one hidden layer and a few neurons.

3.13 Usage of Large Language Models (LLMs)

Clinical chatbots [13] help dentists with patient communication and office tasks, as well as text classification. Virtual assistants and automated documentation support clinical charting. To extract dental status, such as the presence of fillings or tooth defects, multimethod approaches are used. To extract pertinent data from Electronic Health Records (EHRs), a rule-based system can be helpful. It might group medical histories. In endodontics, the CHATGPT-4 scored 57% accuracy on 60 questions. Automated dental charting can be accomplished through speech-based reporting.

Radiological requests, prescriptions, and referrals can all be handled via information extraction systems.

With a 76% accuracy rate, the LLM (GPT-2) model utilized in dental charting was able to predict the following word in clinical notes. For chat-based engagement with medical data, LLM is connected to the EHR. Clinical reports can be generated using GPT-1.

3.14 Digital Dentistry

To identify and diagnose bone and dental disorders, Tooth AI—an intelligent preventive system—was put forth [8]. To extract diagnostic data from input medical images or volumes obtained from dental exams utilizing CT scanners, it features an integrated CV and knowledge-based system. If the patient receives no treatment, it can simulate the disease's future progression, provide a real-time examination of the teeth and skull geometry, and recommend appropriate courses of action.

OHIP is the most extensively used OHRQoL questionnaire for oral health [15] that has been translated into other languages, verified by science, and is broadly utilized. Four main dimensions—oral function, orofacial pain, orofacial aesthetics, and psychosocial impact—that are clinically significant features of the OHRQoL have been identified. Using a gadget like "smart" electric toothbrushes that have sensors to track variables like timing, pressure, and location, a home-based strategy advocates oral health through mobile applications. To evaluate chewing performance digitally in a home environment, there are other programs like View Gum software. The usage of mobile phones, CBCT, 3D intraoral scans, sophisticated software, and customized CAD/CAM equipment all have a substantial impact on how well patients respond to therapy.

3.15 Regenerative Dentistry

In numerous restorative treatments, the stem cells taken from the tooth pulp were evaluated using the neuro-fuzzy inference method [18]. This approach predicted the outcome by measuring the stem cells' survival with bacterial lipopolysaccharides in a simulated clinical setting. Bioprinting has promise for reconstructing lost oral hard and soft tissues from sick or accidental sources by creating living tissue and even organs in successively thin layers of cells.

4. CONCLUSION

Finally, the incorporation of artificial intelligence with dentistry ushers in a new age in dental healthcare. AI's ability to process and analyze data at unprecedented speeds and accuracy ushers in a new era of precision diagnosis and individualized therapy. As we approach the tipping point of this technological transformation, we must embrace AI as a helpful ally in the pursuit of better dental health.

The combination of AI and dental expertise provides the path for more efficient, effective, and patient-oriented care. While AI has enormous potential in dentistry, the proper deployment of these technologies by dental professionals will decide the trajectory of its influence. The future of dentistry, assisted by AI, promises not only better patient results but also to move the frontiers of what is possible in oral treatment.

The dental community must ensure that these instruments are utilized appropriately and ethically as research develops and artificial intelligence becomes more advanced. Artificial Intelligence in dentistry has the potential to improve everyone's health and well-being in the future, provided that innovation and patient care are prioritized.

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