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Original Article

3D Printing in Pediatric Dentistry

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ABSTRACT

The integration of three-dimensional (3D) printing technology into healthcare has revolutionized patient-specific treatment approaches. As an advanced additive manufacturing method, 3D printing has paved the way for a new era of customized, efficient, and minimally invasive dental care tailored specifically to the needs of young patients. This review article explores the current applications, notable advancements, material innovations, and clinical impacts wof 3D printing in Pediatric dentistry.

Keywords: 3D Printing, Pediatric Dentistry

INTRODUCTION

Pediatric dentistry requires highly specialized approaches due to the unique anatomical, physiological, and psychological needs of children. Traditional dental practices often face challenges in achieving precision, comfort, and cooperation from young patients. The advent of 3D printing, also referred to as additive manufacturing, addresses these limitations by enabling the production of highly customized dental devices with unmatched accuracy.

HISTORY OF 3D PRINTING

The early stages of 3D printing technology date back to 1980 when Dr. Kodama from Japan introduced the concept, initially known as rapid prototyping (RP). In 1986 The stereo lithography (SLT) device was patented by Chuck Hull. Then, in 1987, Carl Deckard of the University of Texas used selective laser sintering (SLS) for RP at the same time. The term "selective laser melting" originated in 1989 when Scott Crump patented his melting layer modeling equipment. In 2008 with the creation of the first 3D-printed prosthetic leg. The first successful 3D-printed jaw was produced in 2012. Furthermore, in 2015, the University of Michigan introduced the first implanted 3D-printed bioresorbable scaffold for periodontal repair.

Principles Of 3D Printing in Dentistry

Additive Manufacturing

Additive manufacturing, commonly known as 3D printing, is a manufacturing process that enables the precise shaping of objects using Computer-Aided Design scanners or 3D object scanners. In contrast to conventional manufacturing techniques, which frequently call for milling or other procedures to eliminate extra material, 3D printing constructs things layer by layer. However, in 3D printing, this occurs in three dimensions through the crystallization, solidification, or bonding of liquid material or powder at various points during the printing process, guided by CAD.

Stage of Processing In 3d Printing

The process of 3D object printing consists of a specific sequence of controlled processing stages:

- **Stage 1:** Generating a three-dimensional file utilizing CAD software.
- **Stage 2**: converting the 3D file into an STL file format that the printer can read.
- **Stage 3:** The STL file is imported into a slicing program, often referred to as a slicer, which divides

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the model into layers and generates G-code instructions for CNC machines and 3D printers. This step is crucial for the actual printing of the model.

- **Stage 4:** The layer-by-layer printing of a three-dimensional model

- **Stage 5:** Processing

Biomaterials In 3D Printing

Biomaterials encompass both natural and synthetic materials employed for the replacement of organs or the repair of injured tissues within the body. These biomaterials can be classified into four main types based on their chemical composition: metals, ceramics, polymers, and composites. Within the field of dentistry and orthopedics, metallic and polymeric biomaterials find prominent use, offering advantageous mechanical properties, stability, and elasticity. Polymers, in particular, have found widespread application in various biomedical contexts.

Thermoplastic Polymers	* Polycaprolactone (PCL) * Poly Lactic-co-glycolic Acid (PLGA) * Polylactic acid (PLA) * Poly(3-ydroxybutyrate-co-3-hydroxyvalerate) (PHBV) * Polyetheretherketone (PEEK)
Thermoset Polymers	* Urethan resin
Hydrogels	- Alginate - Collagen - Fibrin - Gelatin - Agar - Chitosan
Composites (Biomaterials or Nanomaterials)	# Titanium alloy # Hydroxyapatite # Ceramic # Metal # Ca/ phosphates

Table 1 Most common used biomaterials [Eshkalaket al. (2020)]

Bioprinting

Cell-based 3D printing is known as "bioprinting," and the hydrogels that are used to contain the cells during printing are known as "bioinks." Hydrogels are preferred because of their great biocompatibility, low cytotoxicity, high water content, and modifiable mechanical and chemical composition. They are also biodegradable. For example, alginate and calcium, and fibrinogen and thrombin. The theory behind laser-assisted bioprinting (LAB) is that a laser pulse causes localized heating in a solution containing cells, which allows for the exact deposition of cells onto a substrate or platform

1. 3D Printing in Dentistry: The dental industry has been using 3D printing for more than ten years. Using laser-sintered alloys and guided implant drills for implant surgery operations were two of the first uses of additive fabrication technologies in dentistry.

2. Digital Workflow: The progress in digital image acquisition and the adoption of CAD/CAM technology have paved the way for a completely digitalized approach to dental treatment. Intraoral scanning has replaced conventional plastic moulds. Data collection utilizing various scanning technologies is the initial step. Using either extraoral or intraoral scanning equipment, like CT, CBCT, MRI and laser digitizing.

3D Printing Techniques in Dentistry

The most often used 3D printing techniques in dentistry are polyjet printing, bioprinting, stereolithography (SLA), selective laser sintering (SLS), and fused deposition modeling (FDM).

In **fused deposition modelling (FDM),** The material on the spool is introduced into a heated nozzle, where it melts and is extruded in the specified dimensions, one layer at a time. Once a layer is completed, the nozzle is lifted, or the print bed is lowered.

SLA (Stereolithography) This process entails continuously raising a container containing the polymer, causing the material to harden progressively and forming a 3D object. Another 3D printing method known as **digital light processing** (DLP), which relies on photopolymerization, has been employed in the fabrication of zirconia implants.

The polyjet printer boasts the highest resolution. It achieves this by building the 3D model layer by layer using printer heads that jet layers of liquid photopolymer onto a build tray, which are then solidified by UV light curing. They feature a quick printing process and can produce a precise resolution as low as 25 microns. They are also capable of replicating complex shapes.

Applications Of 3D Printing in Pediatric Dentistry

1. **Aesthetic restorations** 3D printed templates provide efficient, convenient and esthetic option for the direct resin composite restoration of fractured anterior teeth. They help to reproduce the anatomy, color, and translucency of the fractured tooth with precision.

2. **Designing & fabrication of space maintainers** the trial design is obtained by scanning the cast using the dental scanner, and the digital design of the band & loop similar to the conventional space maintainer. Materials used -titanium based powdered metal material and clear photopolymer resin.

3. **Impression making** Small children and those with special needs may experience gag reflex during placement of loaded impression trays in the mouth. Scanning & 3D printing treatment reduces the chair side time.

4. **Splint designing during dental traumatology** Contemporary splints even after best modifications cannot guarantee accurate repositioning and durability. According to Tiwari et al, digitally scanned information through CBCT will enable designing of a splint which can be cemented or cured into its position in traumatised region.

5. **3D scaffold printing in regenerative dentistry** Use of 3D printing has already been utilised for designing and creating customised scaffolds, where stem cells can be retained and regenerated in presence of growth factors.

6. **Auto transplantation** 3D printed templates help to achieve a guided atraumatic approach in auto transplantation of tooth. Strbac et al stated that this can lead to fewer failure rates and improved outcome. Vandekar et al used 3D printing to scan and replicate an impacted permanent maxillary central incisor.

7. **3D printing in sports dentistry** 3D technique can help in manufacturing the customised mouth guards in single appointments and keep the information stored for re-orders even at a click of a smart phone-based application.

8. **Education models for student's** 3D printed tooth models base on computerized tomographic images of extracted teeth are more realistic anatomical passage structure compared to plastic typodont teeth. Marty et al compared the perception of students between 3D printed models versus series Models in Hands-On Pediatric Dentistry Sessions.

CONCLUSION

3D printing is poised to redefine pediatric dentistry by enabling patient-specific, efficient, and minimally invasive care. While challenges such as cost, training, and regulation remain, ongoing advancements in materials, software, and printing technologies are likely to accelerate its integration into everyday practice. With its ability to enhance precision, patient comfort, and clinical outcomes, 3D printing holds the potential to become an indispensable tool in the future of pediatric dentistry.

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