Review Article

Application of 3D Printing in Pediatric Dentistry

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Abstract

3D-printing is a newer advancement in digital technology in the wake of digital diagnostic images from cone-beam computed tomography and computed tomography. Using the image data, a digital model of restoration can be outlined by a computer-aided design or computer-aided manufacturing system. The digital model is then transferred to a specific 3D file on the computer to be produced as a physical object by a 3D printer using a variety of 3D materials. 3D-printed objects are used in pediatric dental practice for diagnosis, maxillofacial growth assessment, facial asymmetry, and creating aligners for malalignment in children. Non-invasive methods of surgical guidance for impacted supernumerary teeth, guided endodontics in the calcified canal of traumatized teeth, and 3D-printed porous scaffolds are noteworthy interventions in regenerative procedures. 3-D printing will acquire a very significant space in pediatric dental offices.

Keywords: 3D printing, Computer-aided design/computer aided manufacturing, Facial asymmetry, Guided endodontics, Scaffold, Surgical guide.

Introduction

Dentistry is a unique combination of art and science. Retention and lifespan of a restoration are dependent upon the scientific concept of retentive properties of a cavity design, the extension for prevention proposed by G.V. Black, as well as the use of various restorative materials that are biocompatible and have optimum compressive strength to withstand masticatory force. The technology of creating a cavity design compatible with retention is materialized by the expertise of the clinician. With the passage of time, dentistry has been improving in the fields of diagnosis, technology, materials, and treatment planning. Very early anesthesia was discovered to make tooth extraction painless, as was the ancient dental drill, which was later revolutionized with the introduction of the aerator handpiece. Dr. Willium H. Taggart introduced the loss-wax casting process in the 20th century. Subsequently came the era of acrylic resin for dentures, silicates for esthetic restorations, and later composite resin materials. Glass-ionomer cements, with their newer generations, were introduced with a myriad of applications. Contributions have been made by many researchers in the field, such as Buonocore, Raphael Bowen, Alan Wilson, Torabinejad, and others, to name a few. In the field of diagnosis, various 2-D X-ray images are now being upgraded to digitized radiovisiography (RVG) and more recently to 3D imaging with cone beam computed tomography (CBCT) and computed tomography (CT). Thus, dentistry is advancing rapidly with newer technologies and materials and has established an exemplary image in the fields of medicine and surgery.

Of late, the use of computer-aided design and computer-aided manufacture (CAD/CAM) technology has been applied in dentistry by Duret and Preston in the 1970s.[1] In CAD/CAM technology, a 3D model of the oral cavity is created, which is then digitized with a laser scanner without taking an impression or pouring a model. The digitized model is used for designing restorations with the help of available software. CAD/CAM is computer-controlled machining. Complex models are made in a relatively shorter time than conventional dental processes, with relative ease. Power-driven machine tools under the control

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of a computer program cut material to prepare the appropriate shape of the restoration from a block of material. Thus, the technology is developed through subtractive manufacturing.[1]

What is 3D Printing?

As opposed to this subtractive manufacturing, the other method of manufacturing objects is known as additive manufacturing (AM), also called 3-D printing. 3D printing generally describes the manufacturing process of making a physical object from a three-dimensional digital model by building one layer at a time and adding multiple layers, which results in the formation of an object. 3D printing can be precisely described as AM, or rapid prototyping (RP), or solid free-form technology. 3D printing is emerging as a promising technology in a wider variety of fields, including aerospace, defense, art, design, architecture, engineering, and medicine, by allowing individualization of designs and fabrication (Figure 1).

A filling in a tooth or prosthesis for one patient is very individual or specific for a particular patient or for a tooth in one patient's dental arch. The process of prosthesis or restorations has inherent intricate technology with a high degree of accuracy. CAD/CAM also provides this accuracy but is time-consuming and as it is a subtractive method, it sustains some material loss. This limitation is overcome in 3D printing, which, as an AM, is very beneficial in dentistry and surgery. The 3D printing procedure is very innate or unique in that it makes structures in many materials ideal for the field of dentistry.[2]

History

Charles Hull in the early 1980s invented the 3D printing[1] in which objects are made by fusing or depositing materials such as plastic, metal, ceramics, powders and liquids in layers to produce a 3D object.[3-5] Hull called it "stereolithography." Stereolithography is a form of 3D printing technology used for creating models, prototypes, patterns, and production parts in a layer-by-layer fashion using a photochemical process by which light causes chemical monomers and oligomers to cross-link together to form polymers. As he called the process stereolithography, it uses a stl (surface tessellation language) file format to interpret the data in a CAD file that allows instructions to be transmitted electronically to a 3D printer. The STL file contains instructions on the shape, color, texture, and thickness of the object.[6] The company 3D Systems developed the first 3D printer, called a "Stereolithography apparatus." In 1988, the company 3D Systems, which was founded by Hull, made the first commercially available 3D printer, the SLA250. The stereolithographic process provides good surface texture, high strength, and accuracy. The process uses UV light on a photopolymer, and as the beam draws the object onto the surface of the liquid, each layer of resin is polymerized.[7] The process is used in implant and surgical stent.[8] The pinpoint accuracy of 3D printing techniques in architecture, aeronautics, and telecommunications has resulted in their use in general medicine as well. 3D printing with computerized scanning has been used in prosthetic treatment without using conventional techniques.[9,10] Specific computer software is used to produce work types with the help of CT results.[11] The use of CAD/CAM in making prosthetic restorations precludes lab work.[12]

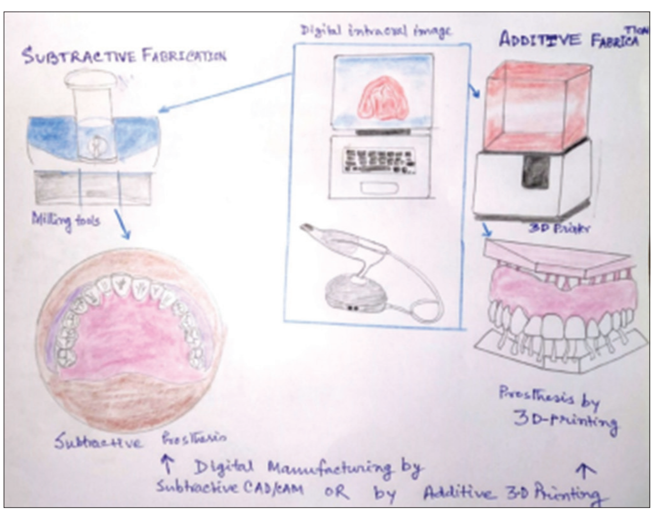

Figure 1: 3D printing in dentistry

Technology- Advantages/Disadvantages

Technologies for different 3D printing processes differ in parameters of speed, material, and clarity. 3D objects of preferred dimensions, after being designing in a CAD file, can be manufactured.[5] Primarily, the 3D printer requires its print head to move along a two-dimensional x-y plane[7] as per the design laid down in the CAD file. The printer then moves the print head along the z-axis to build the vertical dimension of the object, adding material layer by layer, following the instructions of the CAD file. 3D printing is thus a process by which 2D images like x-rays and minor CT scans can be interpreted into digital 3D print files. This can ultimately result in the fabrication of complicated structures that are individualized medical and anatomical parts.[7,13,14]

The advantages of 3D printing are: (1) opposed to subtractive manufacturing, it does not have material loss; (2) instead of joining the parts, 3D printing produces objects as a single structure; (3) data can be saved withnot needing space and sent through computers for technical purpose, (4) it manufactures core structures with some limitations; and (5) the manufacturing process eliminates the cost of high skilled labor in traditional manufacturing.

The disadvantages of 3-D printing are that, being a mechanized procedure, the physical model may have deficits in the created model, of which the clinician needs to be aware. So also, improvement is necessary in speed, dependability, range of materials, and cost of the process.

Applications in Medicine and Dentistry

Medical RP is defined as the manufacture of dimensionally accurate physical models of human anatomy derived from

Table 1: Multiple applications of 3D printers in dentistry

3Dprinter	Materials	Possible application
Stereolithography (SLA)	Different types of resins e.g UV light cured , ceramic filled resin	Guided surgery , orthodontics , fixed prosthesis
Polymer printing	Different photo polymers	Maxillofacial prosthesis (ear , nose , eyes) Drilling and cutting guides , anatomical models
Bio printer	Collagen based gels inks alginate chitosan hyaluronicetc . Photopolymers resin	Scaffolds for many tissue printing
Selective laser sintering (SLS)	Polyurethane polyamide , Alumide powder etc.	Partial prosthesis metal or resin hospital setup for metal crowns coping and bridges
Fused deposition modeling (FDM)	Polycarbonate polyether ether ketone , thermoplastic polymers etc.	Uncomplicated anatomical parts , prosthetic in - house production of conceptual models

medical image data using a variety of RP technologies.[15] CT was invented in the 1960s by Godfrey N. Hounsfield, an electronics engineer, in collaboration with Allan McLeod Cormack, a physicist. Using CT data from a patient's examination, a 3-D model was manufactured in the 1990s. Improvement of CT quality and production of specific software in this direction enabled 3D model fabrication. Neurosurgery, orthopedics, maxillofacial surgery, and dental implantology are the different medical uses of RP or 3D printing (Table 1).

A three dimensional assessment of surgical planning provides a visual analysis of the surgical technique. Looking at the visual representation provides a trial of the surgical procedure before surgery. Hence, the surgeon can touch and comprehend[16] the physical model through accurate reproduction of the object from 3D medical image data. This type of surgical planning reduces the duration of surgery and postoperative complications. Medical RP is also being used in dental implants. Osteotomies in the jaws and CAD/CAM-assisted RPD manufacture can be done more accurately using RP surgical guides.[4]

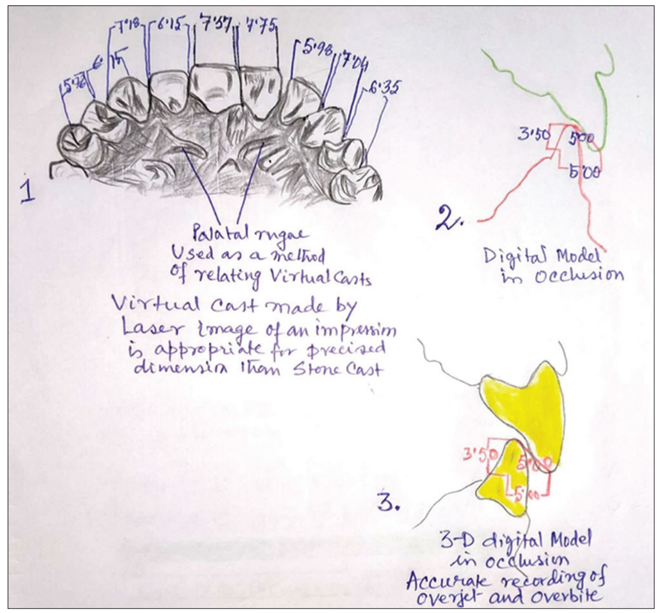

Figure 2: Role of 3D printing in diagnosis

Applications in Pediatric Dentistry

Diagnosis: Analysis of casts for the diagnostic process.

1. Detection of arch form distortion in the virtual model: premature loss of primary canines due to severe crowding leads to lateral shift of the incisors. Similarly, early loss of deciduous molars can cause posterior tooth migration. These discrepancies can result in asymmetry within the dental arch, present in an apparently symmetric arch form within a symmetric face[17] (Figure 2).
2. Individual tooth sizes in the upper and lower arch must be proportional as an integral part of achieving good occlusion. Tooth size anomaly, for example, mesiodense or tooth size discrepancy of lateral incisors, is most common, as are too large maxillary teeth occluding too small lower dental structures. A computer template is of advantage to measure the individual tooth size during space analysis, as the discrepancy can be detected by the computer. A comparison of the total widths of the anterior upper and lower and the total mesiodistal widths of all upper to lower is provided from the standard table. Tooth size analysis is readily available from digital casts (Figure 3). Precisely digitized data determines the accuracy of a computer analysis. Second, the correction approach is guided by how the patient meets the assumption, although computer calculations are quicker and easier. A tooth size discrepancy exceeding 1.5 mm will be challenging in achieving ideal occlusion.[18]
3. Facial asymmetry: Analysis of the facial asymmetry could only be done qualitatively from cephalometric (frontal and lateral) and standard panoramic images. Lateral cephalometric view shows the longer ramus and mandibular body; panoramic view detects a longer condylar neck; and the chin abnormality is detected in the frontal cephalometric view, but a quantitative difference could not be ascertained (Figure 4). A stereolithographic model created with accurate dimensions from CT data of an asymmetrical facial skeleton helps to see the three-dimensional model rather than images. Determining the shape of fixation plates and the precise position of fixation screws can be done in the planning of surgery.

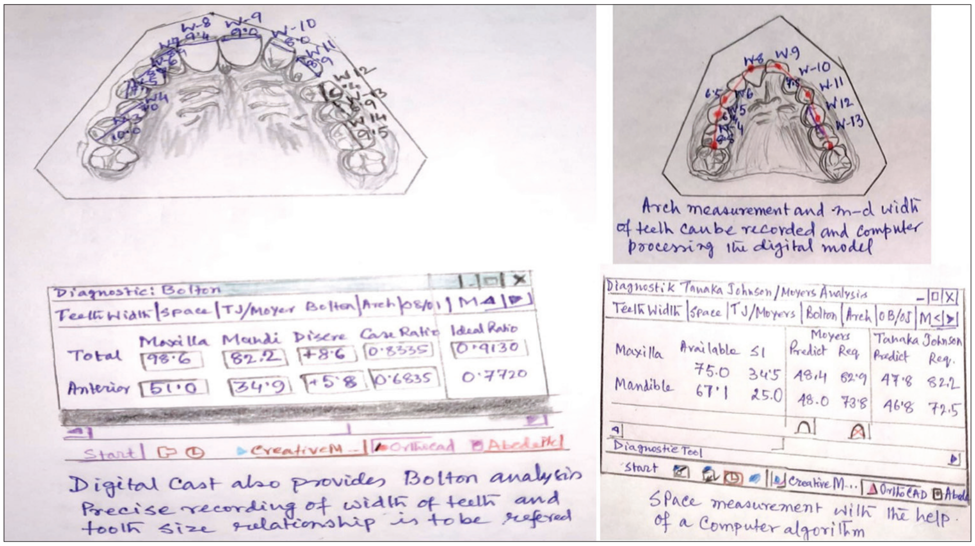

Figure 3: Space measurement

Figure 4: (a-c) Facial asymmetry

3D Printing in Maxillofacial Growth Analysis and TMJ Dysfunction in Children and Adolescents

Mandibular growth analysis from a 3D printed model of the mandible using CT data can be obtained in an adolescent orthodontic patient in a cross-sectional study.[19] Orthodontic tissue response can thus be recorded by bioprinting of oral hard and soft tissues. 3D printing is thus a reliable method to explain and helps in understanding maxillofacial growth.[20,21]

TMJ dysfunction, as in juvenile idiopathic arthritis or as a sequelae to malocclusion, e.g., Cross-bite[22] with characteristic myalgia, can be treated with 3D-printed, fabricated splints.[23] RP has reduced muscle spasm and enhanced precision.

3D printing technology can be used to fabricate orthodontic bracket to cause computer-planned tooth movement. Bracket design and precise position of the brackets are planned digitally by 3D-printed guides.[24] Printing can also guide temporary anchorage or bracket position and contribute to correcting malocclusion. CAD/CAM technology can be utilized to manufacture functional appliances like Herbst and Andresen and for sleep apnea.[25,26]

Minimal Invasive Treatment Using a Patient-Specific Template for Pediatric Mandibular Fracture "WINGSPLINT"

A mandibular fracture in children can be treated with a circumferential wire and splint. Using one customized template, external immobilization can be done with a less invasive process. Using maxillofacial CT data from the patient, a 3-dimensional virtual model is created in the software. An accurate location of screws is created in the virtual model of the mandible to avoid damage to the surrounding structures. Cylinders that are created are merged before reduction on the virtual model. Reduction of the mandible is done virtually, along with cylinders with proper occlusion, in CAD software. One "WING SPLINT "is created of 3mm thickness on the buccal aspect of the teeth. The wing splint covers the lower

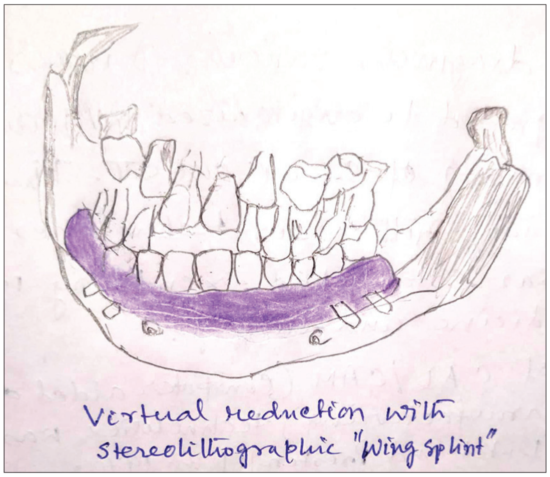

Figure 5: Educational approaches

third of the teeth and should be rigid. "WING SPLINT "is fabricated with a 3D printer with the help of a STL (stereolithographic) file to reduce the fracture under GA with the splint. The template is fixed with appropriate-dimension orthodontic implants[27] (Figure 5). A surgical guide is digitized to guide the surgical drilling with minimum bone loss.

3D-printed models of dental arches produced by intraoral scanning of patients' mouths provide more accurate and challenging learning for the dental students as the natural teeth are more variably placed than typodonts.[28] Normal tooth components and carious dental tissue can be created by polyjet printing models of different hardness, enabling different working sensations for novices in dentistry.[29]

Conclusion

3-D printing technology is a computer-guided method that, using data from CT and CBCT, can manufacture physical objects using 3D printed materials and make dental treatment quick, efficient, precise, and with fewer post-operative complications. In pediatric dental practice, 3D printing technology can provide noninvasive surgical removal of supernumerary teeth, conservative access preparation in calcified canals of previously traumatized teeth with guided endodontics, etc. Also, 3D printing methods on the material front are capable of producing porous scaffolds to be used in regenerative tissue engineering for the revascularization of traumatized open apex teeth. Clinicians in pediatric dental practice will have to update their knowledge through relevant articles and acquire practical skills to work with this new technology. Practitioners cannot ignore the advancement, or they will lose their opportunity to survive.

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