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Guest Editorial

Mechanical properties of 3D printed orthodontic aligners

Amit Bharadwaj[1]*

[1]*Dept. of Orthodontics, Modern Dental College, Indore, Madhya Pradesh, India*

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3D-printed orthodontic aligners mechanical properties are dependent on the 3D printer used, and thus, differences in their clinical efficacy are anticipated.

Direct three dimensional (3D) printing technology aids in eliminating the step of the physical construction of the dental model and the aligner is directly constructed based on electronically stored 3D dental data. The materials used are different from epoxy resins and photopolymers being predominant.

Direct light processing (DLP) and liquid crystal display (LCD) are fast 3D printing processes that utilize a conventional light source applied to the entire photopolymer resin and gain acceptance and preference by the majority of aligner 3D printer manufacturers.[1]

The factors responsible for the mechanical properties of aligners among the printers tested depended upon factors like resin used, after curing process, the 3D printing process of each printer, Wavelength of the printer, the extent and depth of cure & laser exposure conditions like power and exposure time/velocity which control the extent of polymerization on x-y level as well as the depth of cure (z-axis), affecting the adherence of curing layer on the previously cured ones and thus the mechanical properties of printed structures in the three axes.[2]

These differences in mechanical properties are attributed to the different technologies used to flash light on the entire layer of resin although both DLP and LCD cure the whole resin layer at once. Projector used in DLPS t directs light on selective areas of the resin layer while LCD technology uses LCD panels to block off the points that are not to be solidified on each layer.[3]

The mechanical properties of 3D-printed orthodontic aligners are significantly influenced by the type of 3D printer used, as well as the materials and printing parameters. Here are some key factors:

Type of 3D Printer

Different 3D printing technologies have varying effects on the mechanical properties of the final product. The most commonly used 3D printing technologies for orthodontic aligners include:

1. **Stereolithography (SLA)**: SLA uses a laser to cure a liquid resin, layer by layer. It can produce highly accurate aligners with smooth surfaces. The mechanical properties of SLA-printed aligners depend on the type of resin used (e.g., flexible or rigid), but generally, they have good surface detail and strength.
2. **Digital Light Processing (DLP)**: Similar to SLA, DLP uses light to cure a resin, but it does so with a digital projector that cures an entire layer at once. This process can also result in very precise aligners, but like SLA, mechanical strength depends on the resin material.
3. **Fused Deposition Modeling (FDM):** FDM printers extrude thermoplastic filament, layer by layer. While

* *Corresponding author*.
E-mail address: dramit2211@yahoo.in (A. Bharadwaj).

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FDM is less commonly used for orthodontic aligners due to potential issues with surface smoothness and precision, it may be suitable for less demanding applications.

4. **Selective Laser Sintering (SLS)**: SLS uses a laser to fuse powder material layer by layer. SLS can produce strong, durable parts with more complex geometries, but it is less common for orthodontic aligners due to cost and material limitations.

Material Properties

Resin plays a crucial role in determining the mechanical properties of the aligners. Some common materials include:

1. **Rigid resins**: Provide stiffness and durability but may lack the flexibility required for certain types of movement.
2. **Flexible resins**: Often used for aligners because they offer the necessary balance of elasticity and strength. The elasticity allows the aligners to exert a gentle force on the teeth without breaking or becoming deformed over time.

The material's flexural strength, tensile strength, elongation at break, and modulus of elasticity are key mechanical properties that affect performance. For orthodontic aligners, a material with a low modulus (i.e., more flexibility) but high tensile strength is desirable to ensure comfort and effectiveness over time.[4]

Print Resolution & Layer Height

- The resolution of the 3D printer (how finely it can print) affects the surface smoothness and the uniformity of the aligner. Higher resolution prints generally result in smoother, more consistent surfaces, which may improve comfort and reduce the risk of wear or damage.

- Layer height (the thickness of each printed layer) also plays a role in the mechanical properties. Smaller layers result in smoother prints with better mechanical performance, while larger layers might reduce print quality and structural integrity.

Post-Processing

After printing, orthodontic aligners typically undergo post-processing steps, such as curing or heat treatment, to fully harden the material. The specific post-processing methods can impact the final strength and flexibility of the aligners. For example, prolonged UV exposure or heat treatment can alter the material's properties, either improving strength or reducing flexibility.

Printer Settings and Calibration

Other factors, such as print speed, temperature, and printer calibration, also influence the final properties of 3D-printed orthodontic aligners. Inadequate calibration or improper settings can lead to weak spots or inconsistent performance.

Wear and Fatigue Resistance

Orthodontic aligners must withstand repeated forces without deforming. The material's fatigue resistance (ability to resist failure after repeated cycling of stresses) is a key factor in determining how long an aligner will last before losing its mechanical properties or shape.

In short, the mechanical properties of 3D-printed orthodontic aligners depend on several factors, including:

1. The type of 3D printer used (SLA, DLP, FDM, SLS, etc.)
2. The material choice (rigid vs. flexible resins)
3. Printer resolution and layer height
4. Post-processing techniques
5. Printer settings and calibration
6. Wear resistance and fatigue limits

Aligners made with high-resolution printers, using advanced flexible materials, and proper post-processing will typically provide better mechanical properties and more consistent performance over time.

Conflict of Interest

None.

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Author's biography

Amit Bharadwaj, Dean, Professor & Head

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