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ARTIFICIAL INTELLIGENCE IN ORTHODONTIC DIAGNOSIS AND TREATMENT PLANNING - AN OVERVIEW

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ABSTRACT:

Orthodontic diagnosis is a comprehensive process that incorporates numerous data from the facial and occlusal structure as well as the requirements of the patient. Because of this, it is difficult to imagine if artificial intelligence (AI) would ever completely replace the current conventional diagnostic procedure. However, new developments in machine learning and artificial intelligence have been used to automate image recognition for cephalometric tracing and model analysis, demonstrating a reasonably high reliability. Based on collective experiences and research findings, orthodontic diagnostics has made a small progress toward automated processes. This review's objective was to provide information on the scope and effectiveness of artificial intelligence-based models that have been extensively employed in orthodontic diagnosis, treatment planning, and prognosis prediction.

KEYWORDS: Artificial intelligence; Artificial neural networks; Automated orthodontic diagnosis; Deep learning; Machine learning.

INTRODUCTION:

In the last decade, technology has grown enormously and Artificial Intelligence (AI) has received a great welcome. Apart from its influence in modern lifestyle, it is also capable of causing evolutionary changes in various specialties like healthcare industry, finance, business & commerce, education, manufacturing industries and gaming. Artificial intelligence (AI) is a software system that simulates human intelligence processes by using data inputs to make independent decisions or help users make decisions.[1] It is generally a method through which a machine can easily do a task that generally require human intelligence & intervention.[2] Although AI is a new technology, it has made deep inroads in the field of medicine in past few years. With other advanced technology it has brought revolutionary changes in diagnosis and treatment planning of a disease and also a plays a crucial role in the learning process.[3] It has been used in the field of dentistry in last few years for processing more accurate and efficient diagnosis which is important in achieving quality patient care.[4] While AI is essential in many fields, it is also becoming more prevalent in the specialty of orthodontics & dentofacial orthopaedics as it includes time consuming diagnostic assessment and therefore different treatment plans among orthodontists due to its complexity.[5] This article will review about the AI with related technologies, orthodontic applications & challenges and future perspectives of AI in dentistry.

WHAT IS AI TECHNOLOGY?

Artificial intelligence is a branch of computer science that involves developing programs for completing tasks without requiring human intelligence. It employs algorithms that can tackle problem solving, learning and logical reasoning. The term Artificial intelligence was first coined by John McCarthy in the year 1956 who is called as Father of artificial intelligence.[6] He defined AI as “the science and engineering of making intelligent machines”.[7]

Machine learning, deep learning (DL), neural networks, cognitive computing, fuzzy logic, robotics, and natural language proce ssing are some of the main components of artificial intelligence (Fig.1).[8]

A subset of artificial intelligence called machine learning (ML) uses computers to learn rules from data and comprehend its intrinsic statistical patterns and structures (Fig.2).[9] Though ML is classified as a part of AI, it also links with a diverse range of other fields, including statistics, information theory and cognitive science.[10] Machine learning has been used in the healthcare industry to accomplish everything from information extraction from medical reports to anticipate or diagnose diseases. The performance of machine learning algorithms in evaluating and delivering more accurate information is being improved constantly via testing and modification.[11]

Deep learning is the process of repeatedly feeding data and labels through the neural network during training while incrementally adjusting the model's parameters to enhance the model's accuracy.[12] Without the necessity for manual feature engineering, DL processes input data employing representation learning techniques with many levels of abstraction, automatically identifying the complex structures in high-dimensional data by projecting them onto a lower dimensional manifold.[13] Medical imaging analysis has been the dominant use of DL systems in healthcare, and they have made impressive diagnostic performance in this area.[14]

An artificial neural network (ANN) is basically a set of algorithms that use artificial neurons to compute signals, motivated by biological neural networks. To design neural networks that function like the human brain is the objective of neural networks. [15,4]

The branch of artificial intelligence termed as natural language processing (NLP) focuses on enabling computers to comprehend written and spoken language in a manner similar to that of humans.[16]

APPLICATION OF AI IN ORTHODONTICS

- **In cephalometric analysis**

Orthodontics is also one of the fields where artificial intelligence is becoming more ubiquitous and it has emerged into a useful tool for accurate diagnosis and effective management. Holly Broadbent Sr in 1931 proposed the cephalometric radiograph assessment of the sagittal and vertical skeletal structures for determining growth, monitoring changes during treatment procedures and it is still used presently in the planning of orthodontic treatment.[17] By doing quantitative and qualitative analyses and superimposing successive radiographs, they are utilised to determine the growth trend. A typical cephalometric analysis process is locating anatomically significant landmarks, measuring various angles and distances between these landmarks, and then qualitatively evaluating pathologies based on these angles and distances.[18]
Medical professionals often take a very long time performing manual cephalometric evaluations and there are also high chances of inaccurate calculations.[19] The enhancement of accuracy and reliability is a result of the advancement of computer power and algorithms.[20]
In computerised cephalometric analysis, landmarks are manually identified using one of two methods: either a direct digitization of the lateral skull radiograph using a digitizer connected to a computer and then location of landmarks on the monitor, or an overlay tracing of the radiograph to identify anatomical or constructed points followed by transferring it to the digitizer.[21]
While in an automated cephalometric analysis, scanned radiograph is stored in a computer and loaded using a software. The measurements for the cephalometric analysis are then carried out by the programme, which also finds the landmarks automatically.[22] Cohen made the first effort at automated cephalogram landmarking in the year 1984.[23]
Sercan Ö Arık et al.,[18] suggested an approach that makes use of CNNs to find landmarks that characterize the patient's anatomy and produce precise estimation of abnormalities in the jaw and skull base areas. CNNs are processed to generate probabilistic estimates from several landmark locations, which are then merged using a shape-based model.[18] It has been shown that CNNs that only accept raw picture patches as input are effective for precise quantitative cephalometry.
Wang C W et al., [19] investigated and contrasted automatic landmark detection methods in application to cephalometric X-ray images. A shared database of 300 cephalograms of patients aged six to 60, obtained from the dental department of Tri-Service General Hospital in Taiwan, was used to test methods.

- **Automated Localization of Anatomical Landmarks in 3-D imaging:**

The foundation of effective orthodontic treatment is a precise study of the craniofacial structure and face proportions. Typically, 2D cephalometric radiographs are used for traditional orthodontic analysis, which might lead to less precise results. Rather than manually localizing anatomical landmarks, orthodontists prefer using digital workflow to avoid this time-consuming process.
The first machine learning approach to automatically locate one significant landmark on CBCT pictures was proposed by Cheng et al.,[24] and they reported encouraging results. A machine-learning approach was suggested by Shahidi et al., [25] to automatically find 14 craniofacial landmarks on CBCT pictures.

An innovative deep learning technique was suggested by Torosdagli et al., [26] and used for completely automated mandible segmentation and landmarking in craniofacial abnormalities on CBCT images.

- **Growth Assessment:**

In the practice of clinical orthodontics, an understanding of growth events is essential. Biological age, bone age, skeletal age and skeletal maturation are the terms used to describe the stages of maturation in an individual. Skeletal age evaluation is important for formulating effective orthodontic treatment plans because of individual variations in the timing, duration, and rate of growth. The diagnosis, treatment objectives, treatment planning, and final results of orthodontic treatment can all be significantly influenced by a patient's developmental stage.

A key sign for demonstrating a child's growth and development is their bone age, which is determined from radiographs of their left hand and wrist and measures skeletal maturity [27]. The Greulich and Pyle (GP) atlas [28] and the Tanner-Whitehouse (TW3) [29] method are the two main techniques used to evaluate BA. [30]. Greulich-Pyle-based bone age estimation is straightforward and simple to use in clinical practise because it involves comparing a patient's left-hand radiograph to typical radiographs in the Greulich-Pyle atlas [31]. To calculate whether a child's skeletal maturity is normal, G&P additionally includes data tables with sex-specific mean skeletal ages and standard deviations for various chronological ages [32]. Another way is the Tanner and Whitehouse (TW) method, which analyses each bone in-depth and then describes it in terms of scores [33]. There are various newer techniques to increase effectiveness, such the TW3 method. Its complexity and heuristics, however, prevent it from being widely used in clinical settings [33]. However, manual BA assessment is time-consuming and fully dependent on the reviewers' knowledge to determine BA, leading to significant intra- and inter-observer variances [30]. Therefore, it is beneficial to establish a computer-aided BAE system to lessen the burden on radiologists and the variances between or within observations [33].

A number of automatic computerized approaches for estimating bone age, including computer-assisted skeletal age scores and computer-aided skeletal maturation assessment systems, have been developed since 1992 in response to concerns about interobserver variability in manual bone age estimate [31]. In the medical industry, particularly in radiology, artificial intelligence (AI), which has a significant potential for lowering labour requirements and intra- and inter-observer differences, is gaining popularity [30]. One of the most cutting-edge AI methods is deep learning. In contrast to conventional machine-learning methods, deep-learning methods enable an algorithm to self-program by learning from the images given a sizable dataset of labelled examples, negating the need for rules to be explicitly specified [34].

According to a study by Fengdan Wang et al., an AI system performs well as a reliable and practical tool for Chinese children's BA assessments in terms of time and energy savings. Clinical BA assessment using deep learning-based AI systems has a promising future. [30]. In their study, Hsieh et al. extracted the geometrical characteristics of the carpal bones and analysed them to determine the bone age of children using computerised form and area description. To categorise bone age, four classifiers—linear, nearest neighbour, back-propagation neural network, and radial basis function neural network—were used, and the findings showed that using neural networks to classify carpal bones can be both accurate and useful [33]. In 2017, Kim et al. developed an AI BA system based on cases from the Asan Medical Center that provided three most likely estimated BA results for a single radiograph. The system was then tested on 200 cases with an even age distribution from the same medical centre, and the authors achieved a first rank accuracy of 69.5% [35]. Larson et al. tested their AI BA system's accuracy in 2018 using 200 sex-stratified cases from Stanford University, one of the two American medical facilities where they trained it. The system had an RMSE of 0.63 years. [36]. The AI BA system developed by Tajmir et al. was tested in 2019 using 280 instances, consisting of 10 representative cases for each class and sex, selected from 8,325 radiographs that were used to train the system. The BA accuracy was 73.2 percent [37]. Lastly, more efforts should be made to improve the accuracy of this AI BA system and to broaden its age range [30].

- **Decision making for extraction:**

Malocclusion is a dentofacial aberration that impairs occlusal function, aesthetics, and quality of life [38]. The evaluation, prevention, and treatment of malocclusions are under the domain of orthodontics [38]. The two types of orthodontic malocclusion treatments are extraction treatments and non-extraction treatments [39]. Teeth extraction is one of the most important and contentious decisions in orthodontic treatment, owing to the fact that extractions are irreversible [40]. These decisions are based on clinical assessments, patient photographs, dental study models, radiographs, and, to a large extent, the experience and expertise of the clinician [40]. A wrong decision might result in undesired outcomes like poor aesthetics, an incorrect bite, functional abnormalities connected to speech and mastication, and, in the worst situation, an incomplete course of treatment [40]. Therefore, newer approaches are required in order to standardise the decision-making process [40]. The computational techniques that have drawn the most focus are those that come from the area of artificial intelligence (AI), notably machine learning (ML), where a computer is trained to create a customized model based on a given dataset and then utilise it to make predictions [38]. Deep neural networks and neural networks are two frequently used types of complex machine learning algorithms [38].

According to the research done by Li et al., neural network models have an accuracy rate of 94.0% for predicting extraction from nonextraction, with an area under the curve (AUC) of 0.982, a sensitivity rate of 94.6%, and a specificity rate of 93.8% [41]. The artificial neural network created by Xiaoqiu et al. in their study was successful, with 80% accuracy, in determining whether extraction or nonextraction treatment was appropriate for malocclusion patients between the ages of 11 and 15 [39]. Using neural network machine learning, Seok et al. created an AI expert system for the diagnosis of extractions and assessed the effectiveness of this model. The models' success rates were 84% for the comprehensive diagnosis of the extraction patterns and 93% for the diagnosis of extraction vs. nonextraction [42]. Treatment planning has been thought to benefit from using AI machine learning techniques. This could also be used as a training tool for dental and orthodontic students [40].

- **In Orthognathic surgeries:**

Orthognathic surgery is used to improve masticatory function and aesthetics by correcting facial asymmetry, dentofacial deformity, and skeletal malocclusion, as well as adjunctive procedures [43]. Traditionally, surgical planning has relied on clinical examination, two-dimensional cephalometric analysis, and manually made splints [44]. However, there are known limitations to 2D cephalometric analysis, such as projection and identification errors, especially in patients with facial asymmetry [45]. However, these procedures necessitate a significant amount of labour and are imprecise [44].

With the rapid advancement of technologies and materials, 3D printers, digital software, and machine learning (ML) are increasingly being used in orthognathic surgery to improve surgical outcomes [44]. 3D printing is commonly used to produce 3D models from digital images in surgical planning, customised surgical devices, and doctor-patient communication [45]. To date, many methods have used 3D digital models to improve overall orthognathic surgery procedures and provide more efficient, affordable, predictable, and convenient planning and simulation [43].

Patcas et al. demonstrated that orthognathic treatment improved the appearance and attractiveness of the majority of patients using a computational algorithm based on a Convolutional Neural Network [46]. According to the study of Shin et al, the authors extracted features from posteroanterior and lateral cephalograms and used DL networks to assess the need for orthognathic surgery [47]. The results showed that the accuracy, sensitivity, and specificity were 0.954, 0.844, and 0.993, respectively, demonstrating excellent performance [47]. Lin et al assessed facial symmetry before and after orthognathic surgery using a CNN with a transfer learning approach on 3D CBCT images [48]. Lo et al used a Machine Learning model based on 3D contour images in a retrospective cohort study to automatically assess facial symmetry before and after orthognathic surgery [49]. In the study by Knoops et al., 4216 3D images of healthy volunteers and patients undergoing orthognathic surgery were used to build a 3D morphable model, a machine learning (ML)-based framework using supervised learning [50]. The model demonstrated great diagnostic accuracy, fulfilling treatment simulation, with a sensitivity of 95.5% and a specificity of 95.2% [50].

The following 4 domains represent the effects of digital solutions on surgical-orthodontic protocols: enhanced diagnosis accuracy using improved maxillofacial images powered by AI, CAD/CAM (Computer Aided Design, Computer Aid Manufacturing) manufacturing of custom surgical and orthodontic tools and equipment, treatment planning utilising 3D models, Due to better interval comparison of results via image superimposing, therapy follow-up has improved [51]. In conclusion, ML has been regarded as a useful tool in orthognathic surgery for determining a precise diagnosis, assessing the need for surgical intervention, and foretelling the course of treatment [44].

- **Aligners:**

Evidently, using AI to aid with orthodontic treatment planning has been a trend for a while. Many companies that make aligners assert that they employ AI algorithms to optimise orthodontic planning, saving orthodontists' time in the process.[52] Invisalign® being the best-known aligner system has become a generic term for various high-quality systems employing CAD-CAM technology.[53] With automated virtual treatment planning and manufacture using stereolithographic prototyping, Invisalign® is a market leader in aligner therapy.[54,55] Clincheck® (Align Technology, Santa Clara, CA, USA) programme calculates the movement necessary for each individual tooth, the mechanical principles to carry out this movement, and the form of the aligner (Fig.3).[56] These merchandise, such as Invisalign, ClearCorrect, ClearPath, eCligner, K Line, and Orthocaps, incorporate 3D CAD/CAM tooth movements, computerised 3D interactive treatment planning and appliance design, bonded resin attachments, and possibly additional features. They are designed for more complex, comprehensive tooth movements and improved control of tooth position in all planes of space.[53]

- **Treatment outcome forecast:**

In the three crucial steps of diagnosis, treatment planning, and therapy, artificial intelligence is helpful in simulating various clinical scenarios. This boosts accuracy and monitoring while lowering effort and time requirements. The assessment of the facial profile is a critical component of the orthodontic diagnostic and treatment plan. Following orthodontic treatment, with or without extractions, Nanda SB et al. [57] demonstrated that ANN could predict changes in lip curvature. For the upper and lower lips, the expected change and actual change were, respectively, 29.6% and 7%. An ANN was utilised by Patcas R et al. [46] to compare the facial attractiveness before and after orthognathic surgery on a scale of 0 to 100. For less experienced orthodontists, Akçam MO et al. [58] created a computer assisted inference model for picking the appropriate kind of headgear device.

- **TAD Placement:**

Nearly 20 years ago, mini-implants/mini-screws/TAD (temporary anchorage device) were debuted in orthodontics for anchorage.[59] The literature has detailed a number of techniques for accurate placement of TAD. CAD/CAM technology has been successfully employed for exact placement of it.[60] Inadequate primary stability, root or even sinus rupture, and mini-implant failure might result from incorrect placement.[61] Insertion guidelines are now used for the placement of TADs to minimise hazards. Static computer aided guided surgery (s-CAIS), static implant guides are the most widely used type.[62] The exact anatomical location of the TADs is verified using the virtual planning programme. The used software enables the precise positioning of the screws in accordance with the anatomical variances of each patient as well as the virtual design and installation of TADs in a range of lengths and diameters.[63]

The programme Easy Driver V 2.0.2019 (Uniontech, Parma, Italy, patent protected) is used in insertion of mini screws for purely mini-implant borne rapid maxillary expanders by Wilmes B et al. [63] In order to facilitate exact placement of the mini-implants into the intended location, the Easy Driver System offers a kit for placing them that is particularly made to match the placement guidelines with very little tolerance, similar to those used with dental implants.

- **Robotic wire bending:**

The most efficient method for treating malocclusion at the present is the fixed orthodontic approach. During this therapy, the force that the deformed archwire created is used to correct the misaligned teeth. Therefore, the archwire bending procedure is important to orthodontic treatment [64]. The quality of the manual archwire bending process depends on the doctor's ability to bend the wires. Archwires with different parameters are also required for the treatment of various diseases. Archwire needs to be bent several times in order to provide the best therapeutic result [65]. These problems can be addressed successfully by using robot technology to bend orthodontic archwires [66]. Improvements in three-dimensional assembling and imaging measures have made orthodontic treatment more customizable. It is possible to develop tools to increase therapy effectiveness. Two patient-explicit items have been produced attributable to innovation advances that create sophisticated treatment plans using computers, and then create a customised item, like the insignia system [66].

The first CAD/CAM system ever developed for the manufacturing of customised orthodontic arch wires is called the Bending Art System. This was created in 1984 by Professor Helge Fischer-Brandies and his coworker; they worked with an engineering company to develop the hardware and software. The first BAS prototype was manufactured. It is used to fabricate orthodontic wires for the lingual and labial arches [67]. This system incorporates a computer programme, an electronic oral endoscope, an archwire bending machine, and a bending machine [68]. Suresmile is an all-digital system that uses robotics to create fixed orthodontic appliances that are customised for each patient. Suresmile incorporates innovative 3-D imaging technology and computer algorithms for diagnosis and treatment planning [68]. The Cartesian type archwire bending robot system employs a multi-component robot. The accompanying software is used to examine the bending process and create the archwire's structural layout [68]. The results of orthodontic therapy that uses a robot or machine to twist the archwire used in fixed orthodontic appliances will be significantly better with noticeably shorter treatment times [66].

- **Customized bracket & wire positioning:**

A customised orthodontic appliance is one that is created especially for a certain patient in order to achieve a specific orthodontic outcome. The system may include with a bracket with a specialised bracket bonding pad for attaching the bracket to a patient's tooth and a slot in the bracket designed to accommodate a customized archwire [69]. The brackets made using CAD/CAM are the result of a unique process that makes them resistant to de-bonding and therefore highly resistant to bracket loss [70]. They can also be used with a real straight wire, making it possible to use prefabricated standard wires [70].

When the tooth is in its finished position, the bracket slot and the archwire can be placed substantially adjacent to the tooth surface to limit induced vertical error and substantially parallel to the directly adjacent portion of the tooth surface to minimise bracket thickness [69]. To further improve end-of-treatment tooth position and reduce treatment times, the bracket slot can also be designed to have a bracket slot width that substantially matches a cross-sectional dimension of the archwire[69]. This will limit torque rotation around the archwire's axis [69]. From the beginning of the assembly line to the finish, a 3D computerised treatment control is used, guaranteeing absolute accuracy in the bonding location [70].

Each patient's appliances are fully unique, taking into account specific anatomical features and professional recommendations [70]. As a result, practitioners will gain access to a number of theoretical benefits that will make therapy more enjoyable and functionally seamless at every stage [70].

- **Customized lingual brackets:**

The three planes of tooth positioning in straight-wire orthodontic devices can be adjusted throughout treatment by placing the brackets in the optimal location [71]. An effective orthodontic treatment is made possible by accurate bracket placement [72]. According to Carlson and Johnson, the perfect bracket location requires the following four components: First, the bracket base should be adapted to the dental surface. Next, the rotational bracket position in relation to the occlusal plane should be evaluated. Third, the vertical position of each bracket should be determined. Finally, the slot angulation should be determined in accordance with the position of the roots [73]. According to several studies, indirect bonding on labial appliances can be more precise than direct bonding, with a reduction in bracket position errors in each of the three orientations examined [74]. Accurate bracket placement can speed up therapy by lowering the need for repositioning [75]. The outcomes of these investigations, which focused on labial rather than lingual appliances, are preliminary and not definitive in terms of treatment duration and positioning accuracy. Therefore, the primary real benefit of indirect bracket placement can be seen as the reduction of chairside time (Fig.4) [76].

Lingual orthodontics makes up a growing portion of orthodontic treatments due to its excellent aesthetic prerequisites and growing practicability, and even more studies have examined its many components [77]. Despite the fact that lingual orthodontic treatment offers a number of aesthetic benefits, its use has been restricted because of the longer chair times and more challenging mechanical control [78]. However, modern technology like intraoral scanning, virtual bracket positioning, and computer-aided transfer tray fabrication can make placing lingual orthodontic appliances easier [79,80]. The Insignia* system is an advanced computerised orthodontic technology that is used to create custom appliances [81]. Insignia treatment begins with precise polyvinyl siloxane (PVS) impressions, exceptionally accurate computed tomography (CT) scans of the impressions, digital modelling of the dental arches, and a virtual setup for optimal archform and occlusion [81]. The clinician then uses Insignia's Ap-prover** software to fine-tune the suggested treatment plan, making the necessary changes as needed.

• Each tooth's torque, tip, in/out, intrusion, and extrusion.

• Archform, within the biological constraints imposed by the osseous structure of the patient.

• A smile arc.

• The final centric occlusion's dental contacts [81].

The Insignia system reverse-engineers the brackets to the correct specifications in one of two ways, depending on the type of brackets chosen by the orthodontist, unlike computerised systems that merely change the thickness of the bracket adhesive. Individual Insignia metal twin brackets are created by precisely milling slots into the faces. The Damon Q* self-ligating model is modified to produce Insignia SL brackets by altering the metallic bases' thicknesses and angulations.

The Insignia system has received a significant feature known as "Overcorrection." This programme determines each tooth's rotational direction in relation to third-order constraints by tracking the three-dimensional movements of the centres of the bracket slot and the roots' center of resistance. The Insignia system's customisation of archform, which is based on skeletal mapping of the mandibular bone's cortical limitations at the level of the teeth's centre of resistance, is another distinctive characteristic [81]. Insignia archwires are uniquely created, not premade, to keep the teeth as much as possible in trabecular bone. To ensure precise and dependable bracket positioning, bracket-transfer jigs are made from a high-tech, spongy material and carefully machined to match the occlusal surfaces of the teeth. In order to make it easier to remove extra composite material before polymerization, the jigs are designed so that during bonding, three-quarters of the bracket-pad edges are exposed. The jigs can be disassembled and reused to reposition and rebond individual brackets in the event that a bind fails during treatment [81]. Therefore, at the time of first bracket placement, this procedure boosts the effectiveness of fixed orthodontic therapy for each patient [82].

CHALLENGES

Despite all the advantages of artificial intelligence, there are certain drawbacks as well. Given that the technology needs regular inspection and updating, it can never fully replace human expertise. Humans can reason, feel, and utilize their senses to solve problems because they are emotional intellectuals. However, a machine's main drawback is that it lacks compassion and understanding.[83] They would need routine maintenance, and fixing the setup will be expensive.[84] Despite having the capacity to hold a lot of data, machines can only operate in the way that has been designed, making it impossible for them to adapt to changing circumstances.[85]

AI won't give direct interpretation; a misunderstanding might happen due to the algorithms' improper conduct. A number of issues have been identified with IBM Watson, indicating that the field's use of AI in healthcare may still be in its early stage and still needs significant advancement.[86]

Concerns regarding data security and protection as well as the outsourcing of crucial medical decisions to computers are certainly legitimate.[87] Hence when analyzing data generated by AI, clinicians should constantly be alert and circumspect.

CONCLUSION

Currently, AI is heavily utilized in the field of dentistry. Dentistry, and more specifically dental research, has a role to play in ensuring that AI will improve dental treatment at lower costs, benefiting patients, providers, and society at large. For clinical decision-making, the clinician in the field of orthodontics mostly uses diagnostic techniques. AI may be applied well for clinical decision-making, patient diagnosis, and failure prediction in the dental profession. Results from the numerous studies included in this review imply that the accuracy of the AI-based systems is quite trustworthy and promising. Although it is still in development, AI is expanding the range of cutting-edge dental models. To evaluate the clinical effectiveness of AI approaches in orthodontics, more research is necessary.

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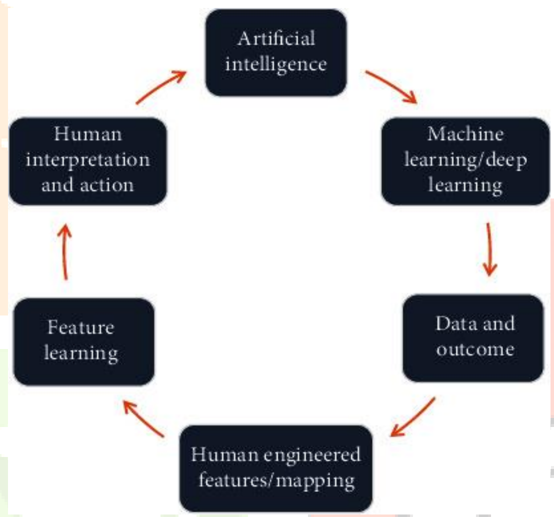

Figure 1- Schematic illustration of artificial intelligence model.

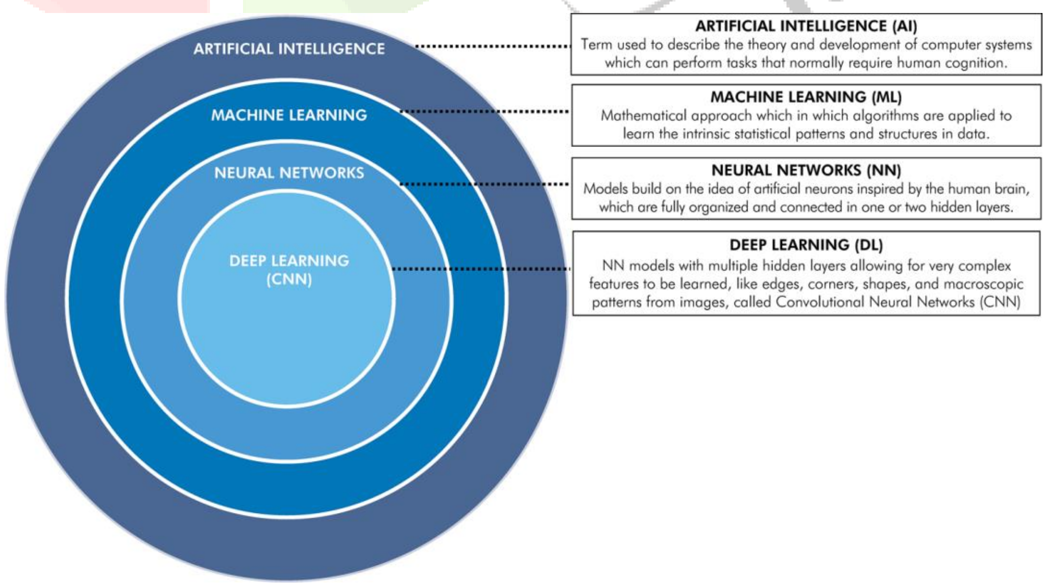

Figure 2- Hierarchy of AI

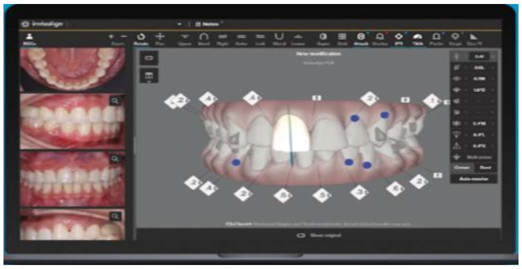

Figure 3 - Clincheck®

Figure 4 - Indirect wire placement