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Editorial

How 3D printing is changing Orthodontics

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The development of digital technologies has revolutionized dentistry, including orthodontics. Three-dimensional (3D) printing has become one of these technologies most revolutionary tools, providing orthodontic appliances with increased precision and easier customisation. 3D printing is "the creation of an object from 3D model data by adding layer upon layer, unlike subtractive manufacturing techniques," according to the American Society for Testing and Materials. A thinly sliced horizontal cross-section of the created object may be seen in each of these levels.

3D printing encompasses various technologies, each with unique mechanisms and applications:

1. Stereolithography (SLA) was the first 3D printing method, patented by Charles Hull. It uses a UV laser to cure liquid photopolymer resin layer by layer. Post-processing involves removing uncured resin and UV post-curing to enhance material properties.
2. Fused Deposition Modeling (FDM) employs thermoplastic filaments melted and extruded through a heated nozzle. Layers are deposited sequentially and solidify to form the final object. It is simple and doesn't require post-processing but can suffer from material shrinkage and lower resolution.
3. Digital Light Processing (DLP) also uses photopolymers but differs from SLA by projecting light across entire layers using a digital micromirror device. This results in faster printing and finer layers (as thin as 30 µm).
4. PolyJet/Inkjet 3D Printing (3DP/IJP) prints by depositing a binder onto a powder base or jetting photopolymer droplets cured by UV light. It supports multi-material printing with fine layer thickness (~12 µm), though surface finish may be inferior to SLA.
5. Selective Laser Sintering (SLS) utilizes powdered materials fused by a CO_2 laser, building objects layer by layer. It offers strong, functional parts without support structures.

These technologies vary in speed, resolution, material compatibility, and post-processing needs.Due to its precision, SLA printing technology gained widespread popularity.

The 3D printer workflow can be summarised in 4 key steps:

1. Scanning – A digital scan generates an STL (Standard Tessellation Language) file, providing the 3D geometry needed for manipulation in CAD software.
2. Designing – The STL file is imported into CAD software, where the model is digitally designed and customized before printing.
3. Printing – The design is processed through slicing software, which prepares the model for printing by setting parameters such as support structures, material type, layer thickness, and print orientation.
4. Post-processing – After printing, the object is washed in 99% isopropyl alcohol, dried, and post-cured using heat and UV light to ensure final strength and stability.

1. Orthodontic Application

1. Functional Appliances – 3D printing streamlines early orthodontic treatment, especially for Class II division 1

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malocclusions. Segnini et al. (2023) demonstrated how devices like Fränkel II can be digitized using CAD/CAM, reducing labor and cost. However, redesign, mechanical validation, and material certification remain challenges.
2. In-Office Appliance Fabrication – Panayi (2023) introduced a workflow for in-office design and printing of fixed appliances using Ubrackets CAD software and resin or zirconia. This method improves customization and speed, though metallic printing is still limited due to toxicity and equipment size.
3. Metal 3D Printing – Technologies like DMLS and EBM enable fabrication of durable, custom appliances such as Hyrax expanders using CoCr alloys (Graf et al., 2023). While expensive, these methods offer high precision but are less suitable for active force applications without added components.
4. Presurgical Orthopedics – Zheng et al. (2019) used 3D-printed nasoalveolar molding plates for infants with cleft conditions. These appliances enhanced surgical outcomes and reduced clinic visits by offering tailored, accurate fits.
5. Surgical Guides – Hou et al. (2019) developed a translucent, rigid guide for piezocision during PAOO procedures. The device improved surgical accuracy, irrigation, and visibility, enhancing safety and efficiency in orthodontic surgery.

2. 3D-Printed Models- Accuracy and Stability

Despite its benefits, the accuracy and long-term stability of 3D-printed models remain under scrutiny. Rebong et al. (2018) compared three 3D printing technologies—Fused Deposition Modeling (FDM), Stereolithography (SLA), and PolyJet—with traditional plaster models. While FDM models exhibited the smallest dimensional differences, each technology had strengths in specific areas, suggesting that selection should be based on clinical requirements.

Additionally, Knode et al. (2024) examined the dimensional stability of 3D-printed resin models over 21 weeks under different storage conditions. They observed measurable shrinkage across all materials, with exposure to daylight exacerbating changes. Their findings emphasize the importance of using printed models promptly to maintain appliance accuracy.

3. Challenges

Despite its many benefits, 3D printing in orthodontics has certain limitations:

1. High Initial Costs: Equipment, software, and training require significant upfront investment.
2. Print Quality Variability: Outcomes depend on printer calibration, material selection, and post-processing.
3. Training Requirements: Staff must be trained in scanning, CAD, slicing, and post-processing protocols.
4. Ecological Concerns: Resins and IPA waste are hazardous if not disposed of correctly. Moreover, low recyclability of materials contributes to environmental impact.
5. Infrastructure: Clinics may need extra space, electrical wiring, and ventilation to support in-house labs.
6. Hardware Longevity: The reliability of printer manufacturers is crucial to long-term success. Unsupported systems risk obsolescence.
7. Return on investment is a key consideration for clinics investing in 3D printing. The financial viability depends on the balance between production costs (equipment, resin, labour) and outsourcing fees. ROI calculators provided by manufacturers can help estimate breakeven points. Items like brackets and retainers offer high-volume, low-cost-per-unit advantages, whereas larger items like models require careful cost planning.

4. Future Prospects

The future of 3D printing in orthodontics is promising. Advancements are expected in:

1. Materials: Eco-friendly, biocompatible, and recyclable resins such as nylon are under development.
2. Direct Aligner Printing: This approach is poised to streamline production, reduce environmental waste, and eliminate thermoforming.
3. Increased Accessibility: Desktop printers are becoming more affordable and user-friendly, allowing even small practices to implement digital workflows.
4. Open-Source Software: The development of CAD software tailored for orthodontics will improve usability and reduce training barriers.
5. Market Disruption: In-house aligner production could challenge commercial monopolies, lowering costs for patients and increasing treatment access.

5. Conflict of Interest

None.

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