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3D Printing In Conservative Dentistry and Endodontics

Research Article

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Abstract

It is necessary to obtain high precision and accuracy for almost all the work carried out intraorally to achieve superior function and esthetics. This is made possible by making use of the latest technologies like 3D printing and CAD CAM. 3D printing is a process in which a 3 dimensional object is made from a digital image. This technology has been used for making prototypes for several years. Here, digital image is obtained by scanning the required object. The digital image is then sliced in to numerous transverse sections which are then reproduced using a software unlike CAD CAM technology where a block of the material is sliced to obtain a three dimensional printed pattern. This technique of digitalization helps to complete task faster, easier, in an accurate manner and permits customization.
This review article gives an overview of the wide applications of 3D printing in conservative dentistry and endodontics.

Keywords: 3D Printing; Rapid Prototyping; Additive Manufacturing; Selective Laser Sintering; Stereolithography; Fused Deposition Modelling; Laminated Object Manufacturing.

Introduction

Prototype production can broadly be classified into additive manufacturing technique and subtractive manufacturing technique. 3D printing which is an additive manufacturing technique was introduced by Charles Hull. It is also known by the names rapid prototyping, layered manufacturing or solid free form fabrication [1]. The principle involved in this process is obtaining a digital image of the scanned object and creating a series of cross sectional slices (0.01mm thick or less in most cases) using a software [2]. This digital data is then sent to the 3D printer which builds object layer by layer, joins, bonds, sinters or polymerizes the layers sequentially to create a 3D printed pattern. This helps in printing patterns with any complex geometries [3]. 3D printing can be opted over CAD CAM technology for the following reasons:

CAD CAM involves wastage of raw material as the unused portions of the blocks are discarded unlike 3D printing where material is laid down in layers without wastage.

The milling tools used in CAD CAM undergo abrasion and wear with reduced cycling time unlike 3D printing.

Brittle materials like ceramics show microcracks due to machining. Hence, it is better to 3D print ceramics.

In dentistry, 3D printing has a wide range of applications. It is used for medical modelling to simulate anatomical models, drilling and cutting guides for implant placements, for crown copings and partial denture frame works, fabricating dental models for restorative dentistry, in digital orthodontics and for designing instruments.

We have numerous highly cited publications on well designed

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clinical trials and lab studies [4, 19]. This has provided the right platforms for us to pursue the current review. This article gives us an overview of the various 3D printing technologies used and the numerous applications of this technology in the field of conservative dentistry and endodontics.

Techniques

Commonly followed 3D printing techniques are [20]:

Stereolithography.
Selective laser sintering.
Fused deposition modelling.
Laminated layer manufacturing.

Applications Of 3D Printing In Conservative Dentistry and Endodontics

Guided Endodontic Access:

Pulp obliteration is a condition occurring as a result of irritation or aging where canals will be located more apically than usual [21]. During root canal treatment of such canals, the chances of perforations are high during locating and negotiating them [22].

For obliterated pulp canals, access guides can be printed and utilized to target burs to canal spaces without causing perforations [22, 23] (Figure 1).The apical third of the calcified canals can be accurately located using these guides, there by avoiding procedural accidents [24]. This technique involves making digital impressions and CBCT scans. Then, CAD software is used to merge digital impression files with CBCT DICOM data to form a STL file which depicts the architecture of the tooth along with the obliterated root canal. This data helps in printing access guides that are used to target the burs into the obliterated root canals without perforation [25]. Hence access guides helps in treatment of malpositioned teeth, teeth with obliterated root canals, altered anatomies and those with extensive restorations [26].

Autotransplantation:

Autotransplantation involves the transplantation of an autologous tooth. The advantage of autotransplantation is that, it is a cost effective alternative to restorative rehabilitation or orthodontic treatment for space management [27]. The conventional method involved the use of donor tooth as a template to prepare the site of transplantation. During this, the donor tooth was fitted into the alveolar bone multiple times in order to prepare the bone to receive the tooth. This results in increased extraoral time and damage to the periodontal cells [28]. The present technique uses computer aided rapid prototyping helps print a replica of the donor tooth which would help to precontour the alveolar bone prior to transplantation (Figure 2). While transplanting an immature tooth care has to be taken to make an allowance for the additional length of the donor tooth corresponding to Hertwig's epithelial root sheath [29]. This technique of guided autotransplantation makes the procedure more predictable with reduced extraoral time of the donor tooth, there by preserving the vitality of the periodontal cells, reducing the time required for the procedure and improving the success rate of the procedure [30, 32].

Printed Model Teeth for Conservative and Endodontic Bench Exercises and as Presurgical Models Prior to Endodontic Surgery:

Training in dental colleges will include exercises on extracted teeth or resin blocks prior to entering into clinics. 3D printing can be used to design teeth with desirable properties for preclinical bench exercises (Figure 3). These teeth can be printed from any selected micro CT scan. This helps better understanding of the principles and techniques of cavity preparation and endodontics by visualizing and improvising the skills making learning easier and interesting [33, 35].

For complex endodontic surgical cases, it becomes challenging to interpret the radio graphic findings in an invivo surgical field. In such cases, a 3D printed presurgical model is prepared which enables the dentist to touch, feel and visualize the surgery field in a 3 dimensional sense as if it was in vivo [36].

Surgical Guides and Stents:

Endodontic microsurgery involves osteotomy and root end resection to eliminate periapical pathology. Errors in osteotomy are possible due to improper orientation, angulation and depth of preparation. This is overcome by using magnification and better armamentarium [37]. In posterior molar areas, access becomes difficult due to close approximation of anatomical structures. In such cases, 3D printed surgical guides can be used to gain access

Figure 1. Picture courtesy-Van der Meer et al 2016. Guided endodontic access a) Planning of a directional guide using a cylinder that guides the direction of the drill. b) Final directional guide design for rapid prototyping. c) Directional guide places and the bur used to locate the root canal system. d) Working length radiograph taken after locating the canal system using 3D printed guide.

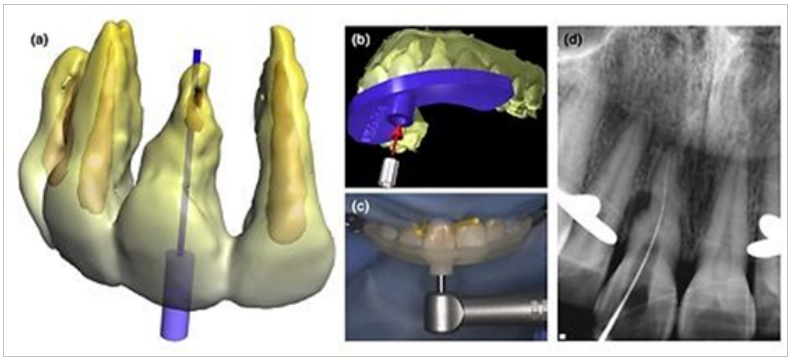
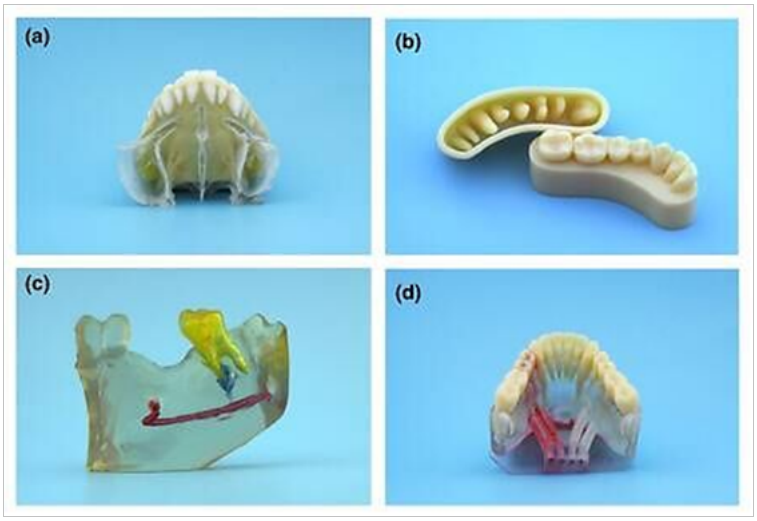


Figure 2. Picture courtesy- J. Anderson et al 2018. Autotransplantation of #21: a) Preoperative presentation b)3D printed model used to assess dimensions and orientation of the tooth to be transplanted. c) #21 prepared for provisional restoration prior to extraction and scanned immediately. d) 3D printed model of #21 prepared which was also used to prepare the transpaltation site of #9. e) #21 used to replace non restorable #9 f)Immediate provisional restoration is planned immediately. g) Immediate provisional restoration done after transplantation. h) #21 is in transplanted site i) Interim restoration given for #9

Figure 3. Picture courtesy: J. Anderson et al 2018. a) 3D printed model used for pre surgical treatment planning b) Study models c) Models mimicking large scale periapical lesions adjacent to mandibular canal d) Model displaying regenerative endodontics for teeth with open apices and ports that mimic apical hemorrhage.



to the periapical area with targeted osteotomy and precise apicectomy preventing the risk of encroaching over the important anatomical structures [38, 39]

Use of surgical guides and stents will reduce additional radio graphic exposures for the patients, minimizes the time required for the procedure and reduces iatrogenic injuries [40, 41].

Designing of Soft Tissue Retractor:

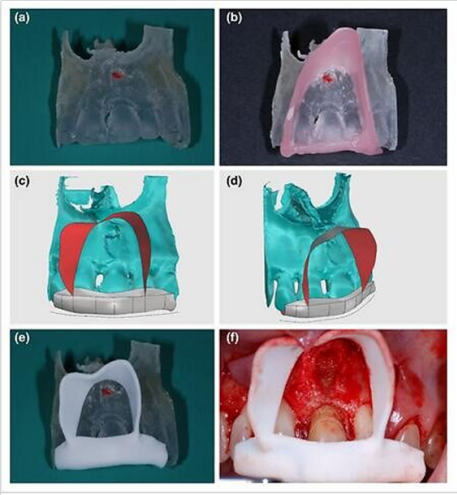
Success of surgical process depends upon the access to the surgical site and soft tissue management. Many endodontic surgical failures have resulted due to poor visibility of the surgical site and inability to .Good handling of soft tissues improve healing and maintains esthetics in the surgical site [42]. CBCT can be used to scan the area of surgery. Red wax is used as a reference point indicating the location of the lesion. Dental wax is used to prepare a mock model. This is 3D printed and tried on the mould to check for fit and access. This helps in improving access soft tissue retraction during periapical surgery, thereby improving treatment outcomes [43] (Figure 4).

Digital Smile Designing:

Designing an esthetic smile is a complex process and requires a combines approach of a periodontist, restorative dentist and a prosthodontist to achieve successful results [44]. With the help of 3D printing technology, the digital scan of the patient is taken in the first visit and in the next appointment the treatment plan is formulated.

In case of veneers, after preparing the tooth, a digital scan is made and the model teeth decided for the patient during treatment planning is superimposed over the scanned design. This digital file is sent to the dental laboratory which mills and finishes the veneers and prepares them for bonding in the patient's mouth.

Figure 4. Picture courtesy- S. Patel et al 2016.Soft tissue retractor a) Surface area of the surgical site was fabricated from CBCT DICOM data and the location of the lesion was marked with red point which served as a reference point for designing the retractor. b) A mock up retractor was designed with wax on the model and passed on to the technician for 3D printing c ,d) CAD software was used to design and modify the retractor against the 3D model used. e) The retractor was tried on the model to check for its fit and access. f) Custom retractor being used for soft tissue management and access during periapical surgery.



3D Printed Guides for Tooth Preparation:

3D printed guides help in reducing the time required from planning the treatment to seating of restoration like crowns, veneers etc. In the first appointment, the treatment is planned and a digital impression is made. In the next appointment, the tooth is prepared and the restoration is placed.

The digital impression that is obtained by scanning is transferred to a software that designs a preparation for the tooth to seat a restoration. The reduction guides are created to simulate the designed preparation. These guides are placed over the teeth to be prepared and a handpiece is placed into them helping the dentist to prepare the tooth in all planes. This prevents over preparation of the tooth. The final restoration is then placed over the prepared tooth.

Templates for Esthetic Restorative Cases:

For esthetic restorations (Class 3 and Class 4), intraoral scan is done to form a digital file. A software is used to design the restoration with contralateral tooth as the reference. Occlusal interferences are eliminated and the overjet, overbite are set right. This digitally restored tooth is presented before the patient for necessary corrections. Once this is done, the data is transferred to a software program where a template is designed which is converted into a STL format to be used by a 3D printer for printing the pattern. This pattern is then placed intraorally to verify the fit. This template is used to restore the missing portion of the tooth [45].

3D Printed Scaffolds for Regenerative Endodontics:

Scaffolds are three dimensionally designed biomaterials which provide correct positioning of the cells to promote cell interactions, permit transport of essential substances for growth and differentiation of cells thereby bringing about tissue regeneration.

Scaffolds can be natural or synthetic. Platelet rich plasma, platelet rich fibrin, chitosan, glycosaminoglycans, demineralised dentin matrix and silk are some of the natural scaffolds. Synthetic scaffolds comprises of polymers like polylactic acid(PLA), poly-l-lactic acid(PLLA), polyglycolic acid(PGA), polyepsiloncaprolactone(PCL).

Synthetic scaffolds are non toxic, helps in customizing mechanical properties, structure and manipulation of physical properties. 3D printing can be used to design polymer based scaffolds with customised geometries having numerous bioactive surfaces. these improve the environment for growth and differentiation of pulpal cells thereby helping in regenerative endodontics [46].

Metal Crowns for Restoring Endodontically Treated Teeth using DMLS:

DMLS is a 3D printing technology that uses lasers to microweld powdered metals into crowns, bridges and frameworks. Endodontically treated teeth show increased susceptibility to fracture on loading when compared to vital unrestored teeth [47, 48]. There are many options for restoration of endodontically treated teeth. When more than 50% of the crown structure is lost, the tooth has to be restored with a crown which provides cuspal coverage and strengthens the tooth.

3D printed crowns can be used to restore endodontically treated teeth. Use of this technology will reduce the chair time, increases production rate, quality control of copings, reduces labor and time to fabricate the patterns and lessens the finishing work of the copings and provides crowns with accurate fit [49]. The present 3D printers use direct metal laser sintering technique to directly print metal crowns for the scanned digital data skips the impression making process and can be used by the clinicians to visualise the preparations with the possibility to review and adjust them accordingly [50, 51]. This helps in fabrication of metal crowns with high density and excellent mechanical properties [52].

Conclusion

3D printing is a relatively new technology showing significant development in product development cycle with accurate fit of the product design and processing patterns that are highly resistant to changes. In endodontics, 3D printing helps in treatment planning by printing virtual anatomic models on which mock surgeries can be carried out. Studies are being conducted on using antimicrobial plastics to 3D print teeth and restorations which not only repalces the tooth or restores them but also reduces the microbial load intraorally thereby reducing caries. The digital data used for 3D printing helps in printing highly precise and accurate patterns and makes the procedure more predictive, less invasive with better treatment outcomes. It helps in improving the quality of the treatment and enhances patient satisfaction.

Declaration of interest:

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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