3D printing in dentistry

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3D printing (3DP), otherwise known as additive manufacturing, is the forerunner in today's digital dentistry. 3DP as a technique surfaced back in the 1980s but has turned mainstream only since lean methodologies entered prototyping more recently in the 21st century. Its advent began when Charles Hull printed, for the first time, in 1983, a 3D object using the first 3D printer [1]. 3DP is a process of producing 3D solid objects from a digital file in STL format (surface tessellation language file or standard triangulation language file) by a 3D printer by joining, bonding, sintering or polymerizing small volume elements [3]. As evident in the Gartner Hype Cycles for 2017, 3DP is making critical inroads today in dentistry driven primarily by its superior customization propensity.

Applications

Its applications stretch across the fields of medical modeling, fabrication of surgical guides, prosthodontics, restorative dentistry, orthodontics, implantology and instrument manufacturing. The adoption in these fields is primarily driven by improvements in affordable high-end imaging technologies like CT scans. Another viable differentiator rises from its inherent advantages over the present computer-aided design/computer-aided manufacturing milling techniques.

3DP finds applications in organ printing by producing cells and biomaterials individually or layer by layer, fabricating a tissue-like structure. This could help overcome the huge shortage currently faced in sourcing organs from donors, once it develops from infancy [2]. Further, 3DP has the potential to produce personalized medicines in new formulations such as pills that include multiple active ingredients, as complex multilayer or multireservoir printed tablets, microcapsules, nanosuspensions and multilayered drug-delivery devices [5]. A hitherto unexplored domain of allopathy – ‘personalization’ now finds new hope at scale through 3DP.

Porous titanium implants can be fabricated with ease using 3DP. Focusing a high-power laser beam that fuses metal particles on a powder bed generates the desired implant design layer by layer, with no postprocessing steps required [6,7]. It also finds extensive use in implantology. An example of its use in digital orthodontics is Invisalign. The Invisalign® system digitally realigns the patient's teeth to make a series of 3D printed models for the manufacture of ‘aligners’, which progressively reposition the teeth over a period of months/years [8]. Other applications in dentistry occur in the fabrication of crown copings, partial denture frameworks, surgical instruments, oral and maxillofacial implants, forensic odontology and simulation models synthesized for education.

Technique

The technique involves three major steps: data procurement, processing and the actual fabrication using additives.

The first step is crucial, which requires images obtained from a comprehensive CT scan or MRI. These images are used to synthesize a computer-aided design drawing of the object to be fabricated. The 3D printer uses the coordinates from the 3D model to enable its servo motors that move the printhead along the x–y plane fabricating a layer. This is iteratively repeated along the z-axis to fabricate the third dimension [5,9]. Other data dictating color, texture and thickness is fed in the STL file format. Various materials used for 3DP include acrylonitrile-butadiene-styrene (ABS) plastic, stereolithography materials (epoxy resins), polylactic acid (PLA), polyamide (nylon), glass-filled polyamide, silver, steel, titanium, photopolymers, wax, and polycarbonate [3].

3DP technologies

The major techniques adopted in 3DP are illustrated below.

Stereolithography, photopolymer jetting and digital light processing use light cure resin. Stereolithography uses a vat of light-cured photopolymer resin and a light-sensitive laser to build successive layers. In photopolymer jetting, an ink type print-head jets light-sensitive polymer onto a platform incrementally building layers. Digital light processing builds the object upside down using liquid resin and light source on an elevating platform. These processes are expensive, have limited shelf life and cannot be heat sterilized [10].

Powder binder is a process that uses water from an inkjet printer head projected onto a powder bed to construct the object. Although this technique is cost-effective, it falls short on the resolution output, easiness to operate and heat sterilization.

Technologies like selective laser sintering and electronic beam melting sinter powder in a heated chamber to a point below its melting point, after which a scanning laser builds the object. Selective laser sintering can be used to print objects from polymers and metals. This is expensive due to its high capex and maintenance costs. It also poses a health risk due to dust inhalation or accidental explosion.

In fused deposition modeling, small beads of thermoplastic material are released from a nozzle to construct the model. The 3D printers adopting this technique find the highest penetration at the domestic level; often nicknamed ‘home-printers’ [10].

Advantages

Conventional standalone subtractive manufacturing techniques such as milling create high wastage by their very nature. This can be minimized by utilizing these techniques in adjunction with additive manufacturing. Among all the available digital processing methodologies used for this purpose, 3DP is clearly the winner. Its higher efficiency, passivity, flexibility and superior material utilization earn it its distinction.

Disadvantages

The benefits from high material utilization might in some cases diminish when contrasted with the drawbacks due to its extended postprocessing duration. Other shortcomings include its high cost, the occurrence of staircase effect (created by layered deposition), inconsistent reproduction and requirement of support materials (that is difficult to remove postprocessing). Ceramics, one of the most popular materials used in dentistry lacks the ability to be 3D printed due to the high porosity caused during fabrication.

Conclusion

3DP is transforming digital dentistry by extensively penetrating opportunities in diagnosis, treatment and education. The accelerated research in this industry and optimism would open more doors to help revolutionize digital dentistry.

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