Perspective

3D printing in dentistry — Exploring the new horizons

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The emergence of 3D (3-Dimensional) printing technology into the field of dentistry has afforded the practitioner capabilities that have recently been restricted to dental laboratories. Over the last 10 years, 3D printing technology has become more attainable for clinicians and has allowed them to deliver more accurate, cost effective, and time efficient treatments to patients.[1–3] This revolutionary modality allows for the fabrication of working models, prosthodontic restorations, orthodontic appliances, surgical guides for implant placement, and maxillofacial prostheses.[4–6]

The foundation to 3D printing technology is the data acquired from intraoral optical scanners (IOS) and cone beam computed tomography (CBCT) images.[7] This data is then converted into standard tessellation language (STL) where it can be uploaded to 3D modeling software to be manipulated to meet the clinicians manufacturing needs. Following these modifications, clinicians upload the files onto a printer of choice. The most common types of 3D printing technology in dentistry are stereolithography (SLA), digital light processing (DLP), and material jetting (MJ).[8,9] These machines use additive manufacturing techniques to generate a product on top of the printer's build platform. The capabilities to produce various material types such as ceramic, metal, or thermoplastic resin. Once manufacturing is complete, post-manufacturing procedures are conducted to ensure the product is free of imperfections and properly cured, the extent of this processes depends on the given material and printer type. It must be noted that the accuracy and precision of each printer type depends highly on 3D printer quality, technology, the materials used, software settings, and the post manufacturing refinement process. The interconnectedness of all of these characteristics' affects overall quality more than the difference between SLA, DLP and MJ manufacturing techniques.

The most widely utilized and oldest 3D printing technique in dentistry is SLA. These printers use an ultraviolet (UV) laser to cure a liquid photopolymer resin into layers. Liquid resin is held in a vat while the laser polymerizes each layer of the resin it contacts. Following the curing of a single layer, the build platform descends, and subsequent layers of resin are cured on top of each other. After fabrication is complete, the product must be refined of excess resin, support struts, then hardened in an UV oven or solvent bath. Advantages to SLA printing include its production speed, high resolution, relatively low cost to other 3D printer types, and ability to construct intricate designs. High end SLA printers have the ability to produce orthodontic aligners, surgical guides, splints, occlusal guards,

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complete dentures, temporary and permanent crowns. The ability of SLA printers to produce a wide array of products with highly accurate results makes them the most popular 3D printer in the field of dentistry.

Similar to SLA printing methods, DLP technology shares the same curing, polymerization, and build-up techniques but varies in light source; DLP printers use a digital projector. Digital projectors allow for a complete polymerization of a material layer in the x-y axis at once making this a significantly faster fabrication method when printing on a large scale. The speed experienced on DLP large scale printing jobs is traded for a decrease in resolution and surface detailing, but when build volume is reduced resolution and surface detailing is restored. However, digital projector light sources are prone to creating voxel lines on products. These lines produce small rectangular steps and affect the formation of curved edges. Refinement of voxels in needed by post-manufacturing modification or fusing/detailing agents to get well defined surface details. Post manufacturing modification is mainly carried out by sandblasting while fusing/detailing agents are specific liquids used to fuse/melt voxels together, both result in a more desired surface finish. Even with this drawback, very good feature resolution down to several micrometers can be attained on small-scale DLP printing jobs making them ideal for products that require extreme accuracy. DLP printers have the capability to achieving this accuracy on complete and partial dentures, thermoform models, surgical guides, single and multi-unit wax-ups. This accuracy, volume, and speed come at a cost, generally DLP printers are more costly than their SLA counterparts.

While SLA and DLP technologies have an established foothold in dentistry's 3D printer marketplace, a new method, material jetting (MJ), has been growing in popularity for its superior production capabilities. MJ is a process similar to the one found in household ink printers. Light sensitive polymer is jetted onto the printers build platform through the printer's nozzle and then cured via UV light one layer at a time. MJ printers are able to construct products with equal accuracy to SLA and small batch DLP printers without the need of post manufacturing modifications. Another unique feature to these printers is their ability to print multiple materials during a single print cycle. These materials can vary in color, biomechanical properties, and textures making them highly versatile and particularly attractive for their potential application in esthetically complex cases. This makes MJ printing favored for the production of crown, multi-unit prostheses, implant models, surgical guides, removable partial dentures and various orthodontic appliances. These printers tend to be large in size and utilize proprietary blends of materials making them less optimal to fabricate a wide range of products and increase production costs. It can be expected that as the field of 3D printing and material jetting advances that more materials will be available for practitioners, strengthening this techniques appeal to the dental marketplace.

Clinicians now have only realized the true potential that 3D printing provides the field of dentistry. In the coming years it can be expected that there will be a shift from the long-standing subtractive manufacturing methods of product milling to additive 3D printing techniques. While 3D printing and its associated materials are in the infancy stage of development, new techniques and materials are entering the dental manufacturing market regularly. Practitioners should be aware of the limitations of this technology to models, provisional restorations, and basic orthodontic appliances. In the near future, clinicians should expect 3D printing technology to be used for a wide array of dental restorations.

Declaration of Competing Interest

The authors have no conflicts of interest relevant to this article.

Acknowledgments

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