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Review Article

Impact of technology on orthodontic practice

Sanjeev Kumar Verma[1], Aiswareya.G[1], Deepika Rajendra Singh Bais[1], Pramod Kumar Yadav[2*]

[1]*Dept. of Orthodontics and Dentofacial Orthopedics and Dental Anatomy, Dr. Z A Dental College, AMU, Aligarh, Uttar Pradesh, India*
[2]*Dept. of Periodontia & Community Dentistry, Dr. Z A Dental College, AMU, Aligarh, Uttar Pradesh, India*

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A B S T R A C T

This paper explores the pivotal role of Artificial Intelligence (AI) in transforming orthodontic practice, focusing on its profound impact on diagnosis, treatment planning, and patient care. AI-powered algorithms, coupled with machine learning techniques, have revolutionized orthodontic workflows, enhancing efficiency, precision, and patient outcomes. By analysing vast datasets, AI facilitates predictive modelling for treatment outcomes, aiding orthodontists in devising personalized treatment plans tailored to individual patient needs. Moreover, AI-driven image analysis techniques enable automated cephalometric analysis, intraoral scanning, and 3D imaging interpretation, significantly reducing diagnostic errors and streamlining treatment processes. Furthermore, AI-enabled virtual treatment simulations empower patients to visualize treatment outcomes and actively participate in decision-making processes. The integration of AI into orthodontic practice also extends to tele orthodontics, enabling remote monitoring and virtual consultations, thereby enhancing accessibility and convenience for patients. Despite the transformative potential of AI, challenges such as data privacy, algorithm bias, and the need for clinician training must be addressed to ensure its ethical and effective implementation. Nevertheless, the advent of AI heralds a new era in orthodontics, characterized by unprecedented levels of efficiency, accuracy, and patient satisfaction. This paper underscores the revolutionary impact of AI on orthodontic practice and highlights the opportunities and challenges associated with its integration into clinical workflows.

1. Introduction

Orthodontics, the branch of dentistry dedicated to the correction of misaligned teeth and jaws, has witnessed a remarkable evolution over the years. As we stand on the cusp of a new era, the future of orthodontics promises ground-breaking advancements that will redefine the landscape of dental care. This paradigm shift is driven by a convergence of cutting-edge technologies, innovative treatment modalities, and a growing emphasis on personalized, patient-centric approaches.

The traditional methods of orthodontic treatment, such as braces and wires, have been effective but come with certain limitations. The future, however, holds the promise of more precise, efficient, and aesthetically pleasing solutions. Advancements in digital imaging, 3D printing, and artificial intelligence are poised to revolutionize the way orthodontic professionals diagnose, plan, and execute treatment plans. These technologies enable a higher degree of accuracy, customization, and predictability in achieving optimal results.[1,2]

Moreover, the future of orthodontics is characterized by an increased focus on patient experience and comfort.

* *Corresponding author*.
E-mail address: pramod468@gmail.com (P. K. Yadav).

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Tailored treatment plans that consider not only the biological aspects but also the individual preferences and lifestyle of patients are becoming paramount.

2. Artificial Intelligence (AI) in Orthodontics

Artificial Intelligence (AI) is a branch of computer science that studies the extent to which a machine can mimic human cognitive processes.[3] Two significant areas of artificial intelligence are machine learning and expert systems. Machine learning is centred on "learning" using training data to increase a system's capabilities, in contrast to knowledge-based expert systems, which are built using predefined rules and expertise.[4,5] A branch of machine learning termed as artificial neural networks (ANNs) has a significant application in the analysis of complex relationships among large amounts of data.[6] An ANN typically has three layers: an input layer, an output layer, and one or more hidden layers.[7] Deep learning, which comes from ANNs with several hidden layers, has shown outstanding results in computer vision applications like segmentation and classification.[8] Furthermore, one significant benefit of deep learning over conventional machine learning is its ability to automatically extract features without the need for human interaction, improving the data's ability to be used for information extraction.[9] Convolutional neural networks (CNNs), one of the most widely used deep learning techniques, do exceptionally well while processing high-resolution photos. Convolutional, pooling, and fully linked layers are the three different functional layers that replace the hidden layers in CNN. CNNs perform better in image-related tasks than algorithms like ANNs.[10]

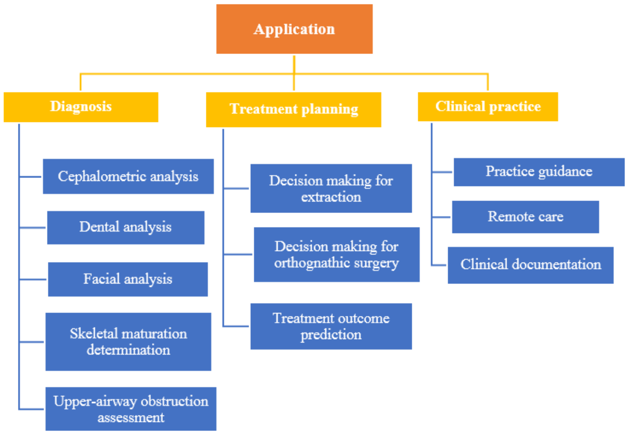

Figure 1: Application of AI in orthodontics

3. Robotic Wire Bending

The quality of the bending is determined by the doctor's degree of proficiency in manually bending archwires. Throughout the bending procedure, the archwires must be bent numerous times to have the best therapeutic result. As a result, the archwire has a low bending efficiency and is more susceptible to fatigue damage.[11] These drawbacks can be successfully addressed by bending orthodontic archwires using robot technology.

The ability to customize orthodontic appliances to increase treatment efficacy is now possible owing to innovations in three-dimensional imaging and assembly techniques.

3.1. *The bending art system*

1. This is the first CAD/CAM system ever created for making personalized orthodontic arch wires.
2. This was invented in 1984 by Professor Helge Fischer-Brandies, and his colleague along with an engineering company built the hardware and software.
3. It is employed in the production of orthodontic wires for the lingual and labial regions.[12]

3.2. *Motoman UP6*

1. It is composed of a computer and devices that twist the archwire. Because the shape of the archwire is complicated, the robot end needs to be flexible when it bends the archwire.
2. Furthermore, the MOTOMAN UP6 robot, which has six degrees of freedom, can accommodate the flexibility requirement of the archwire bending.[13]

3.3. *LAMDA system*

1. A system for precisely and quickly bending archwire is called the LAMDA system, or lingual archwire manufacturing and design aid.
2. It was created by Alfredo Gilbert and relies on a robot that can bend archwire in two planes, which limits its possible application.

3.4. *Cartesian type archwire bending robot*

This archwire bending technology makes use of a multi-component robot.

With the help of a stepper motor and a screw nut moving platform, the cartesian orthodontic archwire bending robot is able to bend wider angles, and its non-standard parts are comparatively small. Its single actuator structure makes it challenging to meet individual archwires bending needs, nevertheless.[14]

3.5. *Suresmile*

With the use of robots to customize fixed orthodontic appliances, Sure smile is a fully digital system that employs advanced 3-D imaging and computer approaches for the purposes of diagnosis and planning of treatment.

The gripping tools of the robot are equipped with force sensors that identify the necessary overbends to provide the archwire the final shape that is intended. Additionally, they might have a heating mechanism where current passes along the archwire while it is bent, keeping it heated and maintaining its bent shape.[15]

Figure 2: Suresmile system[16]

Table 1: 3d Printing

Most commonly used 3d printer	
1	Stereolithography
2	FDM (Fused Deposition Modelling)
3	DLP (Digital Light Procession)
4	Polyjet photopolymer (PPP)
5	Selective Laser Sintering

Technology advancements have had an impact on dentistry in a number of ways. One such way is the fabrication of appliances using additive manufacturing and three-dimensional (3D) printers.

Charles Hull introduced a stereolithographic 3D printer in 1986, laying the basis for 3D systems. Ely Sachs first employed the term "3D printing" and created the inkjet printer technology that could be utilized with metal components.[17]

Charles Hull introduced the STL file format to assure the printing of three-dimensional models by defining their surface geometry through triangles.[18]

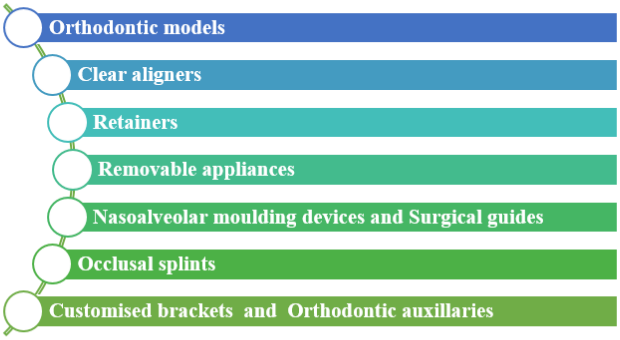

Figure 3: Orthodontic application of 3d printers

3.6. Orthodontic models

The majority of research have demonstrated that 3D printed models are appropriate for usage in therapeutic settings.

When Dietrich et al. compared the accuracy and precision of models made using SLA and Polyjet printing in 2017, they discovered that both were clinically appropriate for use. SLA models had greater precision whereas Polyjet models had greater accuracy.[19]

Through digital scanning of models created using DLP, FFF, SLA, and Polyjet rinting, Kim et al. assessed accuracy and precision. It was found that models created using Polyjet and DLP had greater accuracy results than that of SLA and FFF, while Polyjet models showed the highest degree of accuracy.[20]

The print layer height has a significant impact on model accuracy and precision as well as printing time. Favero et al. constructed models with three different print layer heights by SLA printing in order to compare the results. Compared to the 50-μm and 25 μm, the accuracy of the 100 μm layer height group was determined to be higher. These findings imply that the accuracy of the model decreases as the increase in number of layers.[21] In contrast to Favero et al, Zhang et al observed that, with the reduction in the print layer height, the accuracy increased.

Model production can make use of a variety of base designs.[22] The impact of various model base designs on the accuracy of SLA and Polyjet printed models was investigated by Camardella et al. Regardless of their base design, the models from the Polyjet printer were accurate; nevertheless, the SLA printer's models were not as accurate. Models with the horseshoe-shaped base design showed transverse shrinkage, although measurements for the standard base and horseshoe-shaped base with bar models did not differ significantly.[23]

3.7. Aligners

Aligners can be constructed directly from 3D printers or fabricated using traditional methods using plaster and 3D-printed models. Jindal et al. compared thermoform aligners with 3D-printed aligners. Accuracy was enhanced by using a 3D-printed aligner by eliminating thermoforming printing process, which also had good mechanical resistance and geometric accuracy.[24]

Jaber et al. assessed the reliability of aligners made from various 3D-printed models using FDM and DLP printing. There was no discernible difference between FDM and DLP and the original models. The two generated 3D-printed models could be employed in clinical settings.[25]

The cytotoxicity of thermoform (SmartTrack Invisalign) aligners and aligners constructed directly from various types of 3D printers was compared in a different study. Dental LT and E-Guard Clear, which were utilized in the 3D printer exhibited little cytotoxicity, but within a tolerable range. However, the SmartTrack Invisalign was thought to be the most biocompatible. The cytotoxicity was decreased by post-curing procedures that eliminated uncured resin following printing.[26]

According to Edelmann et al., printing aligners directly out of a 3D printer can cause them to thicken by 0.2 mm, which will impair their functionality.[27]

Figure 4: 3D Printed aligners[28]

3.8. Retainers

When compared to conventional vacuum-produced retainers, 3D-printed ones have proven to be more accurate and dependable.[29] Jiang et al. conducted a study aimed at addressing potential issues arising from patients forgetting to take their medications. They utilized a 3D printer to fabricate Essix retainers, specifically designed to consistently release low doses of drugs into the oral cavity. While the initial three days of their in vitro simulation experiments demonstrated a high level of drug release, the subsequent stabilization observed over time indicates the potential promise of 3D-customized retainers in future applications for controlled and regular drug release.[30]

3.9. Removable appliances

Sassani and Roberts pioneered the production of the initial semi-automatic acrylic orthodontic devices using 3D printers in 1996. They emphasized the feasibility of employing digital systems for fabricating orthodontic devices, while noting the necessity of pre-attaching wires and screws to the model.[31]

In 2015, they undertook a subsequent investigation wherein they utilized computer-aided design (CAD) software and additive manufacturing technology to fabricate metal components, such as Adams clasps and labial bows. The Hawley appliance was manufactured exclusively through intraoral scanning, eliminating the need for traditional impressions. This development also holds promise for future design possibilities.[32]

3.10. Orthodontic auxiliaries

Various orthodontic auxiliaries have been generated using 3D printing technology.

Nagib et al. utilized 3D printing to create a customized chain for impacted canine teeth based on CBCT images.[33]

Ahamed et al. highlighted the versatility of 3D printing technology by stating that components like retraction hooks, bite turbos, lingual retainers, and aligner attachments can all be manufactured with this technology.[34]

Furthermore, literature includes case reports featuring the use of custom-made 3D-printed miniscrews.[35]

3.11. Customized brackets

Wiechmann et al. identified bracket positions on virtual models acquired and devised bracket bases that are suitable for the particular tooth. They then utilized customized brackets produced via rapid prototyping for indirect bonding in the patient.[36]

In order to ensure robust anchoring for the Herbst appliance, the brackets for the upper first molar and canine were configured in a band shape and manufactured as a unified unit with pivots using a 3D printer.[37]

Yang et al. utilized DLP printing to transform virtual bracket models into wax patterns. In this research, a customized aesthetic ceramic bracket (CCB) system was created by employing 3D printing technology.[38]

3.12. Occlusal splints

The advancement of 3D printing technology has impacted the construction of occlusal splints for the treatment of temporomandibular joint disorders. Researchers have successfully employed 3D printers to create occlusal splints with sufficient precision, leading to a reduction in laboratory processes and patient waiting period compared to conventional methods. Salmi et al. created a digital model of an occlusal splint by scanning a plaster model and utilized SLA printing to produce the splint. The study found that splints manufactured with a 3D printer demonstrated comparable success to those produced through conventional methods, leading to a recommendation for their use.[39]

3D printers play a role in surgery beyond creating surgical guides; they are also utilized for generating intermediate and final splints in significant procedures like orthognathic surgery.[40]

4. Nonalveolar Moulding Devices

Advancements in digital technologies have impacted the treatment approach for individuals with cleft lip and palate. These innovations, focused on minimizing aspiration risk through scanning, appear to enable clinicians to create appliances with reduced effort and in a shorter timeframe.

Rapid NAM-The recently introduced system, named Rapid-NAM, autonomously recognizes alveolar ridges through a user-friendly graphical interface and formulates plates based on growth data from healthy new-borns, enabling the rapid production of plates within minutes. The system demonstrated favorable outcomes upon completion of the treatment.[41]

Split type NAM -In the 2019 investigation conducted by Zheng et al., devices created using CAD software and produced via a 3D printer were crafted without the inclusion of the nasal hook and were termed as "split type-NAM devices."[42]

In 2019, Batra et al. conducted a case series, followed by Bous et al. in the subsequent year, which integrated the principles of clear aligners and presurgical infant orthopaedics. Their findings revealed that the NAM plate made with clear aligners effectively achieved segment closure; however, a minor segment ended up in a slightly more mesial position, contrary to the anticipated outcome.[33,43]

4.1. Surgical guides

To ensure precise placement of miniscrews while avoiding potential contact with anatomical structures like dental roots, the vascular-nerve pack, and delicate bones, 3D printers have been utilized to create personalized surgical guides.[44]

5. Smart Materials in Orthodontics

5.1. Shape memory polymers

These polymers fall under the category of "actively moving" polymers with dual-shape characteristics. They have the ability to alter their form, where a temporary shape is achieved through mechanical distortion, and a permanent shape is established by subsequently fixing that deformation. External stimuli, including heat, light, IR radiation, electrical and magnetic fields, as well as immersion in water, can induce changes in the shapes of these polymers.[45,46]

Shape-memory polymers hold significant promise in orthodontics for both functional and aesthetic purposes. These materials are particularly useful in the production of polymeric transparent wires with minimal stiffness.[47]

6. Self-Healing Materials

There are ongoing endeavors to improve the self-healing characteristics of polymers and their composites. Upon the initiation of a crack, the healing liquid (HL) is released from microcapsules and undergoes a reaction with the healing powder (HP), resulting in the formation of a reparative glass-ionomer cement (GIC) that fills and seals the fissure.[48]

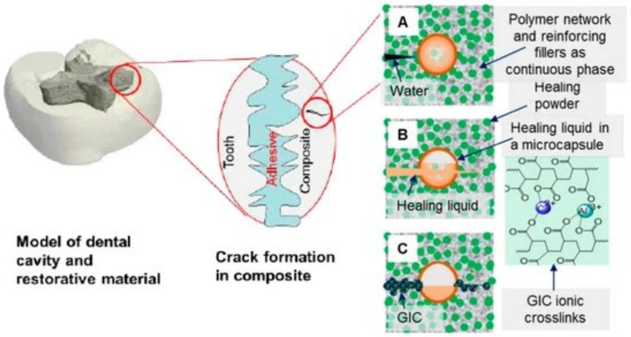

Figure 5: Self-healing dental composites (SHDC) – Steps of self-healing[49]

In additional investigations, the remineralization process was controlled by the presence of Nano-calcium phosphate, while dimethylaminohexadecyl methacrylate (DMAHDM) was added as an antibacterial agent.[50]

6.1. Self cleaning materials

Previous studies in this field used the idea of the "lotus effect," which was brought about by minute bumps on lotus leaves that change their waxy surface to highly water-repellent substance.[51]

A recently found coating material with self-cleaning properties has been developed to prevent the formation of biofilms. A photo-activated acrylate material was added to fluoroalkylated acrylic acid oligomer (FAAO) at different concentrations. According to assay experiments, when the concentration of FAAO in the materials increased, the amount of biofilm that was sustained on the coated materials gradually reduced. FAAO-incorporated materials are thus discovered to have self-cleaning properties and to successfully inhibit the formation of biofilm on the surface.[52]

6.2. Biomimetic adhesives

The term "biomimetic" describes how creatures effectively employ components of nature to address environmental issues.[55] Two exceptional natural instances of bonding that have received extensive research to date are the footpads of geckos and the adhesion processes of mussels. The flat pad on the gecko's foot is packed with fine hairs that have been separated at the ends, creating more contact areas than if the hairs were not split. This results in a substantial rise in the adhesion force, through localized van der waals forces. This binding mechanism works best in dry conditions; it is not appropriate for moist surfaces.[53]

Figure 6: Footpads of geckos[54]

Subsequently, mussels overcome the gap in the gecko mechanism is another instance of bonding in nature. A novel adhesive substance known as "geckel" is created by combining the adhesion mechanisms of geckos and mussels. It has a strong but reversible adhesion in both water and air.[55]

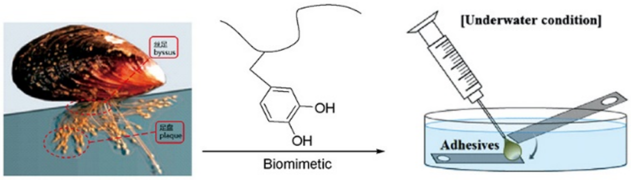

Figure 7: Adhesion mechanism of mussels[56]

7. Conclusion

In conclusion, the integration of technology has significantly transformed the landscape of orthodontic practice. The advent of innovative tools, such as digital imaging and computer-assisted diagnosis and treatment planning systems like Sure smile, has revolutionized the way orthodontic procedures are conducted. These technological advancements not only enhance the precision and efficiency of orthodontic care but also contribute to a more patient-centric approach. The ability to leverage 3-D imaging and digital techniques allows orthodontists to tailor treatments more accurately, resulting in improved outcomes and patient satisfaction.

8. Source of Funding

None.

9. Conflict of Interest

None.

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Author biography

Sanjeev Kumar Verma, Professor https://orcid.org/0000-0003-0155-8498

Aiswareya.G, Post Graduate Student https://orcid.org/0000-0003-1404-2474

Deepika Rajendra Singh Bais, Post Graduate Student https://orcid.org/0000-0003-1268-4465

Pramod Kumar Yadav, Assistant Professor https://orcid.org/0000-0001-9262-2832

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