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3D PRINTING IN ORTHODONTICS

Orthodontics

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ABSTRACT

The field of orthodontics is moving forward to fresh technological perspectives in its new era. A relatively new technique, additive manufacturing has a wide range of expanding applications in several areas of dentistry and medicine. The transition from gypsum laboratory to 3-D printing represents a paradigm leap. For orthodontists, 3D printing is currently a readily available manufacturing technique that can be employed in many areas of orthodontic practise. Its potential is continually expanding. The article covers the necessary background information on the history, evolution, and existing technologies of additive manufacturing and offers updates on its use in orthodontics.

KEYWORDS

INTRODUCTION

After understanding the concepts and applications of scanners, CBCT, and integration of the information obtained from them in digital software, we need to understand what comes next in the digital workflow. To make digital appliances a reality, the process of 3D printing is very important.

A process founded in 1990 by Wilfried Vancraen, (CEO and Director of Materialise NV,) 3D printing allows manufacturing models, physical objects, prototypes, and parts of any shape from a designed virtual model. These models can be produced in a variety of materials ranging from metals like aluminum, steel, titanium, nickel, and cobalt to materials like plastic and resin as well.[1]

Process Of 3d Printing

The process of 3D printing begins with, the data acquisition of the model, followed by its design in digital software. The 3D virtual model is then converted from the point cloud into an STL file. STL is a file format that enables the transfer of a 3D model from a computer screen to a 3D printer. These STL files then undergo cleaning, repairing, base modification, hallowing, and labeling (Fig.1) before being forwarded to the manufacturing machine to build the object layer by layer.

Fig 1. The image shows the Hardware and software steps required to prepare the STL file for 3D printing.

The object is manufactured by joining the material selected for it in successive layers, one on top of the other by additive processes under the control of computer technology (Fig 2). Additive manufacturing is likely to undergo rapid growth in conjunction with intraoral scanning technology. This is a more effective system for orthodontic practices and laboratories for the automatic fabrication of high-resolution study models, retainers, metal appliances, aligners, and indirect bonding, accelerating the production time and increasing the capacity.[2]

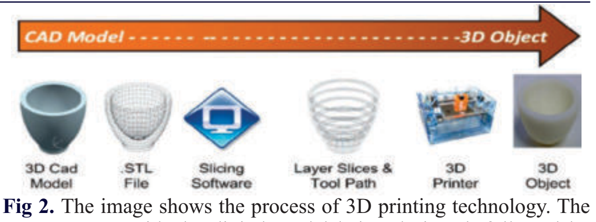

Fig 2. The image shows the process of 3D printing technology. The process starts with the digital model being designed, followed by conversion into STL files. This is sliced into layers with the slicing software and the layers are printed with additive technologies using the 3D printer.

Printing Technologies

A wide variety of additive printing technologies are available that can be used in the field of orthodontics. Some of these are:

1. Fused Deposition Modelling (FDM)
2. Selective Laser Melting (SLM) and Selective laser Sintering
3. Electron Beam Melting (EBM)
4. Stereolithography
5. Inkjet 3D printing
6. Digital Light Processing (DLP)
7. Laminated Object Manufacturing (LOM)

1. Fused Deposition Modelling

Introduced by S. Scott Crump in the late 1980s this technology was popularized by Stratasys, Ltd in 1990. It is one of the most widely used processes in 3D printing today and is frequently used for modeling, manufacturing appliances, and prototyping. It employs the "additive" method of laying down layers of thermoplastic material. Two different approaches can be used for manufacturing the 3D structures; first, using a heated nozzle with a metal wire or a plastic filament wound in a coil. The melted material is supplied through the heated nozzle and hardens immediately after extrusion, thus increasing its accuracy. The second approach is for the material to be supplied from a basin through a small nozzle. This technique is used to build body parts with different microstructural patterns including blood vessels, bone, and soft tissue.[3]

2. Selective Laser Melting and Selective Laser Sintering

This technique builds 3D objects by melting metallic powders and fusing their particles with the help of a high-energy laser beam directed by scanning mirrors. The process includes partially or fully melting the metal particles layer after layer until the object is formed. This technique is commonly utilized because of its ability to form parts with complicated geometries with very thin walls and hidden channels or voids directly from the digital CAD data. It has high productivity and can make objects from a wide range of powdered materials such as

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polyamides, polycaprolactone, hydroxyapatite, ultra-high molecular weight polyethylene, polyethylene, ceramic, glass, etc. The technique is commonly for the production of orthopedic and dental implants, dental crowns and bridges, partial denture frameworks, and bone analogs.[4]

3. Electron Beam Melting

This technique is used for creating near-net-shape or highly porous metal parts that are strong, void-free, and fully dense. It lays down successive layers by using the energy from an electron beam. Fully melted metal powder is used layer by layer for the manufacturing of objects using a computer-controlled electron beam under a high vacuum. The technology operates at higher temperatures of up to 1000 °C which could result in differences of the phases formed through solidification. It is commonly used in orthopedics and oral and maxillofacial surgery for manufacturing customized implants.

4. Stereolithography

The technique was introduced by Charles W. Hull in 1986. It is known for producing solid items by consecutively printing thin layers of material that are solidified by concentrated ultraviolet laser light. It is considered to be the first rapid prototyping process of its kind. The resolution of the 3D object-built increases with a rise in the number of layers added which may range from 5-20 per millimeter. Post the manufacturing process; objects are immersed in a solvent bath to remove any excess resin material followed by a UV oven to complete the curing process (Fig 3). The process's time frame varies depending on the object's complexity and size.

SLA models are currently used for planning cranial, maxillofacial, and neurosurgical procedures and constructing highly accurate replicas of human anatomy, customized implants, cranioplasties, orbital floors, and onlays. Surgical guides for dental implant placement are routinely produced by stereolithography.[5]

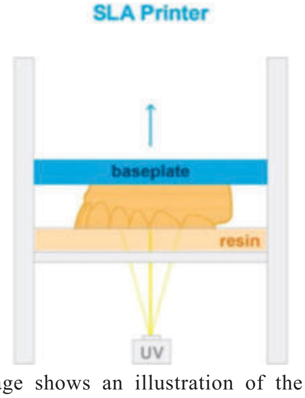

Fig 3. The image shows an illustration of the working of a Stereolithographic (SLA) printer, where the printer layers on polymer as the model platform is "pulled" out of the tank

5. Inkjet 3D printing

The inkjet printing technology employs a nozzle that "prints" a pattern on a thin layer of powder substrate by propelling a liquid binding agent. Pressure, heat, or vibrations are used to force the small ink droplets through the orifice. Immediate phase transformation occurs from liquid to solid after droplets are deposited upon the substrate by UV curing light, drying, chemical reaction, or heat transfer (Fig 4 and 5).

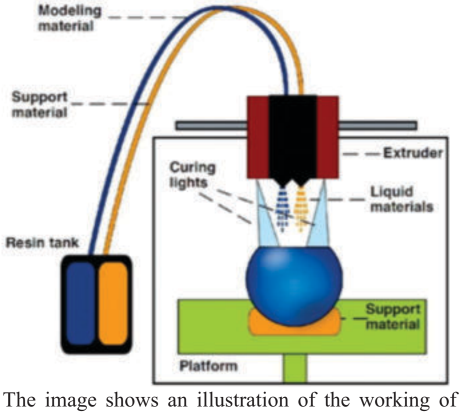

Fig 4. The image shows an illustration of the working of PolyJet photopolymer (PPP) 3D printing. The resin tank holds the powder substrate as well as the binding liquid which under pressure gets extruded. Here phase transformation occurs from liquid to solid, and results in the formation of volumetric color objects.

Fig 5. The image shows the post-manufacturing steps for the PolyJet printer. (A). The model is seen to be coated with gelatinous support material. (B). Support material is removed with water in a washing station. (C). shows a cleaned model ready for fabrication of thermoformed retainer.

The inkjet printer allows the manufacturing of colored volumetric objects with a variety of materials with unique physical properties. Dental applications of the printer include the reproduction of study models, surgical guides for implant placement, sleep apnoea appliances, orthodontic bracket guides, and try-in veneers.[6]

When compared to the other technologies, inkjet printing technology is faster than fused deposition modeling, however, in terms of the material and process, surface finish, object density, and accuracy may be inferior to stereolithography and selective laser sintering.

6. Digital Light Processing

Digital Light Processing (DLP) is a type of nanotechnology that forms objects by curing liquid resin into solid 3D objects by using a digital micro-mirror device as the power source projector. DLP technique shares a similarity with stereolithography as both methods employ light polymerization. DLP printing is faster and can build objects with a higher resolution, typically able to reach a layer thickness of almost 30 microns.[7] Once manufactured, the objects are then rinsed to remove the excess resin material. DLP can produce objects with a wide variety of properties such as high clarity, flexibility, water resistance, thermal resistance, and durability. Objects may begin to show cracks and become more susceptible to breaking due to the resin material used. DLP-based technologies are found in such diverse applications as movie projectors, cell phones, video walls, digital cinema, medical, security, and industrial uses.

7. Laminated Object Manufacturing

Laminated object manufacturing (LOM) is a process that combines additive and subtractive techniques to build an object. It works by successively layering sheets of material one on top of another and binding them together using adhesive, pressure, and heat application. Once the process is complete, objects are cut into the desired dimensions with a knife, a laser, or additionally modified by machine drilling. The technology can produce relatively large parts since no chemical reaction is necessary. The most common materials used with this technique are plastics, paper, ceramics, composites, and metals. Materials can be mixed in various layers throughout the printing process, giving more flexibility in the outcome of the objects. The surface accuracy of this technique is slightly inferior to stereolithography and selective laser sintering. LOM systems are used in sand casting, investment casting, ceramics processing, concept modeling, and architectural applications.[8]

Applications of 3D printing

3D printing can manufacture a large variety of products with very high precision. Amongst the various applications of 3D printing, a few in the field of orthodontics are:

Manufacturing of

- Dental models
- Occlusal Splints
- Customised archwires
- Customised buccal and lingual brackets
- Removable appliances
- Clear retainers and aligners

3D printing has taken orthodontics to new heights where the clinician can move the teeth to their final ideal position, print a sequence of physical models in the office, and use a thermoplastic material to fabricate aligner trays similar to any clear aligner firm. 3D printing has also been used to make Digital titanium Herbst, Andresen, and sleep apnoea appliances with smooth surfaces, no sharp edges, and excellent fit on the teeth, palatal and gingival tissues. Additive manufacturing also enables features such as hinge production, building threads, and wire insertion to be completed in a single build without assembly.

CONCLUSION

The development of technological tools and the accessibility of appropriate software have made it possible to make single scan digital images in the modern day.

orthodontic appliances can be designed virtually, 3D printed, and made using impressions. Orthodontics has benefited greatly from 3D printing technology, which is now extensively used. It's interesting to note that the possibilities for its prospective uses are continually expanding.

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