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AI INNOVATIONS IN DIAGNOSIS AND TREATMENT PLANNING IN ORTHODONTICS

INOVAÇÕES DE IA NO DIAGNÓSTICO E PLANEJAMENTO DE TRATAMENTO EM ORTODONTIA

INNOVACIONES DE IA, EN EL DIAGNÓSTICO Y LA PLANIFICACIÓN DEL TRATAMIENTO EN ORTODONCIA

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ABSTRACT

Digital dentistry, initiated in 1973 by Professor François Duret, has evolved considerably in orthodontics, through the use of digital flow and artificial intelligence (AI). These technologies enable accurate diagnosis, prognosis and treatment. AI has greatly improved the efficiency of diagnosis and treatment planning in orthodontics, with increasing applications due to advances in algorithms, processing and data availability. Objective: Evaluate AI applications for diagnosis, orthodontic treatment planning and improving patient satisfaction. Conclusion: The integration of AI into orthodontics has significantly transformed the way treatment is diagnosed, planned and administered, offering notable advantages in terms of precision and efficiency. However, its use presents challenges, such as the need for specialized training, prior professional experience to determine reference standards and the integration of these technologies into clinical practice. As technology continues to advance, the tools used will be improved and the current limitations overcome.

KEYWORDS: Artificial intelligence. Cephalometry. Diagnosis. Machine learning. Orthodontics.

RESUMO

Introdução: A odontologia digital, iniciada em 1973 pelo professor François Duret, evoluiu consideravelmente na ortodontia, por meio do uso de fluxo digital e inteligência artificial (IA). Essas tecnologias permitem o diagnóstico, o prognóstico e o tratamento precisos. A IA melhorou muito a eficiência do diagnóstico e do planejamento do tratamento em ortodontia, com aplicações crescentes graças aos avanços em algoritmos, processamento e disponibilidade de dados. Objetivo: Avaliar os aplicativos de IA para diagnóstico, planejamento de tratamento ortodôntico e melhoria da satisfação do paciente. Conclusões: A integração da IA na ortodontia transformou significativamente a maneira como o tratamento é diagnosticado, planejado e administrado, oferecendo vantagens notáveis em termos de precisão e eficiência. No entanto, seu uso apresenta desafios, como a necessidade de treinamento especializado, experiência prévia do profissional para determinar padrões de referência e a integração dessas tecnologias na prática clínica. Com o avanço contínuo da tecnologia, as ferramentas usadas serão aprimoradas e as limitações atuais serão superadas.

PALAVRAS-CHAVE: Inteligência artificial. Cefalometria. Diagnóstico. Aprendizado de máquina. Ortodontia.

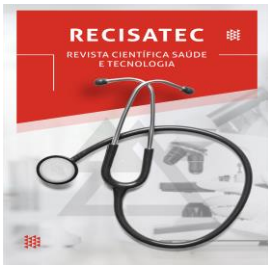
RESUMEN

Introducción: La odontología digital, iniciada en 1973 por el profesor François Duret, ha evolucionado considerablemente en ortodoncia, mediante el uso del flujo digital y la inteligencia artificial (IA). Estas tecnologías permiten un diagnóstico, pronóstico y tratamiento precisos. La IA ha mejorado enormemente la eficacia del diagnóstico y la planificación del tratamiento en ortodoncia, con aplicaciones cada vez mayores gracias a los avances en algoritmos, procesamiento y disponibilidad de datos. Objetivo: Evaluar las aplicaciones de IA para el diagnóstico, la planificación del tratamiento

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de ortodoncia y la mejora de la satisfacción del paciente. Conclusión: La integración de la IA en la ortodoncia ha transformado significativamente la forma de diagnosticar, planificar y administrar el tratamiento, ofreciendo notables ventajas en términos de precisión y eficiencia. Sin embargo, su uso presenta retos, como la necesidad de formación especializada, experiencia profesional previa para determinar estándares de referencia y la integración de estas tecnologías en la práctica clínica. A medida que la tecnología siga avanzando, se mejorarán las herramientas utilizadas y se superarán las limitaciones actuales.

PALABRAS CLAVE: Inteligencia artificial. Cefalometría. Diagnóstico. Aprendizaje automático. Ortodoncia.

INTRODUCTION

Objective

Evaluate AI applications for diagnosis, orthodontic treatment planning and improving patient satisfaction.

Justification

In orthodontics, as in other health areas, there is a need to innovate and improve diagnostic and therapeutic procedures through the use of new technologies to obtain more effective results. AI is a useful tool to achieve these objectives, and it is essential to carry out a study that allows professionals to understand the usefulness of these tools and how they are applied in the diagnosis and planning of orthodontic treatments. The present study is a literature review, in which 14 articles were selected through a search in scientific databases such as PubMed, Google Scholar and Scopus, in order to gather information on artificial intelligence (AI) and its application in orthodontic treatments.

Background

Digital dentistry began in 1973 with Professor François Duret. In the field of orthodontics, tools such as digital flow and artificial intelligence allow the use of software that facilitates the diagnosis, prognosis and treatment of patients, as well as administrative management. They also make it possible to create complete medical records, with photographic records, studies, model indexes in "Standard Three-Dimensional Language (STL) format and cephalometric tracings (1).

The digital flow is based on three main pillars: digitization, processing and construction. Digitization makes it possible to obtain a 3D file that is an exact copy of the object, using intraoral or extraoral scanners. This 3D file, known as STL, can be processed with various types of software. In orthodontics, these programs make it possible to edit STL files, analyze 3D measurements, plan treatments and study biomechanics (1).

Artificial intelligence (AI) will also be able to analyze large volumes of historical orthodontic treatment data to more accurately predict the outcomes of different treatment plans. This will enable



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orthodontists to offer personalized treatment plans based on more accurate predictions of time and outcomes (1, 2).

Using radiographic images and intraoral scans, AI systems can automatically identify dental and occlusal anomalies, providing an initial diagnosis that the orthodontist can review and confirm. In this way, advanced software can suggest optimal treatment plans based on the diagnosis, helping to design customized appliances and predict tooth movement accurately (2, 3).

OPERATION AND APPLICATION OF AI IN ORTHODONTICS

Diagnosis

Diagnosis in orthodontics encompasses several analyses, including cephalometric, dental, facial, skeletal maturation and upper airway evaluation, in order to comprehensively establish the patient's profile (4).

Facial Analysis

Facial photographs are crucial to evaluate facial symmetry and proportions in orthodontics (4). According to Bravo et al. in 2023 in a narrative review on the state of the art of artificial intelligence in orthodontics, they have focused on two main areas: assessment of facial attractiveness and estimation of apparent age. To achieve this, convolutional neural network (CNN) an algorithm used to extract facial features, followed by a framework for combining these features and finally classifying facial attractiveness based on a visual analog scale (VAS) has been employed. In addition, apparent age, which corresponds to the difference between the patient's actual age and the age estimated by A.I., has also been determined through CNN (2).

Analysis Of Lateral Cephalic Radiographs

Cephalometry is fundamental in orthodontic treatment, as it allows for the evaluation of growth patterns, diagnosis and planning of orthodontic therapies (3). Traditionally, manual landmarking is a slow process and dependent on operator experience, which can impact both accuracy and efficiency. The introduction of automated landmark detection has improved dramatically with artificial intelligence, offering higher levels of reproducibility, efficiency and accuracy (4).

Among the most widely used artificial intelligence methods are CNNs, a deep learning algorithm that requires many numbers labeled images for training. These networks are useful for determining bone maturation, automatically locating cephalometric points, performing orthognathic surgery, assessing facial attractiveness and apparent age. As for cephalometric analysis, CNNs have a performance comparable to that of expert orthodontists, with the advantage of being able to complete an analysis in less than one second (3).



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Dental Analysis

In orthodontics, intraoral photographs and study models are crucial for assessing molar relationships, dental crowding, arch width, overbite, protrusion, and oral health. Manual analysis of these examinations is tedious and time consuming, suggesting the possibility of using AI to automate the process (4). The YOLO algorithm was used to detect malocclusions from intraoral photographs, achieving an accuracy of 99.99%. Ryu et al. used four CNN algorithms to evaluate dental crowding, highlighting VGG19 with minimal errors in the maxilla and mandible (4).

Digital technologies, such as 3D intraoral scanners and digital dental models, facilitate automated analysis to improve accuracy and efficiency in orthodontics.

Determination Of Skeletal Maturation

The determination of bone age is crucial for orthodontic treatment, especially in functional and orthopedic therapies (4). To estimate bone age, radiography of the hand and wrist is used, and for this purpose a CNN has been developed that analyzes the entire image and has proven to be effective in patients from 0 to 18 years of age (3).

As for bone maturation, the cervical staging assessment (CVS) of Hassel and Farman is commonly used, but nowadays, the combination of the cervical vertebral maturation method (CVM) with Artificial Intelligence has also been used to assess bone maturation by analyzing lateral cephalograms (4).

Upper Airway Obstruction Assessment

Airway obstruction can affect craniofacial development and lead to malocclusions. Shen et al. and Zhao et al. (2023) mention that AI has been shown to be useful in the evaluation of these obstructions, especially in detecting adenoid hypertrophy by lateral cephalograms and CBCT using CNN models where high accuracy has been shown (Shen et al. and Zhao et al.). Two deep learning algorithms were also proposed to be used to segment the upper airways and diagnose adenoid hypertrophy from CBCT, they are HMSAU-Net and 3D-ResNet to segment the airways and diagnose adenoid hypertrophy with high accuracy (Dong et al.) (3).

These developments indicate that artificial intelligence is transforming orthodontics by increasing accuracy and effectiveness in identifying bone maturation and detecting upper airway blockages (4).

Decision Making For Extractions

Determining whether teeth need to be extracted during orthodontic treatment has been a difficult problem due to the lack of a standardized method and reliance on the orthodontist's expertise. Artificial intelligence may be useful in decreasing the possibility of erroneous decisions in this regard (4).



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Artificial neural networks (ANN) are the most widely used algorithms for predicting extraction patterns. A system was developed with a success rate of 93% and 84% in extraction/non-extraction and detailed extraction decisions (Jung et al.).

However, there are other algorithms including Random Forest (RF), Support Vector Machine (SVM) and logistic regression (LR). Although these algorithms are used for classification and regression, ANNs have shown significant advantages in decision making for extractions, but it is considered that with the use of radiographic images, CNNs may offer better results (4).

Use of ai for Orthognathic Surgery

One of the main applications of AI in the field of orthognathic surgery is the automatic identification of cephalometric landmarks in 2D and 3D images. This automation significantly reduces the time and manual effort required, improving accuracy and consistency in surgical planning. Studies have shown that neural network and deep learning algorithms can detect landmarks with accuracy comparable to that of human experts, optimizing diagnosis and preoperative assessment (11).

In addition, AI is used to create customized surgical models that can simulate complex maxillofacial movements and predict the outcomes of different surgical approaches. For example, the use of algorithms such as BR-XGBoost has proven to be highly effective in classifying dento-maxillofacial deformities and generating optimized surgical plans. These models not only help surgeons plan procedures more accurately, but also allow for real-time adjustments based on surgeon preferences and specific patient characteristics. The combination of objective and subjective assessments of AI-generated plans ensures that the results are clinically feasible and effective. Likewise, the ability to adapt to new technologies will determine the ability to create new solutions and provide better treatment (10).

Despite the advances, further improvement of AI models to handle a wider range of cases, especially the more ambiguous ones, is necessary to improve their diagnostic and orthodontic treatment planning capabilities (3).

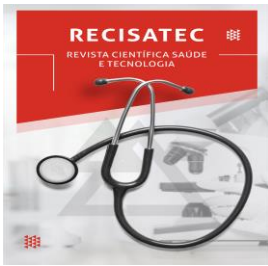
TREATMENT

AI applications can automate and streamline treatment planning, enabling orthodontists to make more informed and personalized treatment decisions.

Treatment Outcome Prediction

AI applications can automate and streamline treatment planning, enabling orthodontists to make more informed and personalized treatment decisions.

Dental changes: automated digital setup tools are available to help visualize treatment progress, although they may still require manual adjustments (3).



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Skeletal and facial changes: AI predicts post-treatment changes with high accuracy using CNN and conditional generative adversarial network (cGAN), prediction of cephalometric changes and 3D facial morphology (3).

Monitoring and Evaluation During Treatment

AI can segment teeth thanks to CBCT and fuses this data with the intraoral scan, allowing root position to be determined. It is transforming the prediction of orthodontic treatment outcomes and improving clinical practice by providing more accurate and efficient tools for treatment planning and execution (3).

Remote Care

Remote monitoring: AI allows orthodontists to track treatment progress through photos or oral scans, reducing unnecessary visits and improving patient comfort through a leading software called Dental Monitoring (DM) is a leader in remote monitoring by AI, allowing patients to scan their dentition through an app on their smartphone uses a bracket and a cheek retractor tube (3). Applications and accuracy: DM detects problems such as ill-fitting aligners, missing attachments and bracket breakage (3).

LIMITATIONS AND FUTURE PROSPECTS

1. Data and generalization: The paucity of training data and their low generalization limit the reliability of AI models. Methods such as transfer learning, data augmentation, and semi-supervised learning seek to mitigate this, albeit with limited effectiveness (3).
2. Data sharing: Ethical and privacy issues hinder data sharing. The use of technologies such as blockchain and federated learning can facilitate secure and collaborative data sharing (3).
3. Comparison of studies: Variability in study designs and evaluation metrics makes it difficult to compare AI studies in orthodontics. The MI-CLAIM (Minimal Information on Clinical Artificial Intelligence) checklist can introduce transparency and effectiveness in clinical AI modeling (3).
4. Interpretability: The lack of transparency of AI algorithms, considered "black boxes," raises concerns. Explainable AI (XAI) techniques such as Grad-CAM and DeConvNet seek to make the AI decision process more understandable, providing data transparency and reliability (3).
5. Overfitting: A common problem in AI, where models perform well on training data but not on test data. Methods to prevent this include data augmentation, cross-validation, and other specific algorithms (3).



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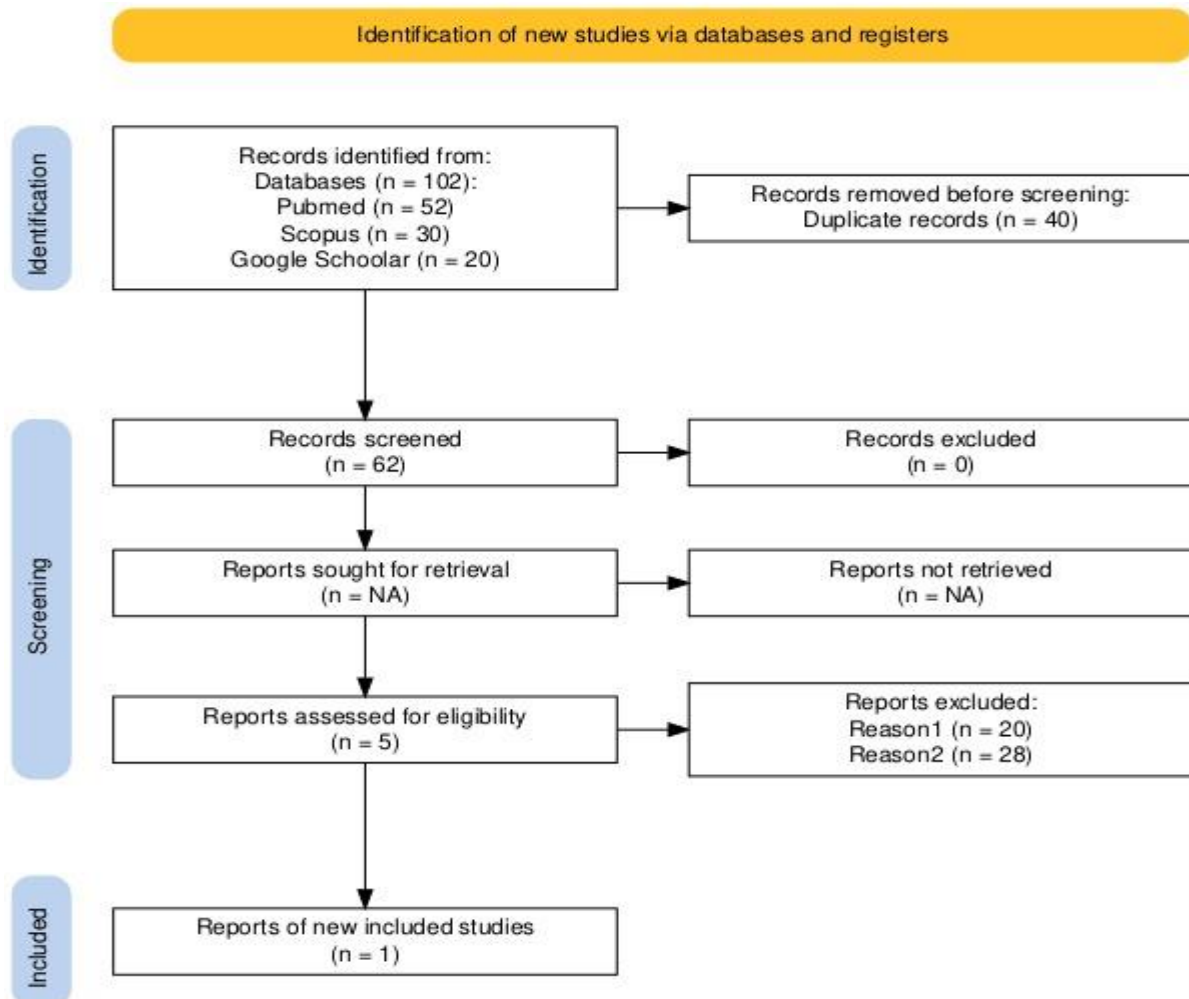
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- 6. Future areas of research: AI could be further applied in automated detection of treatment needs and in guiding the orthodontic treatment process, addressing problems such as correction of deep overbites and prevention of osseous dehiscence (3).

METHODOLOGY

A search was performed in scientific databases such as PubMed, Google Scholar and Scopus, using MeSH terms combined with Boolean operators such as AND and OR, to gather information about AI and its application within orthodontic treatments. Clinical studies, systematic reviews, meta-analyses, and review articles containing information on the use of all in orthodontics from 2019 to 2024 were included. Studies that were not directly related to orthodontics or lacked clinical relevance were excluded; and after review of all articles, 14 articles were selected for investigation.

A total of 102 articles were initially collected, of which 40 were excluded due to duplication, resulting in 62 unique articles. Of these, 5 were randomly selected and reviewed to establish eligibility criteria. Subsequently, 20 articles were excluded for lack of clinical relevance and 28 for not meeting the eligibility criteria, leaving a total of 14 articles for review in the present study.





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DISCUSSION

With regard to the use of artificial intelligence in orthodontic treatment, recent years have seen great advances and increased frequency in the study and application of artificial intelligence in dentistry, as Albalawi et al. point out, the research trend shows a gradual increase in the number of research publications over the past two decades. However, in the last two years, the number of articles reported on the application of AI models in orthodontics has increased rapidly (14).

Regarding digital models, according to Homsí et al. in 2023 evaluated the iTero intraoral scanner and with the DM application and stated that there are no clinically significant differences between both reconstructed models (3, 6). They measured the intercanine and intermolar width, DM-generated models and plaster models and determined that there is no difference in quality, as long as the scan quality with DM is acceptable, however if the patient's scan is incorrect the DM application will send a message requesting a new scan (7); however, a prospective study that evaluated 30 patients in treatment with clear aligners which were scanned twice using a remote monitoring app with a smartphone and a repeatability and reproducibility analysis of the caliper was performed found that there are still issues with the consistency of the DM instructions (8).

According to Tomás 2023, he states that the use of AI in orthodontics is more prevalent because of its focus on identifying and analyzing cephalometric landmarks, taking permanent teeth extraction, predicting orthognathic surgery, determining chronological age, growth patterns, facial analysis and temporomandibular joint. Today, AI integrates orthodontic device planning and fabrication, thus employing accurate 3D scans and virtual models to determine a unique treatment strategy. So that data is processed, an algorithm is developed that intelligently determines how the diagnosis and treatment planning should be handled (9).

The use of AI in orthodontics also raises important ethical and privacy considerations. The collection, storage, and analysis of large volumes of patient data require strict security protocols to protect patient privacy. In addition, it is crucial to obtain informed consent from patients before using their data to train AI algorithms. Transparency in the use of data and the purpose of its use must be a priority to ensure trust and privacy.

CONCLUSIONS

The integration of artificial intelligence in orthodontics has significantly transformed the way in which treatments are diagnosed, planned and administered, because it offers remarkable advantages with good precision and efficiency, allowing faster and more accurate diagnoses, analyzing images and clinical data. The use of AI-based technologies provides us with simulations such as tooth movements in addition to 3D planning, allowing orthodontists to design better treatment plans.

However, the use of AI in orthodontics poses challenges that include the need for specialized training of practitioners, the practitioner's prior experience in determining benchmarks within AI tools, in addition to the integration of these technologies within clinical practice.



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In conclusion, AI in orthodontics represents an important advance that improves treatment accuracy and efficiency. As the technology continues to advance, the tools used will be improved and the various limitations they currently present will be addressed.

It is crucial to continue research in this field to optimize the integration of AI into orthodontic practice and overcome current challenges. Investment in research will enable new applications to be developed and existing ones to be improved, thus ensuring a future in which orthodontic treatments are increasingly accurate, efficient and personalized.

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