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3D Printing: A Silver Lining in Pediatric Dentistry

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Abstract

Dental treatment of children poses significant challenges for clinicians. They often face fear and anxiety in a dental set up which leads to difficulty in achieving their cooperation. Hence, there is a need for modern technologies which will help a pediatric dentist to deliver oral health care to child with utmost comfort and quality treatment. 3D printing is emerging as a promising technology which have a wide range of scope in dentistry. The main idea behind this innovation is that the 3D model is sliced into many thin layers. The manufacturing or assembling equipment uses geometric data to build each layer sequentially until the final desired product is completed. There is sufficient literature which have discussed about the scope of 3D printing in various other fields of dentistry. But there is insufficient literature about its application in pediatric dentistry. Through this paper we intend to propose the scope of 3D printing in the field of Pediatric dentistry.

INTRODUCTION:

Dental treatment of children poses significant challenges for clinicians. An adult patient can understand the gravity of the situation and the consequences that come with it, so they work with their doctors to tackle the issues. While a child patient is emotionally immature and have lots of fear and anxiety associated with dental treatment. Hence it would not be fair to expect from them the magnitude of concern and cooperation towards dental treatment.

To meet the needs and requirements for pediatric dental patients, Pediatric dentistry is advancing and shifting towards better to perform dental treatment effectively and efficiently. [1] Among these advancements concept of 3D printing has recently emerged. 3D printing is a manufacturing process in which formation of object is done by building one layer at a time. [2] Various sectors from education to industry are covered through 3D printing. A significant application has been shown by 3D printing in clinical and laboratory techniques in many areas of dentistry.

The origins of 3D printing can be traced back to 1986. Charles (chuck) Hull who has first invented his SLA (stereo lithography apparatus) machine in 1983. In the earlier at 1980s 3D technologies were called as rapid prototyping technologies. New technologies continued to introduce in 1990s and early 2000s. 3D Printer was first commercially available in kit form in 1909. Introduction of alternative 3D printing processes at market was in 2012. [3]

The 3D model is sliced into many thin layers. The manufacturing or assembling equipment uses geometric data to build each layer sequentially until the final desired product is completed. This is the main idea behind this innovation. A virtual model that is near enough to the desired item is needed to

get started with. 3D model scanners might be used to examine and record the anatomy that has to be delivered. The 3D model is cut after which it is prepared to be taken into the 3D printer of the appropriate type. This is done possibly by the means of USB, Wi-Fi or SD. The record is transferred to a 3D printer and then the model or item is prepared to be 3D printed in layers. [4] 3-D printing can replicate the human form more accurately than traditional manufacturing technique. 3D printing has provided comfort and better quality treatment and enhanced treatment procedure to dentist. Patients treatment becomes fast, smooth and with greater precision. [5] Thus looking into this newer technology, this paper is focussing on various applications of 3d printing in pediatric dentistry.

TECHNOLOGIES INVOLVED IN 3D PRINTING

The following techniques are employed for Additive manufacturing or 3D printing of various applications in dentistry:

1. Stereo lithography (SLA).

2. Fused Deposition Modelling (FDM).

3. Selective Laser Sintering

4. Photopolymer Jetting

5. Electron Beam Melting (EBM)

6. Power binder printers

7. Direct light processing

Stereolithography: It is the earliest and most commonly employed technique. Charles Hull created the first 3D model using this apparatus. A photosensitive monomer resin when exposed to UV light gets converted into a polymer and solidifies is the principle of additive manufacturing with stereolithography apparatus. Sequential curing causes the layers bind to each other and form a solid mass, the formation of which begins from the bottom and keeps building upwards.[6] [Fig 1(a)]

Fused deposition modelling: Schott Crump developed the FDM. Layers of molten material are deposited from a nozzle in this technique and then solidification takes place within 0.1 seconds. It is less expensive than other 3D methods and is used by most of the low-cost 'home' 3D printers. In addition to this, it is easy to be installed and easily available. But the disadvantage of FDM is that it is less accurate. [7] [Fig 1(b)]

Photopolymer jetting: Photopolymer material or light cure resin material and multiple print heads is used in this technique. The use of print heads is to lay down the layers of the material. After deposition or laying down, each layer is cured. A variety of materials can be printed using this technique namely resins, waxes for casting, silicone rubber, materials with complex geometry and fine details. It gives a resolution of approximately 16 microns. It is quick, cost-effective, produces materials with high resolution and high-quality finish. Disadvantages include difficulty incomplete removal of the material, high cost of material, skin irritation and inability to sterilize the material by heat. [Fig 1(c)]

Electron beam melting: An electron beam as the power source is used in this technique instead of a laser. This electron beam liquefies the metal powder in successive layers inside a high vacuum chamber and complete liquefying of the material is achieved. [Fig 1(d)]

Powder binder printers: A modified inkjet head, a pigmented liquid (usually water) and a powder (mostly plaster of Paris) is used in this apparatus. Deposition of a single layer of the powder and liquid droplets are made to infiltrate into the powder. This is done layer by layer, in increments. Thus the final model is built of many layers with a new fine layer of un-infiltrated powder on the surface. This uninfiltrated powder layer serves the purpose of support material. [8] [Fig 1(e)]

Direct light processing: A projector is used as a light source. Through the projector the photosensitive resin is deposited and cured layer by layer. The object is constructed on an elevating platform and the layers are created upside down. As and when the resin is cured Printing occurs sequentially in layers. [Fig 1(f)]

Selective laser sintering (SLS): Selective laser sintering, also known as selective laser melting (SLM) has been used since the 1980s. It was developed by the University of Texas. A fine material powder is fused by a scanning laser for the incremental building of structures. As the powder drops down, the material is uniformly spread as a layer using a computer-directed roller. It is employed in the production of anatomical study models, cutting and drilling guides, dental models, etc. Ease of autoclaving the materials, full mechanical and functional efficacy of the printed objects, no support material is required as the surrounding powder itself serves the purpose and low cost of materials if used in large volumes. Disadvantages are that the powders are messy with having an increased risk of inhalation, the cost of purchase and running is high and the technology requires specifications of climatic conditions for its working. [9] [Fig 1(g)]

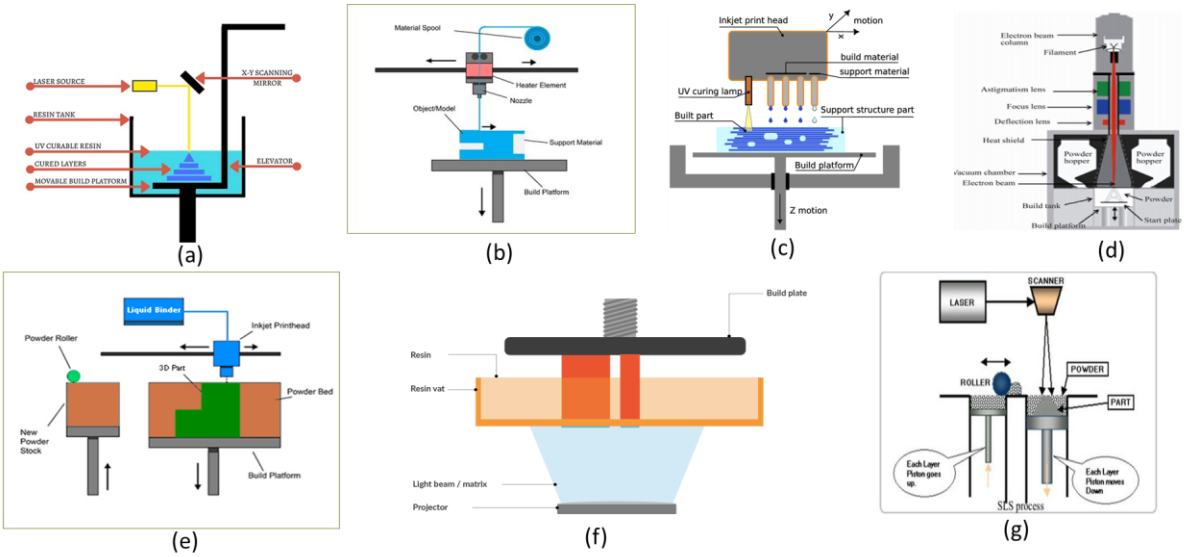


Figure 1: (a) Stereolithography, (b) Fused deposition modelling, (c) Photopolymer jetting, (d) Electron beam melting, (e) Powder binder printers, (f) Direct Light Processing, (g) Selective Laser sintering

ADVANTAGES OF 3D PRINTING:

3D printing has the following advantages:

1) Flexible design: 3D printing allows for the design and print of more complex designs
2) Print on Demand
3) Rapid Prototyping: 3D printing manufactures within hours
4) Strong and Lightweight parts
5) Minimising wastage
6) Ease of Access
7) Environmental friendly
8) Used in advanced healthcare

DISADVANTAGES OF 3D PRINTING:

3D printing has the following disadvantages:

1) Limited materials
2) Restricted Build size:
   The printers currently have small print chambers which restrict the size of parts that can be printed. Anything bigger will need to be printed in separate parts and joined together after production.
3) Part structure:
   With 3D printing parts are produced layer-by-layer. It means that they can delaminate under certain stresses or orientations.
4) Reduction in manufacturing jobs
5) Design inaccuracies:
   Another potential problem with 3D printing that final parts may differ from the original design. It is directly related to the type of machine or process use. This can be fixed in post processing, but it must be considered that this will further increase the time and cost of production. [10]

APPLICATIONS IN THE FIELD OF PEDIATRIC DENTISTRY:

Pediatric dentistry is a unique speciality of dentistry, where it deals with all fields of dentistry for a particular age group. Because of this reason itself, paediatric dentist is the one who should be multi skilled. A pediatric dentist should be a versatile person who have to take the role of a various specialists because they have to deal with lot of areas like behaviour management, oral surgery procedures, preventive and interceptive orthodontic procedures, conservative and endodontic procedures, prosthodontic procedures etc. The patients whom they deal with are the little minds and the future of tomorrow. So at the same time paediatric dentist is a person who needs lots of skill and facing lots challenges.

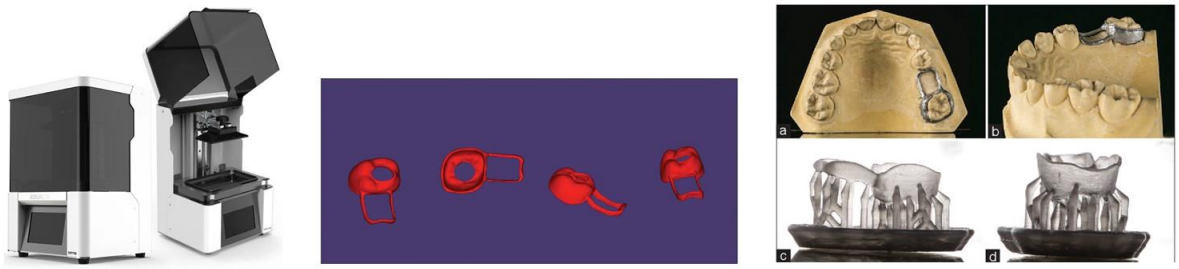
Challenges Faced in Pediatric Dental Practice

- Managing fearful and anxious child
- Managing uncooperative child
- Managing differently abled child
- Delivering tedious and lengthy procedures to the child
- Multiple dental visits which are inconvenient for children as well as their parents now a days in their busy schedule.
- Gag reflexes during dental procedures like impression making.

Something which makes the work easier and hassle free such that reduced chairside time, reduced multiple visits, reduces gag reflexes, removes fear and anxiety and which is harmless to children have a great role in pediatric dental practice. Hence the technology of 3D printing gains attention and relevance in the field of pediatric dental practice.

- **A) Fabrication of Space Maintainers:**

Bhaggyashri et al., 2019 reported the fabrication of band and loop space maintainer using 3D printing technology helped in decreasing human errors by automating the dental model manufacturing process with three-dimensional printing. The digital 3D model is saved in STL format and then sent to the 3D printing lab where the layer by layer design of an entire 3D object is formed. An impression was taken and cast was made and then scanned using a 3D digital dental scanner (Medit T500, Medit Corp., Seongbuk-gu, South Korea) followed by the designing of the band and loop. The printed SM was tried inside the patient's oral cavity and after confirming its adaptation, cementation with GIC was done [11]



(A) (B) (C)

(**PICTURE COURTESY** : Bhaggyashri et al, Maintenance of space by innovative three-dimensional-printed band and loop space maintainer)

Figure No 2: (A)**3D printing system** (courtesy: Ackuretta's Ecosystem), (B) Digital design of the band and loop space maintainer similar to the conventional, on the Dental CAD 2.2 Valletta computer software, (C) a and b) Metallic three-dimensional-printed space maintainer of titanium-based powdered metal material and (c and d) using a clear photopolymer resin

- **B) Fabrication of Custom Trays:**

Custom trays can be fabricated or 3D printed from computerised scans of impressions or models. Model printing which can be done directly from intraoral scan helps quick fabrication of prosthesis.

- **C) Fabrication of Fixed and Removable appliances:**

In fixed and removable prosthodontics, restorations could be designed using CAD software and 3D printers can be used for printing crowns, bridges, copings, abutments, etc. [5] This helps to avoid the unnecessary irritations due to gag reflexes, tedious lab procedures and long appointments. Kids and teens with gag reflexes and special needs can especially find difficult for making impressions for crowns, fillings and other dental restoration. Scanning and 3D printing treatment not only faster but friendly and more comfortable. [12]

- **D) Fabrication of Pediatric Crowns:**

Sangho Lee et al., 2016 had described fabrication of anterior short crowns for primary teeth. Four primary anterior crowns were required. The left maxillary central and lateral incisors were made with the help of CAD-CAM technology. Then this model was scanned with the help of digital scanner and a stent for strip crown was made for the right central and lateral incisors. Then the stent was tried and cemented with help of composite resin. [13]

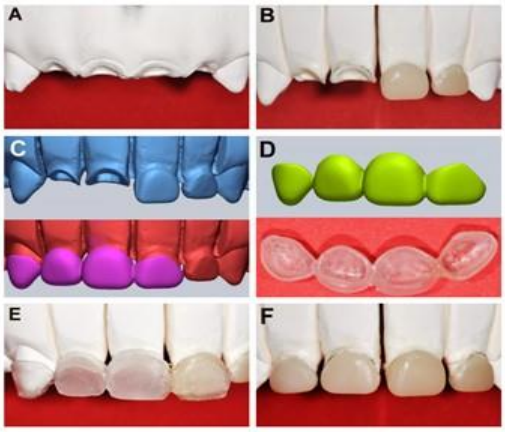


Figure 3: Fabrication of short post crowns for primary anterior teeth.

(PICTURE COURTESY: Sangho Lee et al; Prospect for 3D Printing Technology in Medical, Dental, and Pediatric Dental Field

A. Preparation of teeth for short post crown. B. Zirconia short post crown made with CAM/CAD system. C. 3D scanning model (upper) and stent for strip crown designed by 3D imaging software (lower). D. 3D stent image (upper) and printed material of stent (lower). E. Checking the stent on working model before placement of composite resin. F. Placement of short post crown, Left central and lateral primary incisors : Zirconia crowns fabricated by CAM/CAM system, Right central and lateral primary incisors : Resin crowns fabricated by 3D printing technology.

- **E) For Educational Purposes**

Marty et al. in the year 2019 developed 3D printed models with simulation of caries to perform pulpotomy and fabrication of stainless-steel crown. As the models are actually made from patients radiographs dental students can visualize the factual pathology in terms of size, extent and deepness of the decayed lesion and in addition it will provide morphological complexities and specific tooth variation. Therefore, it will make possible to alter the models, by the teacher, as per the educational objectives. [14]

- **F) In Pediatric Endodontic therapies:**

3D printing can be used are in pediatric endodontics for guided RCTs. This leads to reduce chairside time and multiple visits can be avoided.

- **G) In Sports Dentistry:**

In sports dentistry, 3D Printing can be used for the fabrication of occlusal guards. Due to this, the prosthesis can be delivered very fast and multiple visits of the patients is prevented.

- **H) In Cleft Lip and Palate Patients:**

3D printing can be used for impression making in the form of a digital scan so the trauma caused to such patients will be reduced. Also it is useful in making obturator.

- **I) In managing patients with special health care needs:**

3D printing will be a promising technology to be used in patients with special health care needs. It will ease the procedure of impression making in such patients. Also the delivery of prosthesis will be easier and hassle free. Multiple visits will be avoided and reduced chairside time which is beneficial in managing such patients can be done with the help of 3D printing.

The applications of 3d printing which is described in all other fields of dentistry are applicable in the field of paediatric dentistry too, which is summarized in figure 4.

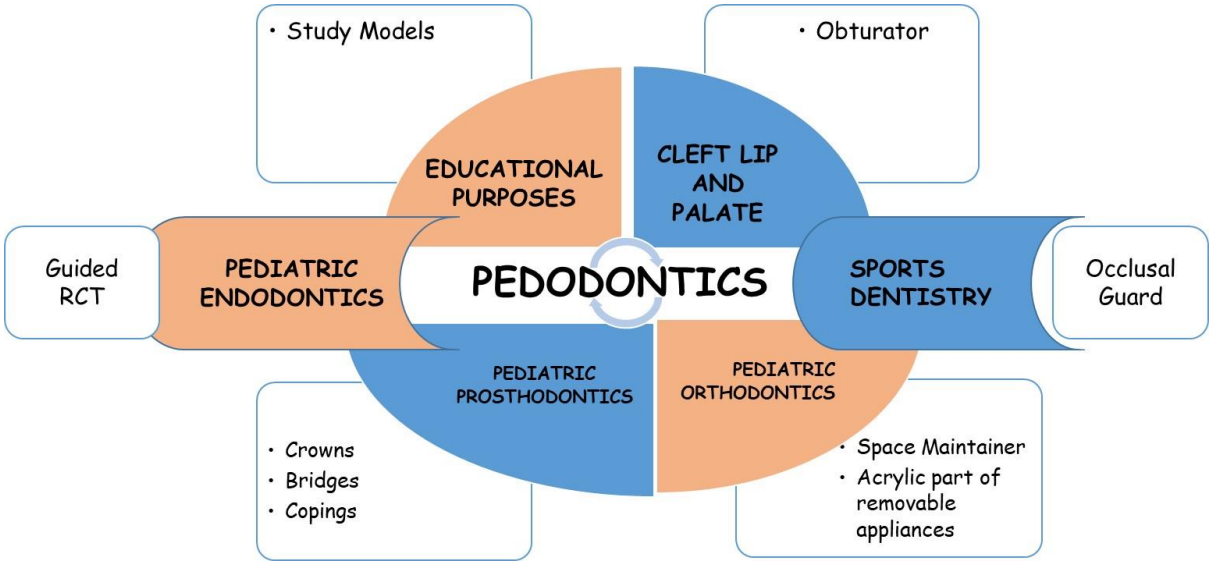


Figure 4: Applications of 3D Printing in Pediatric dentistry

APPLICATIONS IN OTHER FIELDS OF DENTISTRY:

Field	Application
Prosthodontics [1,3,5]	• Fabrication of custom trays. • Fabrication of resin frame works. • Printing of crowns, bridges, copings • Fabrication of provisional crown and bridge. • Fabrication of metal frame work of RPDs and its replication.
Implant dentistry [5,15]	• Helps in fabrication of complex geometry of dental implants, surgical guides or drill guides. • Prints bone tissue favouring the requirements of the patient which can act as a biomimetic scaffold in the mouth for bone cell enhancement, tissue growth and differentiation.

	• 3D printed bone implants can replace the deficient part using biocompatible materials like PEEK (polyetheretherketone). • 3D printing is capable of producing implants with bone-like morphology, in order to reduce the stress-induced on the bone. • Prefabricated dental implant surgical guides can be used for verifying or guiding the proper location, angulation and rotational positioning of the implant prior to the placement in order to provide better aesthetics and functionally stable prosthesis.
Surgery [4]	• Current application of 3D printing in oral maxilla-facial surgery includes trauma surgery, pathology induced defects, tissue engineering, complex temporomandibular joint reconstruction and correction of complicated facial asymmetry. • Manufacturing of customized occlusal splints save time required for laboratory work, are more precise and reduce manual errors in fabrication • Anatomical models can be constructed which can be used as a new approach for surgical treatment planning and simulation. • To produce customised reconstruction plates and morphological reconstruction of bony defect area for cases of fractures and reconstruction surgery. • To design and construct a customised non-absorbable barrier of titanium mesh.
Endodontics and restorative dentistry [4,16]	• Used for guided access cavity, guide root canal treatment and for endo guided-surgical procedures. • For apical root canal lesions and calcified root canals endodontic access guided 3D printed stents are used. • Access guide stent provides proper direction towards the obliterated root canal during conventional root canal treatment. • Can produce temporary crowns with greater accuracy than the conventional methods.
Periodontics[3,17]	• 3D printed guides are commonly used for aesthetic gingival reconstruction. • Patient specific surgical guides are utilized for gingivectomy and smile designing which enables a precise and customized approach. • 3D scaffolding technologies can be used in combination with either biologic or cell therapies to create bio-active scaffolding systems for tissue repair.
In orthodontics [14,18]	• Manufacturing of orthodontic braces. • Brackets are custom built which are tailored to individual tooth surfaces and they can be accurately positioned using 3D printed guides. • 3D printed orthodontic aligner reduces clinical visits and chair side appointments. • Various removable appliances like Hawley retainer, splints, functional appliances, arch expansion appliances, clear aligners, retainers, arch wires, brackets, set up models which will make lingual orthodontics and mock surgeries fast and easy also study models.

Educational purposes [19]	• 3D printing is the very good tool for educational and training of students in oral surgery, endodontic and prosthodontics. This is achieved by using high end 3D printers that allow both hard and soft tissue replication in a single training jaw. • Offers great opportunities in the field of replicating orofacial anatomy and complex geometry with highest precision that can be used to train students and practitioners for performing various maxillofacial surgeries. • Intra oral scans of the patients are utilized to print 3d models that are customised real patient based models. These customized models are used to train dentist in prosthodontics for veneer and crown preparation.
Orthognathic surgery [20]	• Fabrication of surgical wafers using orthodontic software package which are linked to 3D printing technology for dental model fabrication.
Maxillofacial prostheses[6]	• 3D printed implants are used for replacement and reconstruction of zygomatic bones, temporal bones including ear ossicles, calvarial bones and mandibles. • Also used in soft tissue reconstruction of head and neck. These are more suitable following a trauma or a tumour resection. • With the help of 3D implants cosmetic defects associated with these surgeries has been reduced significantly.

Table No 1: Applications in other fields of dentistry

CONCLUSION:

Dentistry can be revolutionized with the help of 3D printing technology. It has a high potential of serving as an educational tool. To provide the most technologically advanced dental treatment to the patients with high accuracy and least discomfort is the ultimate goal in dental practice. Innovations like 3D printing are useful in creating the most accurate models and provide extended learning opportunities to provide better care to the patients [4]. Even though 3D printing is becoming cost effective in the present but still the cost of running, materials used and maintenance of the machines are still areas of concern. The demand for well-trained operators, post processing, adherence to strict health and safety measures should be considered. [5] The advantages outweigh the disadvantages of 3D printing technology. Overall, 3D printing technology has an enormous potential to transform education, research and treatment care in dentistry. [4]

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