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3D Printing: The Next Frontier In Pediatric Digital Dentistry

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Abstract:
Three-dimensional (3D) printing has revolutionized dentistry, pediatric dentistry included. With nearly three decades of refinement in manufacturing, 3D printing, offers unprecedented precision, efficiency, and customization in various dental applications. This review gives a brief insight into an analysis of 3D printing technologies in dentistry, covering their applications, benefits and limitations, and highlighting their potential to transform treatment outcomes and patient care through customized dental models, appliances and surgical guides. Despite challenges such as high cost and size limitations, the benefits of rapid prototyping, minimized material waste and personalized care make 3D printing an increasingly valuable tool in pediatric dental practice. The future of this technology holds significant promise for further advancements and improved patient experiences

Key Word: *LASERS, CALCIUM SULPHATE, ELECTRONS, COMPUTER AIDED DESIGN, VACUUM, STEREOLITHOGRAPHY.*

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I. INTRODUCTION

The provision of dental care for pediatric patients frequently presents a considerable challenge for dental clinicians, as children often exhibit anxiety and fear, resulting in an uncooperative behaviour during treatment. To meet the needs and demands of these patients, 3D printing is revolutionizing pediatric dentistry by pioneering novel solutions to conventional treatment challenges. This technology facilitates the production of precise and customized dental appliances, reducing chair side time, dental visits while also improving treatment outcomes and patient comfort.

3D printing is a way of making objects by adding material in layers using a computer aided design (CAD) or computer aided manufacturing (CAM). It is also known as Rapid Prototyping (RP) or Additive Manufacturing (AM). Objects fabricated can have smoother surfaces due to layer-by-layer deposition process.

In recent years, there has been tremendous advancement in the use of 3D printing in medicine and dentistry. This technology has enabled customization and personalization of dental products based on individual patients' needs. Its role in pediatric dentistry is becoming pivotal as it offers an alternative to the intimidation of traditional manual techniques.

Process Of 3D Printing:

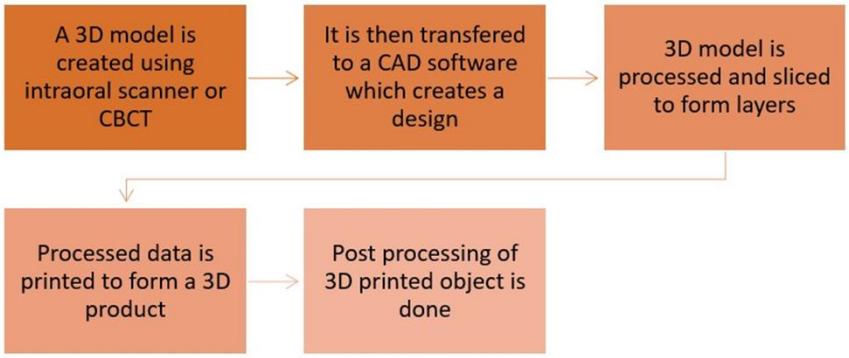

Figure 1: Depicts 3D printing process [1,2]

Materials Used In 3D Printing:

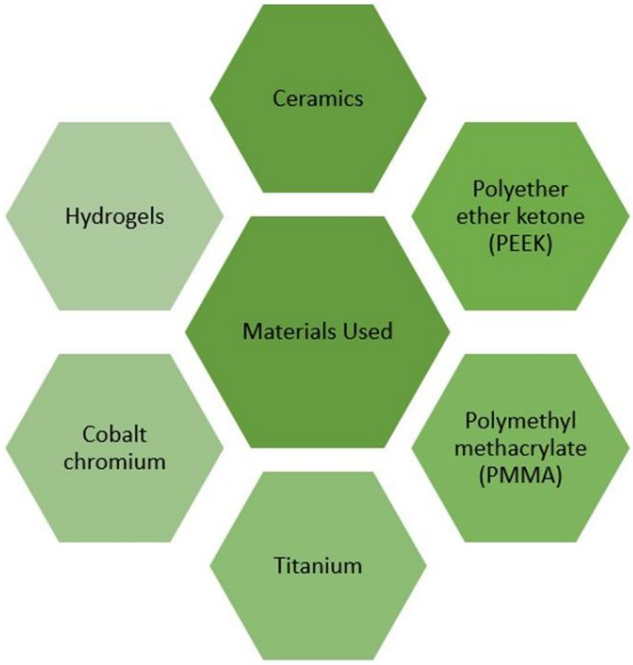

Figure 2: 3D printing materials[3]

Technologies In 3D Printing:

- *Stereolithography (SLA)* - SLA employs a laser to solidify liquid resin in a layer-by-layer process. A photosensitive resin is exposed to UV light which converts into a solid polymer. Layers are cured sequentially, binding to each other. Wiper blade recoats the surface after each layer this process starts from the bottom and builds upwards.[2]
- *Fused deposition modelling (FDM)* – It uses melted thermoplastic material to create objects. Thermoplastic material is melted and pushed out of a nozzle and is deposited in layers.[4]
- *Selective laser sintering (SLS)* – It is also known as Selective Laser Melting (SLM). It uses a laser to fuse together powdered material layer by layer. A powdered material is spread evenly as a layer using computer-directed roller. A scanning laser fuses the powder together. This process is repeated building up layers.[4]
- *Powder binder printer* – It uses modified inkjet head, pigmented liquid, plaster of Paris powder. Powder and liquid droplets are layered incrementally. Liquid droplets penetrate the powder, binding the particles together forming a uniform layer. The printer gradually builds up the powder bed, incrementally until the complete model is formed. [2,5]
- *Digital light processing (DLP)* – It is similar to SLA, only difference is that DLP uses a high-power LED or digital light projection whereas SLA uses a laser. DLP employs a digital micromirror device to generate a light mask, which irradiates the manufactured layers. [4]

- *Photopolymer jetting* – Print heads lay down layers of photopolymer material. Each layer is cured after deposition, solidifying the material. The process is repeated building up layers to form final product. A variety of materials can be utilized, including waxes, resins and silicone rubber.[2]
- *Electron beam melting (EBM)* – EBM utilizes a focused electron beam as its power source, differing from laser-based techniques. The process takes place within a controlled vacuum sealed environment. The electron beam liquifies metal powder in successive layers enabling the creation of complex geometries.[2]

Table 1 Below shows the advantages and disadvantages of 3D printing

ADVANTAGES [6]	DISADVANTAGES [7]
• Enables rapid prototyping, manufacturing objects within hours	• 3D printers' size limitations require large parts to be printed in sections
• It minimizes material waste	• It is expensive
• It offers increased precision	• Limited availability of suitable materials
• Reduces human error	• Parts printed in layers can separate under stress
• Reduces chair side time and laboratory work	
• It is less invasive	
• It can be easily stored and accessed	
• Used in advanced health care to create customized models, implants and prosthesis	
• Improve patient comfort	

Application In Pediatric Dentistry:

1] Autogenous transplantation of teeth:

Tooth transplantation is a treatment for missing or impacted teeth. To ensure success it is crucial to preserve the surrounding tissue of the donor tooth with minimal damage. 3D printing enables the creation of a customized recipient socket. A surgical replica of the tooth is created, enabling customized preparation of recipient site before the donor tooth is extracted. The donor tooth can be placed precisely in the new socket, minimizing damage to surrounding tissue. It produces sterile and biocompatible dental replicas for use during surgery.[3]

2] Educational purpose:

3D printing creates realistic models of teeth, gums and oral structures for students to practice and learn. It helps dentists train for complex cases such as pediatric rehabilitation and plan treatments accurately. Empowers patient with knowledge about their oral health, motivating them to pursue necessary treatment accordingly. It also offers opportunities for hands-on training and practice.[8]

3] Surgical management:

Pediatric patients may require special care and consideration therefore, 3D printed models help surgeons plan and visualize complex surgeries. These models act as reference models and helps in performing mock surgeries. A primary problem faced during orthognathic surgery is autorotation of TMJ leading to instability of condyle. A Personalized Orthognathic Surgical Guide (POSG) is created using 3D printing which helps correct positioning of the condyle during surgery. This ensures high accuracy and better surgical compatibility. It also makes customized bone grafts for jaw defects.[1]

4] Designing of splint:

Splint helps keep injured teeth in their natural position by guiding teeth back into their correct position and repair surrounding tissues over time. A customized 3D splint is designed utilizing CT scan data and can be securely fixed in place using cement or curing methods[1]

5] Aesthetic restoration and endodontics:

3D printed templates facilitate the accurate replication of injured teeth, including their architecture, colour and translucency. Customized 3D printed guides enable precise navigation during root canal treatment and apicectomy. 3D printed guides provide optimal direction for root canal treatment ensuring accurate access to the obliterated canal. Custom designed guides minimize the risk of iatrogenic root damage during endodontic procedures. Also helps in treatment of microdontia and restoration of anterior teeth using composite injection method. [8,9]

6] Orthodontics:

3D printing has transformed the field of orthodontics helping patients visualize facial changes. They can virtually see 3D models of corrected arches. They receive customized orthodontic appliances such as space

maintainers, myofunctional appliances with precise fit, resulting in enhanced patient comfort, improved adherence to treatment, and superior outcomes. It minimizes human error. It also enables the creation of customized appliances for sleep apnea and feeding aids for infants with cleft lip and palate, such as obturators and feeding plates, improving feeding efficiency. Advantage is that, they have smoother surfaces that reduce the risk of irritation and discomfort, quick production, light weight and lower risk of gingival trauma. [1,4]

7] Prosthodontics:

3D printing creates aesthetic dental crowns for children, offering a faster, more comfortable and accurate solution. Stainless steel crowns are commonly used, but zirconia crowns offer better aesthetics and clinical performance. However, zirconia crowns are more expensive and prone to wear. Benefits of 3D printed crowns is that it reduces chairside time and eliminates tedious lab procedures and are more comfortable for patients, especially those with gag reflexes or special needs. It is also used to fabricate bridges, abutments, copings, custom trays.[6]

8] Pediatric rehabilitation;

Pediatric rehabilitation through traditional methods can be time consuming traumatic and cumbersome. Traditional methods require multiple appointments and procedures and needs specialized expertise to produce good maxillofacial prosthesis. Whereas, 3D printing creates maxillofacial prosthesis directly from digital data workflow reducing number of appointments and procedures, producing more precise and aesthetically pleasing prosthesis than conventional prosthesis. It enhances overall functionality and patient satisfaction. [2]

9] Maxillofacial prosthesis and reconstruction of fractured mandible:

3D printed implants are used in replacement or reconstruction of facial bones – zygomatic, temporal, calvaria and mandible. It also helps in reconstruction of head and neck soft tissues particularly post trauma or a tumour resection. Customized 3D implants minimize cosmetic defects associated with surgeries. 3D printed templates simplify bone plate contouring in complex mandibular fractures. It produces customized bone tissue and biomimetic scaffolds which facilitate bone cell growth, differentiation and tissue development.[7]

10] Topical fluoride application

Traditional fluoride application face challenges in maintaining effective concentrations in the oral cavity due to factors like saliva and food, washing away the fluoride and reducing its efficiency. To overcome this, 3D printing technology customizes fluoride formulations, creating thin film coatings which is attached to the tooth surfaces, providing prolonged fluoride release and effectiveness, enhancing oral health outcomes.[8]

Pictures Of Cases Treated In Our Department:

A tooth post root canal treatment with compromised occlusal height. An Endo crown was placed for its minimal invasiveness and as alternative to a crown that would further reduce the crown dimensions. Figure 1, 2 and 3 depict the clinical scenario.

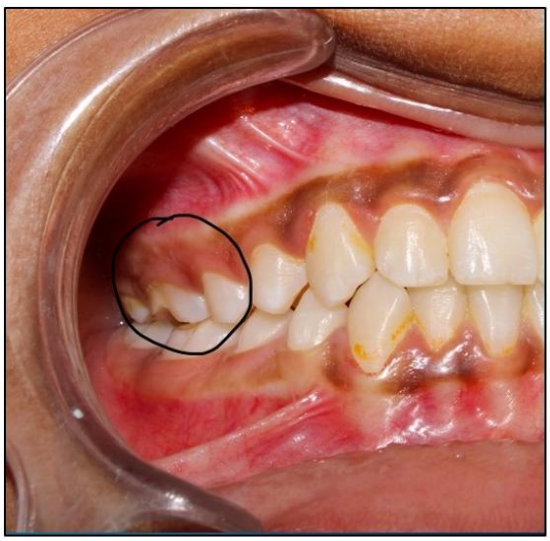

Fig. 3: Reduced occlusal height with 16

Fig. 4: Pre-operative view of post endodontic treatment

Fig. 5: Post-operative view after 3D printing of Endo Crown

Pic courtesy: Dr. Anand Tavarageri

Management Of Pediatric Mandibular Fracture

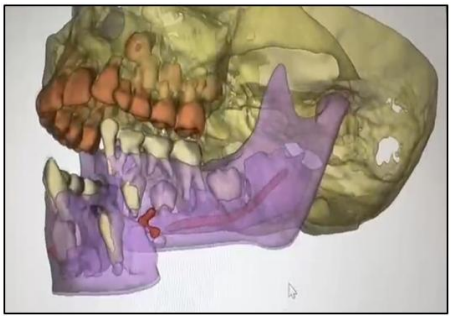

Fig 6: CBCT imaging of fractured parasymphysis

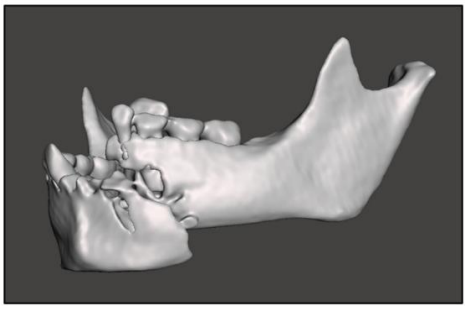

Fig 7: 3D reconstruction of mandible

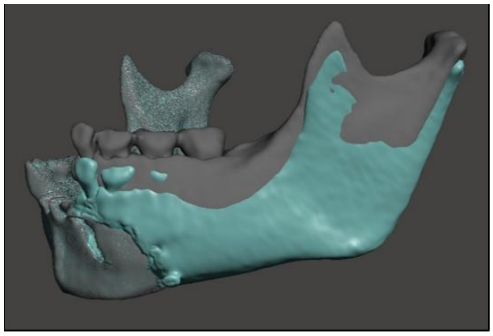

Fig 8: CAD aided fracture reduction and cap splint designing

Fig 9: 3D printed cap splint

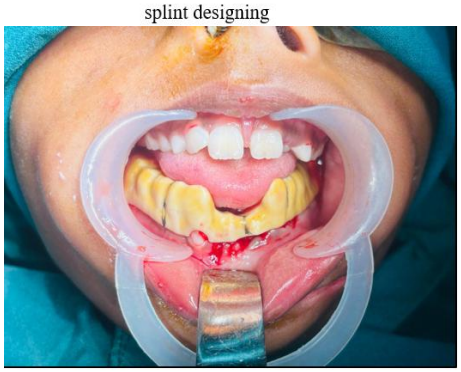

Fig 10: 3D printed cap splint attached with circum mandibular wiring

Fig 11: Post-operative view

Pic courtesy: Dr. Anand Tavarageri, Dr. Adrij Dutta

II. Conclusion:

Dentistry is undergoing a transformative shift driven by 3D imaging, CAD technologies and 3D printing. As pediatric dentists, we can harness 3D printing to address complex patient needs enhancing care and transforming young smiles. Its benefits extend to children with behavioural challenges or special needs, simplifying treatment planning. The intersection of technology and dentistry is revolutionizing oral healthcare. 3D printing is transforming dentistry, one smile at a time.

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