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3-D Printing in Orthodontics

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Abstract

Three-dimensional (3D) printing in digital dentistry is one of the major developments in dentistry. It replicates the dental cast in the most accurate forms. This allows for supreme precision and minimal human errors. Besides decreasing the laboratory procedures, it has the least chance of failure or breakage. Digital technology has resulted in decreasing human errors by automating the dental model fabricating process with three-dimensional printing. Digital fabrication technology, also referred to as 3D printing or additive manufacturing, creates physical objects from a geometrical representation by successive addition of materials. 3D printing technology is a fast-emerging technology. Nowadays, 3D Printing is widely used in the world. 3D printing technology increasingly used for the mass customization, production of any types of open source designs in the field of agriculture, in healthcare industries. The first commercial form of Spritam immediate-release tablet was approved by FDA in 2015, which promoted the advancement of 3D printing technology in pharmaceutical development. Three-dimensional printing technology is able to meet individual treatment demands with customized size, shape, and release rate, which overcomes the difficulties of traditional technology.

Introduction

Three-dimensional (3D) printing technologies are advanced manufacturing technologies based on computer-aided design digital models to create personalized 3D objects automatically. 3D printing can create physical objects from a geometrical representation by

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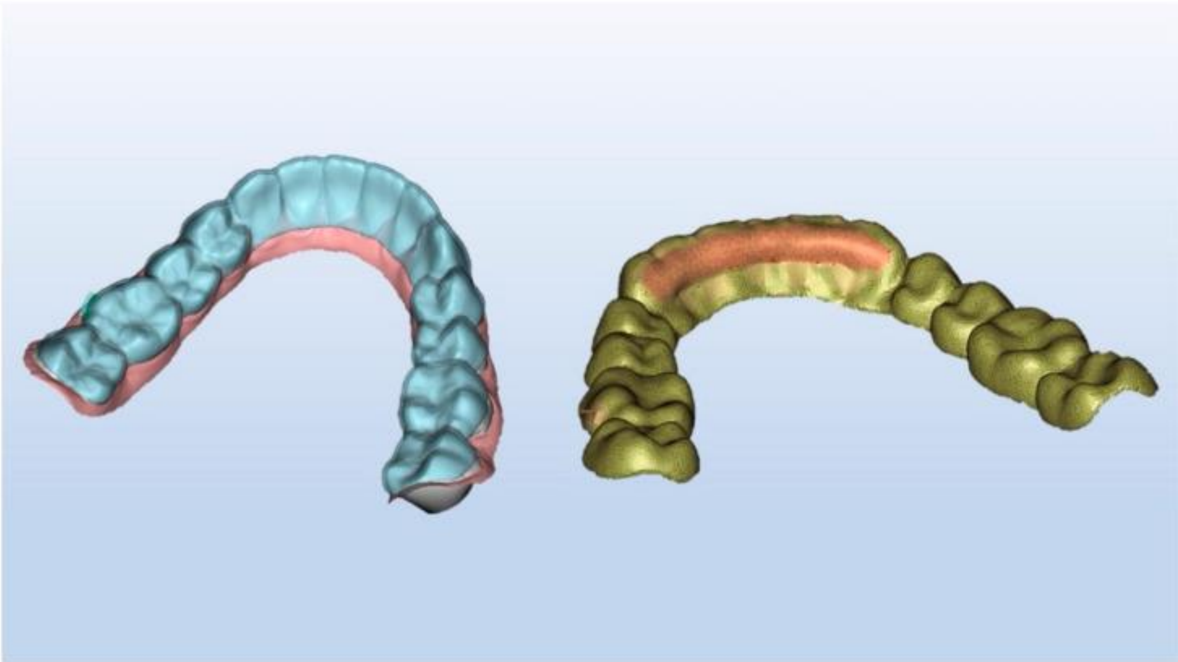
successive addition of material. This 3D process had many experienced a phenomenal expansion in recent years. First commercialised of the 3D printing processes in year 1980 by Charles Hull. Currently, 3D printing primarily used for producing artificial heart pump, jewellery collections, 3D printed cornea, PGA rocket engine, steel bridge in Amsterdam and other products related to the aviation industry as well as the food industry. 3D printing technology has originated from the layer by layer fabrication technology of three-dimensional (3D) structures directly from computer-aided design (CAD) drawing. 3D printing technology is a truly innovative and has emerged as a versatile technology stage. It opens new opportunities and gives hope to many possibilities for companies looking to improve manufacturing efficiency. Conventional thermoplastics, ceramics, graphene-based materials, and metal are the materials that can be printed now by using 3D printing technology. 3D printing technology has the potential to revolutionize industries and change the production line. The adoption of 3D printing technology will increase the production speed while reducing costs. At the same time, the demand of the consumer will have more influence over production. Consumers have greater input in the final product and can request to have it produced to fit their specifications. At the meantime, the facilities of 3D printing technology will be located closer to the consumer, allowing for a more flexible and responsive manufacturing process, as well as greater quality control. Furthermore, when using 3D printing technology, the need for global transportation is significantly decreased.

1-In clear aligners

The recent introduction of three-dimensional (3D) printing is revolutionizing dentistry and is even being applied to orthodontic treatment of malocclusion. Clear, personalized, removable aligners are a suitable alternative to conventional orthodontic appliances, offering a more comfortable and efficient solution for patients. Including improved oral hygiene and aesthetics during treatment. Contemporarily, clear aligners are produced by a thermoforming process using various types of thermoplastic materials. The thermoforming procedure alters the properties of the material, and the intraoral environment further modifies the properties of a clear aligner, affecting overall performance of the material. Direct 3D printing offers the creation of highly precise clear aligners with soft edges, digitally designed and identically reproduced for an entire set of treatment aligners; offering a better fit, higher efficacy, and reproducibility.

The use of 3D printed models was the first step towards minimization of errors and mistakes (e.g., geometric inaccuracies) occurring during impression collection. Rather than using error-prone plaster models that are scanned and modeled to develop various alignment stages, it is superior to use digital impression taking and 3D printing for improvement. Use of a clear aligner that is 3D printed for direct usage can eliminate the cumulative errors introduced from analogue impression taking and the subsequent thermoplastic workflow. In addition to greater accuracy, direct printing produces other benefits such as shorter supply chains, significantly shorter lead times, and lower costs. It is also a more sustainable process that generates significantly less waste than subtractive and thermoforming processes

Theoretically, various 3D printing processes may be used for direct printed clear aligners, such as fused filament fabrication (FFF), selective laser sintering (SLS) or melting (SLM), stereo lithography (SLA), multi-jet photo cured polymer process, HP Multi Jet Fusion technology or continuous liquid interface production technology. However, due to specific characteristics of clear aligners and specific requirements on their material properties and performance, 3D printing by photo-polymerization from clear resin seems like the most appropriate option. .



2-In Preventive Orthodontics

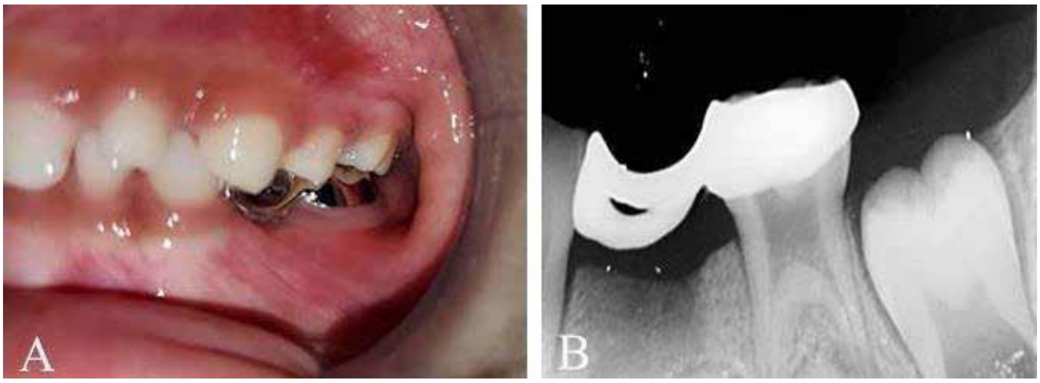
According to Richardson, the most severe space problems occur when the primary teeth, in particular, the first primary molars are exfoliated before the eruption of the first permanent molar. Arch length maintenance during primary, mixed and early permanent dentition is of prime importance for normal development of future occlusion. A greater percentage of space loss occurs by mesial migration of posterior teeth than distal migration of anterior teeth, especially in the mandible. Hence, it is important that the space created by premature loss of primary teeth be maintained until the eruption of permanent successors. Space management is an important moiety for monitoring the developing dentition. The use of space maintainers may preclude the need for later extractions and/or complex orthodontic treatment. Various appliances can be used for space maintenance depending on the child's age, development and occlusion of dental arches. However, little attention has been given by the researchers on the clinical efficacy of space maintainer and how variables in design and construction affect survival time. In cases of premature loss of primary first molars, it is important to place a band and loop space maintainer on the primary second molar prior to the 'dynamic' eruption phase of the first permanent molar, because the force of eruption of the permanent molar will exert significant mesial force on the primary second molar.it is important that the space created bypremature loss of primary teeth be maintained until eruption of permanent successors.

CASE REPORT

A 6-year old boy reported to the Department of Orthodontics & Dentofacial Orthopedics with a chief complaint of pain and mobility of teeth in the lower right region of his jaw for one week. Intraoral findings revealed deep occlusal caries with mandibular right first primary molar. Intraoral periapical radiographic examination with mandibular right first primary molar revealed coronal radiolucency involving enamel, dentin and pulp with furcal involvement. It also revealed resorption of root with loss of 2/3rd of the root length.

Extraction of mandibular right and left first primary molars were planned under 2% lignocaine with 1:1,00,000 adrenaline followed by the placement of bilateral band and loop space maintainers.

The printed space maintainer was tried; the post- operative occlusion was checked and found satisfactory. Further, both conventional band and loop and the 3D printed space maintainers were cemented using glass ionomer cement.



Khanna S, Rao D, Panwar S, Pawar BA, Ameen S. 3D Printed Band and Loop Space Maintainer: A Digital Game Changer in Preventive Orthodontics. J ClinPediatr Dent. 2021 Jul 1;45(3):147-151. doi: 10.17796/1053-4625-45.3.1. PMID: 34192758.

3D Printing Processes

<u>1-SLA(Laser stereoscopic lithography)& DLP(Digital light Processing)</u>

Laser stereoscopic lithography, also known as the stereoscopic apparatus, is the most widely researched, mature, and until today the widely used 3D printing technology. With the help of the ultraviolet laser beam, liquid monomers are converted to solid state through polymerization, which can produce parts with excellent surface quality and fine detail. Under the control of computer, the lithography machine coats the resin on the surface of the part (x-y direction), and the laser scanner controls the laser beam to move and scan point by point within the cross-sectional profile according to the layered contour data of the CAD model; once the beam penetrates the surface of the resin, instantaneous solidification by polymerization is realized, and then, the platform will be lowered by the amount of the specific layer thickness to provide curing of each layer and connection to the previous layer.

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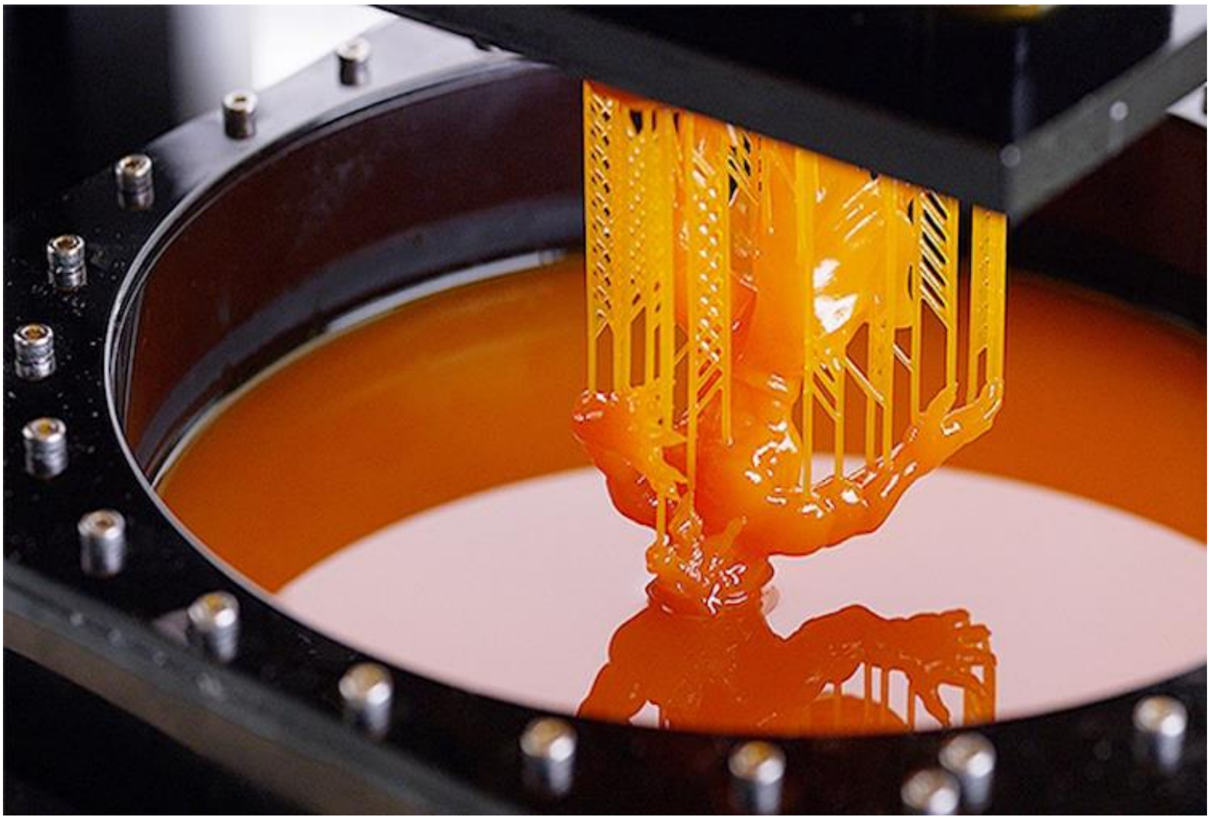
SLA shows many advantages such as the highly automated printing process, high-dimensional accuracy with the smallest details of 0.02–0.2 mm, extraordinary speed, excellent surface quality, and high resolution to produce complex parts. But the parts are easy to bend and deform due to materials' limitation; therefore, the building process requires support which limits the options for the orientation of the parts as the support will leave marks on the surface of the parts after removal. Then, a smaller range of materials is available, especially resins, which now also contains nanoparticles made of carbon or ceramic materials. This technique is most commonly used to print dental or bone models for diagnosis and treatment design and is also applied to manufacture clear aligners, occlusal veneers, denture teeth, and customized surgical guides. DLP technology is similar to SLA technology, and it also uses the characteristics of photosensitive material to polymerize and solidify under ultraviolet light irradiation. But its speed is much faster than SLA as DLP technology uses a digital light projector to cast ultraviolet light, which can directly allow any selected portion of the entire x–y workspace to be exposed simultaneously and speed cycle times between layers.



2-SLM(Selective Laser Melting)

It is a manufacturing technology often used to process powder materials. This technology uses the laser beam as a heat source under the control of a galvanometer and is guided by computer-aided design data to melt the selective area of the powder layer by layer. As the beam continues to move, the melted part solidifies to produce a solid layer due to the heat transfer by thermal conductivity to the surrounding powders, and then, the next layer is sintered, and the layer-to-layer bonding is realized. On account of making good use of metal material, SLS/SLM has advantages in manufacturing customized brackets, removable partial dentures, and dental implants. Compared with the conventional working process, the process of SLS has strongly shown the advantages of simple operation and produces molds with high hardness. Without support, the unsintered powder plays a supporting role during the process. But there are still some shortcomings: 1) the material needs to be preheated and cooled, and post processing is troublesome; 2) the sintered material has many voids that lead to poor density and mechanical properties; 3) the surface of the part is rough and porous with the layer thickness of 0.05–0.15 mm, which can be improved by post processing, it costs a fortune to fill the processing room with nitrogen to ensure sintering safety. SLM is developed on the basis of SLS for manufacturing metal parts with very accurate density, and the mechanical properties of SLM products are comparable to those of the conventional products. Laser melting is very similar to the abovementioned laser sintering process, except that during the printing process, the powder material is completely melted by the laser to produce a local (selective) melt pool, which results in complete dense parts with good mechanical properties after solidification. However, the surrounding powders cannot provide sufficient support due to the weight of the material and the limitations to the printing process; thus support is required during the SLM process.

3-FDM(Fused Deposition Modelling)

This process is suitable for thermoplastic materials such as acrylonitrile butadiene styrene (ABS) and polylactic acid (PLA), which can produce color parts by using color materials with dimensional accuracies typically in the order of 0.1 mm. From a technical perspective, FDM is an extrusion process that is formed by single-layer contour superposition. Among the

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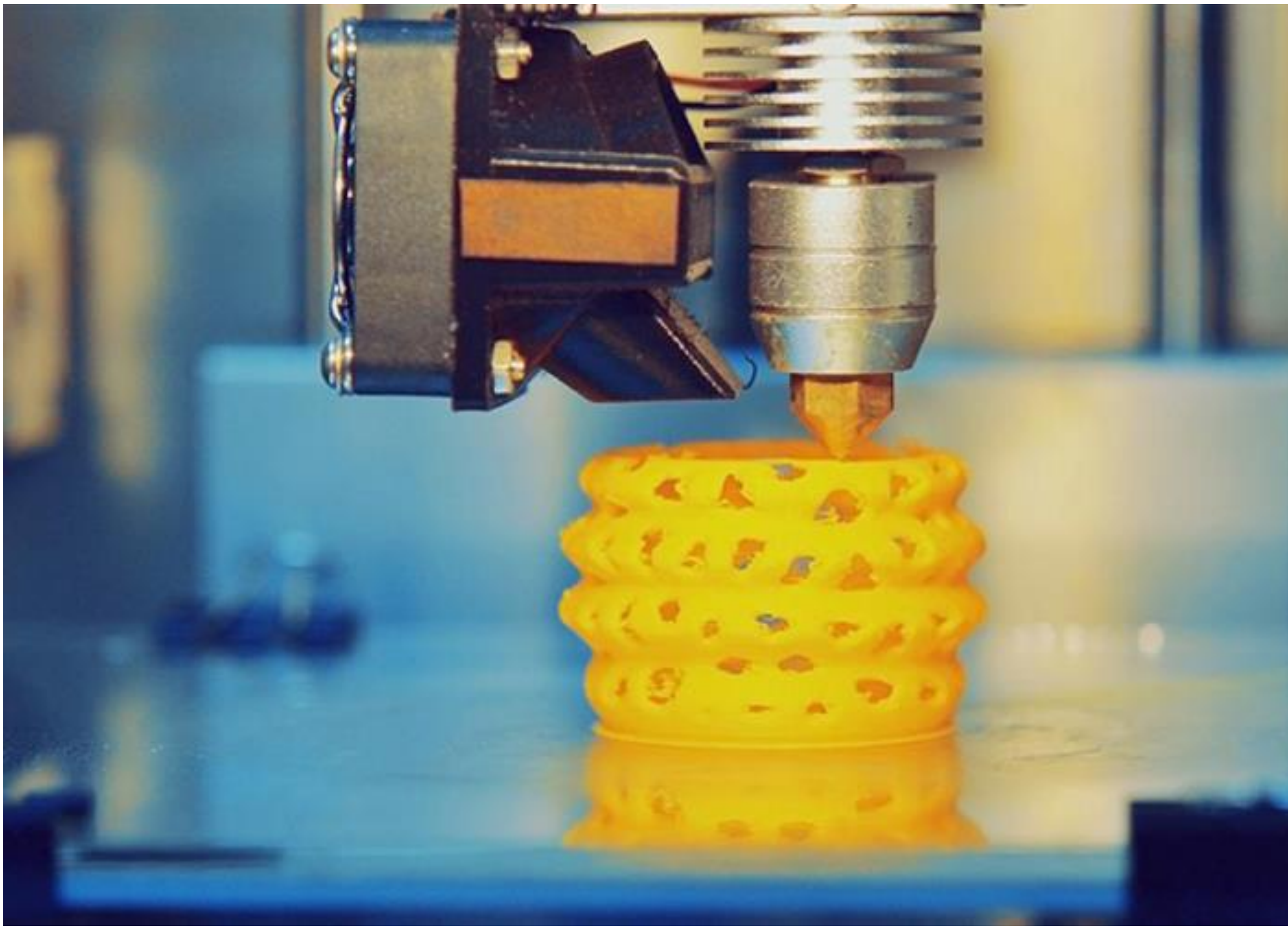
3D printing technologies, the design of FDM is the simplest and is currently widely used. An FDM machine can work without a laser and consists of a sealed and heated construction space (approximately 80° C for ABS), equipped with an extrusion head and a build platform. After being fed into the extrusion head, the filamentous thermoplastic material is partially melted by electric heating and then extruded through the nozzle. Under the guidance of the contour information, the nozzle moves in the x-y direction, while the build platform moves in the z direction. As the molten material cools, the bonding between layers is realized until the parts are finished. The build process requires the addition of supports, which are generated through a second nozzle and can be added simultaneously with the molded material using different plastic materials. However, limited control over the placement of the material and the creation of voids adversely affect its accuracy, especially when printing more complex shapes.



CONCLUSION

Three-dimensional printing is used in multiple fields of dentistry. 3D printing technology is a suitable method of fabrication of clear aligners and offers several advantages over the conventional thermoforming process. While the current state of published literature about directly printed clear aligners shows that such a process is technically possible, no approved material marketed for this purpose exists, and software tailored to this aim has to be

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developed. For this reason, no clinical studies of such printed aligners can be found. Based on these premises, further in vitro and in vivo studies are needed to test these new technologies and materials.

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