WEST AFRICAN JOURNAL OF ORTHODONTICS

ISSN 2315-9502

VOLUME 12, NUMBER 1

JUNE 2023

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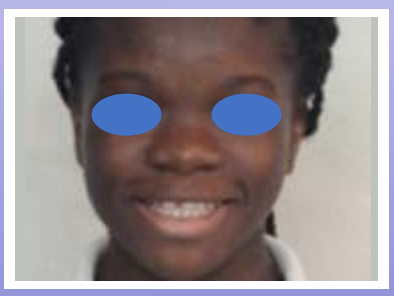

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"DENTISTRY'S FIRST SPECIALTY JOURNAL IN SUB SAHARAN AFRICA"

Artificial Intelligence in Orthodontics

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Abstract

Artificial Intelligence (AI) refers to the development of computer systems that can perform tasks that would typically require human intelligence.

In recent years, the integration of artificial intelligence (AI) in orthodontic practice has revolutionized the way orthodontists diagnose, plan treatments, and monitor progress, leading to more efficient and accurate outcomes. AI is being applied in the evolution of Intelligent Aligner Systems, Robot-Assisted Orthodontics, AI-Enhanced Bracket Placement, Adaptive Orthodontic appliances and others.

AI plays a crucial role in improving patient communication and engagement by assisting orthodontists in creating interactive treatment simulations and visualizing potential treatment outcomes. This empowers patients to make informed decisions about their treatment options and fosters a stronger doctor-patient relationship.

There is the need for ethical considerations such as: Patient Data Privacy and Confidentiality, Informed Consent, Accountability and Responsibility and Regulatory Compliance as AI technology is embraced.

The limitations of AI include the need for large datasets, lack of interpretability, limited incorporation of subjective factors, and ethical considerations. In Nigeria, the challenges of constant power outage, rising inflation, lack of good internet connectivity and lack of regulatory compliance compound these challenges.

In conclusion, the integration of AI into orthodontic practice holds immense potential for enhancing treatment outcomes, improving efficiency, and strengthening patient engagement. The decision to embrace AI technology is not just a choice but a necessity for orthodontists and trainees who strive to deliver the highest quality of care to their patients.

Keywords: Artificial Intelligence, Orthodontics

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ORIGINAL ARTICLE

Introduction

Artificial intelligence is the ability of machines to work like humans. AI has been defined as the ability of a computer to perform tasks intelligently, equivalent to a human being, incorporating understanding and processing language with reasoning skills and problem-solving ability.[1] It is a subfield of computer science that refers to the ability of a machine to imitate the cognitive functions of human intelligence.

Artificial Intelligence (AI) in orthodontics has reached a pivotal juncture, where it is revolutionizing treatment planning. AI-driven software is emerging as a game-changer for orthodontists by significantly enhancing their ability to design individualized treatment plans. This transformative technology considers a multitude of crucial factors such as tooth movement, occlusion, and aesthetics, resulting in treatment plans that are not only more efficient but also tailored to the unique needs of each patient[2]. With the advent of AI, the days are gone of one-size-fits-all orthodontic approaches.

Malocclusion is considered the world's third most prevalent oral disease, and nearly 30% of the population presents with a great need for orthodontic treatment. [3,4] Clinical orthodontic practice often requires a significant amount of time to conduct various analyses that necessitate the extensive clinical experience of orthodontists. These workloads have affected the efficiency of clinical orthodontic practice. A series of studies have shown that AI can significantly enhance the efficiency of clinical orthodontic practice. Several commercially available AI-driven software (3Shape Dental System 2.22.0.0, Uceph 4.2.1, Mastro 3D V6.0 etc.) programs have found widespread applications in orthodontic care19. With the ongoing advancement

of AI algorithms, computing capabilities and the growing availability of datasets, the scope of AI applications in orthodontics is expanding, accompanied by continuous performance improvement.

A New Era

In the digital dentistry era, new tools, algorithms, data science approaches, and computer applications are available to researchers and clinicians. However, there is a strong need for better knowledge and understanding of multisource data applications, including three-dimensional imaging information such as cone-beam computed tomography images and digital dental models for multidisciplinary cases .[3]

The clinician needs to plan the treatment based on state-of-the-art diagnosis for better and more personalized treatment. The tools and approaches presented are toward personalized treatment and better prognosis, following the path to a more automated clinical decision-making system based on multisource three-dimensional data, artificial intelligence models, and digital planning.[4] In summary, the orthodontist needs to analyze each patient individually and use different software or tools that better fit their practice, allowing efficient treatment planning and satisfactory results with an adequate prognosis.[5]

Among the most noteworthy advancements over the past decade are the establishment of universal aesthetic rules and guidelines based on the assessment of natural aesthetic parameters, anatomy, and physiognomy; the development of tooth whitening and advanced restorative as well as prosthetic materials and techniques, supported by the pioneering discovery of dental adhesion[6] the significant progress in orthodontics and periodontal as well as oral and maxillofacial surgery; and, most recently, the implementation of digital technologies in the 3-dimensional planning and realization of truly natural, individual, and aesthetic smiles.

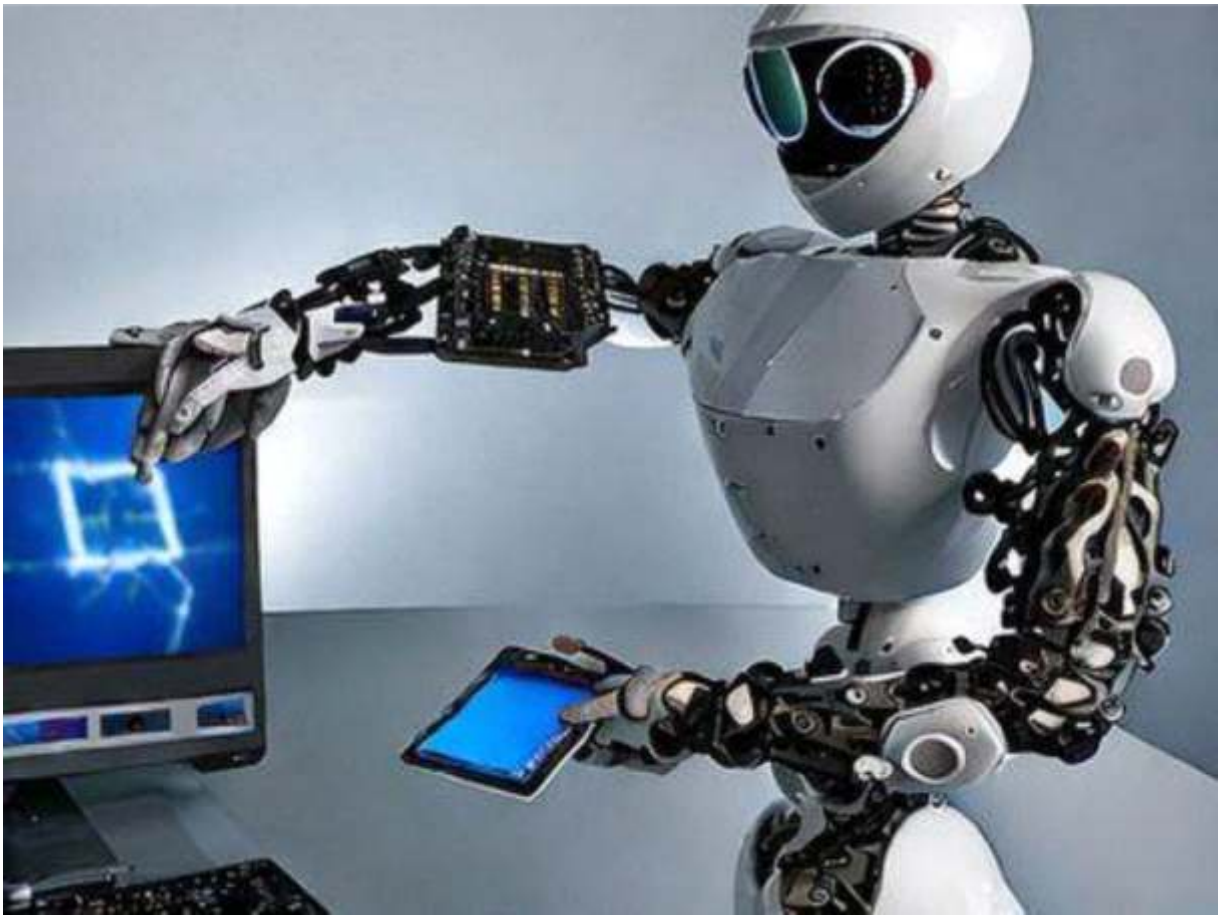

Figure 1

Applications of Artificial Intelligence

AI in Orthodontic Diagnosis

A satisfactory orthodontic diagnosis relies on a series of analyses , like cephalometric analysis, dental analysis, facial analysis, skeletal maturation determination and upper-airway obstruction assessment, to comprehensively evaluate patients' overall profile, including their facial profile, dental and skeletal relationship, skeletal maturation stages and upper-airway patency.[2] Automated Image Analysis and Computer-Aided Diagnosis are also included.

AI in the identification of anatomical /pathological structures and decision support for extraction.

One of the most remarkable aspects of AI in orthodontics is its capacity to generate highly detailed virtual models of patients' dental anatomy. These 3D virtual models serve as invaluable tools for orthodontists and their patients alike. Orthodontists can use these models to meticulously analyze and predict the outcomes of orthodontic treatment, providing a visual representation of the proposed changes.[6] This enhances the communication between orthodontists and their patients, enabling them to have a clearer understanding of the treatment process and expected results. Patients can now embark on their orthodontic journeys with a more informed perspective, fostering a sense of partnership and trust with their orthodontists. In orthodontics, expert systems and machine learning have aided clinicians in making complex, multifactorial decisions. The AI model showed an accuracy of 97.97% for extraction and non-extraction decision-making in borderline complex cases.[8]

AI in Cephalometric Analysis

One of the main uses of artificial intelligence in the field of orthodontics is automated cephalometric analysis. Evaluating whether developmental stages of a dentition, fixed orthodontic appliances or other dental appliances may affect the detection of cephalometric landmarks has been made easier and faster.[9]

Cephalometric analysis, especially landmarking on lateral cephalograms, serves as the foundation of orthodontic diagnosis, treatment planning and treatment outcome assessment. Conventional manual landmarking is time-consuming, experience-dependent and can be inconsistent within and across orthodontists, significantly affecting the efficiency and accuracy of clinical practice. Automated landmark detection was reported as early as the mid-1980s, but the error margin was too high to be implemented in clinical practice. In recent years, with the advancement of AI, numerous studies have been conducted using cephalometric analysis, the reproducibility, efficiency, and accuracy of which are continuously being enhanced Notably, cephalometric analysis has emerged as the most extensively explored domain of AI applications in orthodontics.

There have almost been no statistically significant differences between humans' gold standard and the AI's predictions. Differences between the two analyses do not seem to be clinically relevant. The AI algorithm can analyze unknown cephalometric X-rays at almost the same quality level as experienced human examiners (current gold standard). Cephalometric analysis is one of the first to successfully enable the implementation of AI into dentistry, in particular orthodontics, satisfying medical requirements.[10]

AI use in Aligner Technology

Artificial intelligence remote monitoring of clear aligner therapy has recently gained popularity. It uses deep learning algorithms on a patient's mobile smartphone to determine readiness to progress to the next aligner and identify areas in which the teeth are not tracking with the clear aligners.[11]

Dental Analysis

In orthodontic clinical practice, the utilization of intraoral photographs and orthodontic study models is imperative for dental analysis. These examinations provide clinicians with comprehensive information regarding various aspects, including molar relationships, tooth crowding, dental arch width, overjet and overbite, and oral health status. However, the manual analysis of these examinations is both time-consuming and labour-intensive. Consequently, there is potential for AI to replace human involvement in this analysis. Talaat et al. utilized the YOLO algorithm to detect malocclusion (specifically tooth crowding or spacing, abnormal overjet or overbite, and crossbite) from intraoral photographs. The results showed an exceptional accuracy rate of 99.99% .[12] The development of digital technology has significantly facilitated the adoption of 3D intraoral

scanner images and digital dental models in clinical practice. Some companies, such as Invisalign (Align Technology, Santa Clara, CA, USA), have effectively utilized 3D oral scan data and digital models for automated measurement and analysis.

Facial Analysis

Facial photographs play a pivotal role in evaluating facial asymmetry and proportions. Overall, automated facial analysis is still in its early stages and requires further research to improve its accuracy and applications.

The determination of patients' growth spurt is critical for orthodontic treatment, especially for those that need functional and orthopaedics treatment. Hand–wrist X-rays have been regarded as the most conventional and accurate way to determine skeletal age. In recent years, several studies have reported combining AI with hand–wrist radiographs to predict skeletal age. Several research studies have revealed that the cervical vertebral maturation (CVM) method is also effective for growth estimation and highly correlates with the hand–wrist radiograph method.

Upper-Airway Obstruction Assessment

Skeletal deformity and airway obstruction mutually influence each other. Upper-airway obstruction can alter breathing, which can affect the normal development of craniofacial structures and potentially lead to malocclusion and other craniofacial abnormalities. Screening the presence of upper-airway obstruction, especially adenoid hypertrophy, is critical for orthodontic diagnosis and treatment planning. Detecting adenoid hypertrophy based on lateral cephalograms has been proven to be highly accurate and reliable.

Decision Making for Extractions

Currently, there is no absolute standardized formula for extraction diagnosis and patterns, and the decision depends, to some extent, on the orthodontists' experience. A wrong decision about extraction could cause a series of irreversible problems like an unfavourable profile, improper occlusion and extraction-space closure difficulties. AI can contribute to reducing the likelihood of incorrect tooth extraction protocols.

Decision Making for Orthognathic Surgery

Overall, AI has made some progress in decision-making for orthognathic surgery. However, there is still a need for further improvement in incorporating a more comprehensive type of cases, especially more borderline cases, which holds the promise of enhancing AI's diagnostic capabilities.

Treatment Outcome Prediction

Predicting treatment outcomes can help orthodontists analyze and treat malocclusions more scientifically, reducing potential risks and complications during and after clinical treatment. Currently, AI can aid in predicting dental, skeletal and facial changes, as well as patients' experience of clear aligners, thereby guiding the treatment planning.

Orthodontic tooth setup, initially proposed by Kesling, enables the visualization of the treatment progress and final occlusion, but manual tasks like tooth segmentation and repositioning are labor-intensive.[13] With the continuous advancements of digital orthodontics and artificial intelligence, automated virtual setups have been widely applied, especially in the field of clear aligners.

Prediction of Treatment Outcomes

In conclusion, the use of AI in orthodontic practice has revolutionized the prediction of treatment outcomes. By analyzing large datasets and training on thousands of cases, AI algorithms can accurately predict how a patient's teeth will move and align during treatment. This enables orthodontists to tailor treatment plans to individual patients and anticipate potential complications. Furthermore, AI can assist in treatment planning by simulating different scenarios and predicting their outcomes, allowing orthodontists to select the most effective treatment strategies. As AI continues to advance, orthodontists can expect even more precise and personalized predictions, leading to improved patient outcomes and satisfaction.

Virtual Treatment Planning

Virtual treatment planning refers to the utilization of AI algorithms and technologies to simulate and predict the outcomes of orthodontic treatments. By inputting patient data such as dental impressions, radiographs, and facial photographs into computer software, orthodontists can generate a three-dimensional model of the patient's dentition. This virtual model allows them to visualize and manipulate various treatment scenarios, making it an invaluable tool for treatment planning. Orthodontic treatment requires cautious decision-making

processes that are the cornerstone of a satisfactory treatment outcome, such as a tooth extraction plan and the possibility of surgical interventions. AI is expected to assist orthodontists, especially those inexperienced in making correct decisions.

The use of AI in virtual treatment planning offers several advantages to orthodontists. Firstly, it provides a more efficient and accurate means of treatment planning compared to traditional methods. With AI algorithms, orthodontists can assess the impact of different treatment options on tooth movement, occlusion, and facial aesthetics, thereby reducing the need for trial and error in real-world treatments.

Furthermore, virtual treatment planning allows orthodontists to involve their patients in the decision-making process. By visualizing the predicted treatment outcomes, patients can better understand the proposed treatment plan and provide their input. This shared decision-making approach improves patient satisfaction and enhances treatment outcomes.

Another significant benefit of virtual treatment planning is its ability to streamline communication among the orthodontic team. With a virtual model, orthodontists can collaborate with other specialists, such as oral surgeons or prosthodontists, to develop comprehensive treatment plans. This multidisciplinary approach ensures that all aspects of the patient's oral health are considered, leading to more successful outcomes.

Virtual treatment planning is not intended to replace the expertise of orthodontists. Rather, it serves as a powerful adjunct tool that enhances their clinical skills and decision-making abilities. Orthodontists should understand the limitations of AI and interpret the results of virtual treatment planning in the context of their clinical expertise and patient needs.

Virtual treatment planning represents a significant milestone in the use of AI in orthodontic practice. By harnessing the power of AI algorithms, orthodontists can optimize treatment planning, engage patients in the decision-making process, and improve interdisciplinary communication. This can elevate orthodontic practice to new heights, benefiting both specialists and trainees in delivering effective and personalized orthodontic care.

Remote Care

Remotely tracks treatment progress and provides timely feedback based on photos or oral scans of the dentition, avoiding unnecessary visits and bringing flexibility and convenience to patients.

Clinical Documentation

Clinical photos and radiographs are routinely taken for diagnosis and treatment planning. AI can aid in classifying and categorizing these images, thereby enhancing the efficiency of clinical practice.

AI in Patient Management

AI is significantly improving patient engagement and compliance. AI-powered apps and virtual assistants have emerged as effective educational tools. These digital companions empower patients by educating them about their orthodontic treatment, its various aspects, and the importance of compliance with prescribed protocols. Furthermore, they provide automated reminders for appointments and home care routines, ensuring that patients remain on track with their treatment plans.[8] This proactive approach to patient engagement has shown promising results, as patients are more likely to adhere to their treatment regimens, leading to better treatment outcomes.

AI in Administrative Process in Orthodontics

AI's impact extends into the administrative sphere of orthodontic practices. Various administrative tasks have been automated, such as appointment scheduling and record-keeping, thereby streamlining the practice's daily operations. This enhances efficiency and also frees up valuable time for orthodontists and their staff to focus on providing high-quality patient care.

AI in Mini Implant Placement

AI systems have shown high accuracy for palatal segmentation and thickness measurement, which is helpful for the determination of available sites and the design of a surgical guide for palatal orthodontic mini implants.[14]

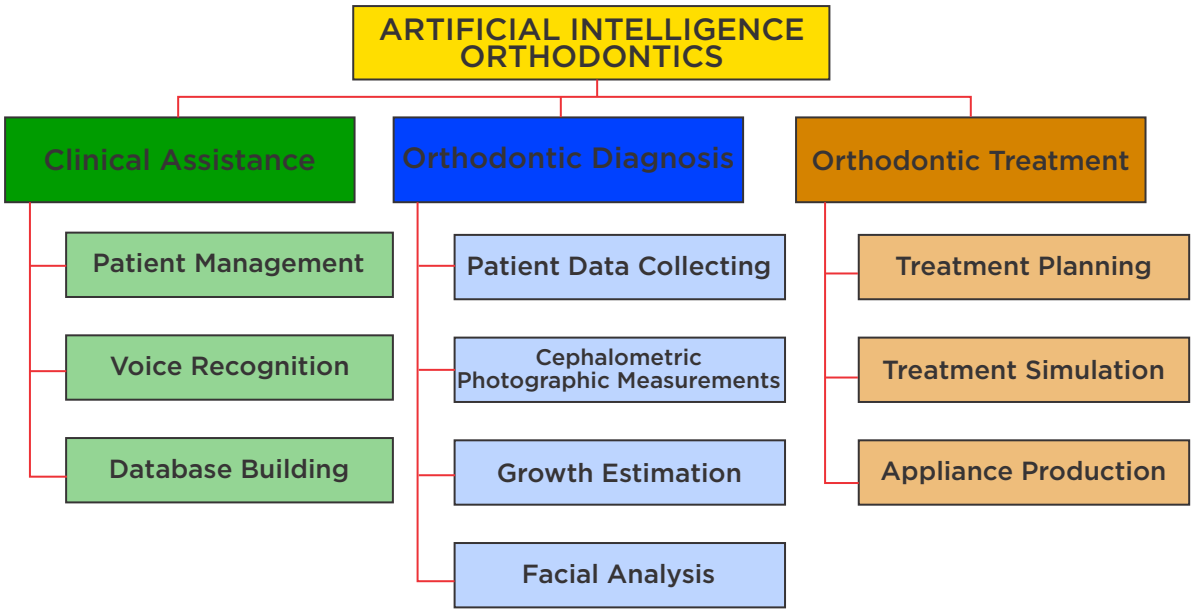

Figure 2: A review of the use of artificial intelligence in orthodontics.

Limitations And Future Perspectives

Currently, AI excels mostly in Orthodontic diagnosis, yet it has limited guidance on the treatment process. Orthodontists may encounter various challenges throughout the entire Orthodontic treatment while correcting deep bites and avoiding bone dehiscence or fenestrations. Using AI to aid in preventing these issues could be a potential area for future development. As clinical data continues to grow and AI computing power improves, there is no doubt that AI will significantly advance the field of Orthodontics. In conclusion, while AI has the potential to revolutionize orthodontic practice, it also has its limitations. The need for large datasets, lack of interpretability, scarcity and low generalizability, no standardization of studies and study design for comparisons, limited incorporation of subjective factors, and ethical considerations are some of the challenges that orthodontists need to be aware of when utilizing AI in their practice. By understanding these limitations, orthodontists can harness the benefits of AI while making informed decisions and providing the best possible care to their patients.

Conclusion

There is growing interest worldwide in AI, Nigeria inclusive. It is a rapidly advancing modality in Orthodontics which is enhancing patient care and management. Soon, AI will become an integral part of Orthodontic analysis and treatment planning. AI can offer many benefits for healthcare in Nigeria, such as: Improving the quality and accuracy of diagnosis and treatment by using data-driven and evidence-based methods. And reducing the cost and time of healthcare delivery by automating tasks and optimizing processes.

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