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Review Article

Application of artificial intelligence in orthodontics – A review

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Abstract

Many orthodontic treatments process, like wire bending, aligner production, and indirect bonding tray fabrication, can be automated as orthodontics becomes more digitally advanced. Planning and evaluating orthodontic treatments, however, is still the province of specialists. Apart from assisting in landmark identification, an advanced artificial intelligence (AI) model can provide help with various linear, angular, and volumetric measurements. This can significantly cut down on measurement time, allowing up researchers to focus on developing novel clinical insights. Orthodontists utilize features collected from multimodal, longitudinal, and standardized orthodontic data sets since it is difficult to forecast how each orthodontic patient will grow and respond to therapy. This scoping review explains about the application of artificial intelligence in orthodontics

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1. Introduction

AI is becoming more and more predominant in various aspects of daily life. Artificial intelligence (AI)-based algorithms are already an integral component of everyday technology. Some examples of its widespread use include spam filtering, speech and image recognition on digital platforms, and internet search engines.[1] Developing a machine the capacity for autonomous thought is the primary goal of artificial intelligence. Stated differently, AI seeks to enable a machine to learn from data and solve problems on its own. The core of AI is machine learning (ML). It uses algorithms to forecast results based on data sets and is influenced by a wide range of scientific fields. Its goal is to enable machines to acquire from data so they can solve difficulties on their own without human assistance. Deep learning is essential to machine learning.[2] To analyze input data, deep neural networks employ networks with several computer layers. Its goal is to create a neural network with automatic pattern recognition to enhance feature detection. Since orthodontic treatments often take a long time—an average of approximately 29 months—orthodontists must become more efficient in order to meet requirements from society. This problem can be resolved with the use of machine learning techniques Cone Beam Computed Tomography (CBCT) and 3D visualizations, intraoral scanners, facial scanners, instant teeth modelling software, and latest appliance advancement using robotics and 3D printing are a few of the orthodontic technological innovations that are quickly transforming medical care and advancing dentistry.[3,4] By facilitating a deeper understanding of the patient's anatomy and enabling the development of dynamic anatomical reconstructions specific to the individual, these techniques open up the prospect of 3D treatment planning.[5,6] This review discuss about various application of artificial intelligence in orthodontics.

2. Discussion

2.1. Dental diagnostics

Since medical imaging techniques facilitate the clinical detection of diseases pertaining to teeth and the structures

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surrounding them, they are indispensable to dental patient care. Orthodontic diagnosis, treatment planning, and monitoring depend heavily on radiological techniques like cone-beam computed tomography (CBCT) and orthopantomograms (OPGs).[7] A complete device is necessary to support the radiological diagnosis process, because the number of radiological examinations done is rising. Multimodular diagnostic systems built on artificial intelligence were developed in respond to this need.[8]

Using CNNs, Diagnocat Ltd.(San Francisco, CA, USA) has developed an intelligence based system that offers accurate and thorough dental diagnostics. The technology allows for volumetric assessment, identification of pathological conditions including periapical lesions and caries, and segmentation and enumeration of teeth.[7,9] The diagnostic performance of this program has been tested through various scientific articles, exhibiting its great efficacy and accuracy. According to the study conducted by Orhan et al., the AI system demonstrated no statistically significant variation in volumetric measurements when compared to manual approaches, and it was 92.8% accurate in identifying periapical lesions in CBCT pictures. Comparable results were also obtained from the study assessing the diagnostic accuracy of the algorithm for periapical lesion detection on periapical radiographs (PRs).[10]

2.2. Treatment outcome prediction

Orthodontists sometimes create many treatment plans, particularly for cases that are on the borderline. However, choosing the best line for treatment might be difficult for orthodontists without much experience. Furthermore, the results of therapy for situations involving interproximal enamel reduction and extraction tend to be irreversible, and inadequate plans may leave patients unsatisfied.[11,12] By implementing treatment outcome prediction, orthodontists can more accurately diagnose and treat malocclusions, reducing the likelihood of potential risks and consequences before and after clinical treatment. As currently developed now, AI can predict changes in the bones, face, and teeth as well as how patients will respond to clear aligners, which helps inform treatment planning dental care.[13]

Recently, a number of AI tools have been created to assist orthodontics in making treatment options. Initial analysis on extraction decision aids has produced encouraging findings, with AI algorithms outperforming expert judgements by more than 80%.[14,15] Xie (2010) found that, despite only analysing 20 cases, AI and experts agreed on extraction judgements in 80% of cases. An artificial neural networkc (ANN) system that Jung and King examined had an 84% success rate for the comprehensive diagnosis of certain extraction patterns and a 93% success rate for the diagnosis of extraction versus nonextraction situations based on 12 cephalometric factors.[15]

Automated digital setups have become increasingly common with the ongoing developments in artificial intelligence and digital orthodontics, particularly in the aligners treatment. In terms of six dimensions of tooth movement, Woo et al. evaluated the accuracy of three different AI digital setup software with a manual setup.[16]

One of the most significant parts of organizing orthodontic movement is choosing the treatment appliance. A poor wearing experience can have an adverse effect on patients' compliance and, as a result, on the results of treatment, especially for those who are using clear aligners. In order to predict patients' experiences with Invisalign therapy, Xu et al. used an ANN model with training data consisting of 17 clinical variables.[3] High prediction accuracy of 87.7%for pain, 93.4%for anxiety, and 92.4%for quality of life were achieved by the proposed model. This was the first study—and as of right now, the only one—to use artificial intelligence (AI) to anticipate how a patient will feel orthodontic treatment, setting the stage for more studies in this field.[14] This capacity to automatically segment teeth in digital dental models has advanced dramatically in recent years, and it now forms the basis for additional automated measurements and analysis. Following the "3DTeethSeg'22 challenge" containing 1,800 labelled intraoral scans, a first multicentric benchmarking data set was recently provided to test several AI-based tooth segmentation and tooth labelling models.[18] To improve generalisability, three different commercial intraoral scanners were used for the scanning process. The best-performing model yielded an excellent segmentation accuracy of 0.99.[17,18]

2.3. Growth predicton

Growth and development predictions for cervical vertebrae are frequently made using the handwrist radiograph and lateral ceph radiographs. Based on cervical vertebrae and hand-wrist radiographs, AI technology precisely calculates the growth and development rate using ANN algorithms. Timing is arguably the most important factors to take into account when creating a treatment plan, particularly for patients who are growing. Numerous techniques, such as menarche, voice and body height changes, chronological age, and bone age, have been caused for growth prediction. The gold standard for determining bone age was handwrist radiographs; however, according to Lamparski, cervical vertebrae stages may be read to get a similar level of accuracy while also avoiding further radiation.[19] Spampinato evaluated bone age using hand-wrist radiographs by utilizing deep learning techniques. 1391 X-ray left-hand scans of children under 18 years old were included in the sample, and two highly qualified radiologists supplied bone age estimates. The outcome revealed an average difference of almost 0.8 years between the evaluations made manually and automatically. Different AI algorithms were examined by Kok et al. to determine growth by cervical vertebral stage. The accuracy of the methods Knearest neighbours, Naive

Bayes, decisiontrees, support Vector machines, Artificial neural networks, Random forests, and Logistic regression was examined. The most stable result was produced by ANN, which was recommended as the best technique for assessing the cervical vertebrae stage.[20]

2.4. Clinical documentation

Radiographs and clinical images are frequently taken for treatment monitoring and diagnosis. AI can help with identifying and classification of these photos, improving the effectiveness of healthcare practice. Five intraoral and four facial shots, as well as five facial photos, were automatically classified by Ryu et al. using CNNs. With 98% of its predictions being true overall, the CNN model performed well. Li et al. used a deep learning model based on Deep Hidden IDentity (DeepID) to increase the number of orthodontic picture categories to 14. These images included one panoramic video, one lateral cephalogram, six intraoral images, and six face photographs.[20]

2.5. Segmentation and landmark identification

The process of separating the pixels representing specific organs or lesions from medical pictures like X-rays, CT scans, or MRIs is known as image segmentation.[16] Volumetric medical image analysis and automated or semi-automatic computer-aided diagnosis systems both rely heavily on picture segmentation. For many years, the diagnosis and treatment planning of orthodontic therapy have depended heavily on landmark recognition in lateral cephalometric X-rays.[21] Machine learning was used in numerous studies to identify landmarks and perform segmentation. A technique to perform automated maxilla and mandibular segmentation using CBCT was created by Wang et al.[18] They used a learning-based framework to segregate the mandible and maxilla from CBCT based on random forest simultaneously. A common method for assessing the volumetric segmentation of medical images is the 19 Dice ratio.[22]

2.6. Cephalometric analysis

Cephalometric analysis (CA) has been a crucial diagnostic technique in orthodontics since its development dated back 1931. Advances in technology have transformed CA throughout time, substituting digital software for manual investigations. This method offers automatic results display for the analysis and streamlines the measurement process. It has been demonstrated that automatic CA is more dependable and consistent than manual analyses, which frequently display notable variability and mostly rely on operator dependent identification of landmark. For CA results to be dependable, landmark identification must be precise and reproducible. Numerous research has shown that AI is capable of recognising cephalometric landmarks. While lateral radiography is still the most widely utilised technique in CA, cone-beam computed tomography (CBCT) has seen a resurgence in interest because to recent advances in AI.[4,5]

Development on artificial intelligence in order to identify cephalometric landmarks were practiced from 1998. Several studies have constantly achieved great accuracy in anatomical landmark identification using different automated techniques. According to the outcomes of a recent study, automated cephalometric landmark detection can be just as dependable as a human reader with expertise.[21] Similar to this, Kim et al., Lee et al., and Dobratulin et al. employed AI to achieve 88% to 92% accuracy in previous assessments. These researchers also found that AI approaches took less time and effort from people and demonstrated more accuracy in detecting landmarks than manual methods did. Comparing manual and automatic cephalometric analysis suggested that it did not differ statistically significantly in study done by Hwang et al. and Yu et al. Furthermore, it has been demonstrated that AI greatly enhances practice workflow, reducing analysis times by up to 80 times when compared to manual analysis. So many studies have shown that AI is precise in identifying cephalometric landmarks. While lateral radiography is still the most widely utilized technique in CA, cone-beam computed tomography (CBCT) has seen a resurgence in interest because to recent advances in AI.[22,23]

2.7. Orthognathic surgery

There are no established guidelines for determining who is suitable for orthognathic surgery, even in spite of tremendous advancements in the fields of surgery and orthodontics. When an orthodontist must choose between referring a patient for surgical procedure or camouflage treatment, this challenge becomes especially difficult. Finding patients who benefit from orthognathic surgery is the main factor that impacts a patient's future prognosis. Lateral cephalograms are the main tool used to evaluate sagittal skeletal abnormalities, and they are typically used to confirm the diagnosis in surgical cases. It has already been demonstrated that orthognathic surgery diagnoses may be identified with greater than 90% accuracy using both AI and ML algorithms. Jeong et al. conducted a study wherein they assessed soft tissue profiles by utilizing facial pictures. 89% of the assessed CNN's surgical case classifications were accurate.[16,17] A lot of money has been funded to R and D for digital orthodontics and 3D orthognathic surgical simulation. Furthermore, computerized treatment planning and tailored surgical setup planning improves diagnosis accuracy, especially for young doctors. Knoops et al. developed a machine learning framework for automated diagnostics and technology assisted planning in plastic and reconstructive surgery. A machine-learning framework with supervised learning constructed utilising surface 3D scan data was introduced: the large-scale clinical 3D morphable model (3DMM).[24]

A computer-assisted planning method based on CT, cephalometric, and plaster model was created by Weichel et al. The knowledge base incorporated into the semantic web standard Resource Description Framework Schema was referred to by the system, which converted human knowledge into data that was readable by machines. To determine the local minimum of the loss function, gradient descent algorithm was employed. The loss function provided an assessment of how well our present regression worked. The loss function increases as the computed result deviates farther from the ideal result. There was found to be good general agreement between the planning result of a maxillofacial expert and the computer-generated planning proposal.[25]

ANN was used by Niño-Sandoval et al. to predict the morphology of the mandible based on the morphology of the maxilla. Colombian patients provided 14,299 lateral cephalograms with 19 landmarks on X and Y coordinates. High predictability of the chosen mandibular elements was demonstrated by the results, and this could be very beneficial for craniofacial reconstruction.[26]

2.8. TMJ evaluation

Robotic surgeries in neurology, obstetrics, cardiothoracic surgery, and many common surgical procedures have been implemented using AI. The prospect of applying AI robotic technologies to orthognathic surgery is highly encouraging in the near future. Because only robotics come into contact with patients, it can lower the infection rate. Simultaneously, increased jaw movement precision is anticipated. Bone remodeling, the development of osteoproliferative bodies, and the progressive degradation of joint cartilage are the hallmarks of osteoarthritis (OA), a disorder that affects the joints. One particular kind of temporomandibular problem that can lead to considerable pain in the joint, dysfunction, dental malocclusion, and a general decline in quality of life is temporomandibular joint osteoarthritis (TMJOA). Shoukri et al. used neural network in order to stage condylar morphology in temporomandibular joint osteoarthritis (TMJOA), To be able to detect and classify the stage of TMJOA and compare its results to the categorisation of clinical experts, a neural network was trained on 259 condyles. Using CBCT images, condylar morphology was categorised into six groups. When comparing the AI's staging of TMJOA to the repeated clinicians' consensus, predictive analytics revealed an accuracy of 73.5 and 91.2%. The findings imply that AI is capable of classifying TMJOA condylar morphology in a thorough manner. When undergoing orthodontic and dental treatments, it is essential to examine the morphology and function of the TMJ. One of the reasons for malocclusion and facial asymmetry is TMJOA. Although MRI is the recommended modality for assessing joint discs, radiographic evaluation, such as OPG/CBCT, shows the presence of TMJOA by revealing bony alterations. Recent research has shown how well AI performs as a diagnostic tool for identifying and diagnosing TMJOA. These studies have demonstrated the possibility to use a variety of imaging modalities, such as OPG, CBCT, and MRI, to automatically and thoroughly examine joint morphology. Thus, the authors hope that future studies on early diagnosis and individualized treatment plans for OA will benefit from the application of AI algorithms for TMJ diagnostic imaging.[23,26]

2.9. Cleft

Studies related to cleft, Zhang examined blood samples from Han and Uyghur Chinese children with non-syndromic cleft lip and palate (NSCL/P) as well as healthy controls in order to confirm the diagnostic efficacy of forty-three single nucleotide polymorphisms (SNPs) that had previously been found through genomewide association studies.Using those SNPs, thirty different machine learning algorithms were utilised to create predictive models, and the accuracy of those models was assessed. The results showed that when it came to risk assessment, logistic regression AI worked the best. Defective mutations in MTHFR and RBP4, two genes involved in the production of folic acid and vitamin A, were found to have a significant contribution to the rate of NSCL/P, according to a logistic regression analysis of feature relevance. This is consistent with the idea that vitamin A and folic acid are necessary to lower the chance of having a child with NSCL/P.[27]

3. Conclusion

Over the past three decades, the number of orthodontic studies involving various uses of AI and ML has increased rapidly, as this scoping review highlights. Orthodontics is one of the fields most benefited by the introduction of AI technology because of the ongoing development of AI algorithms that enhance pretreatment diagnostic processes, enable the visualisation of results, and ease decision-making throughout treatment. However, these tools should be used cautiously, and the results should be routinely and carefully checked, given the great complexity and inherent unpredictability of AI.

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None.

5. Conflict of Interest

None.

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