3D PRINTING..... A PARADIGM SHIFT IN ENDODONTICS

Dental Science

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ABSTRACT

The process of 3 Dimensional (3D) printing is used to create a 3D object with the help of a computer aided design (CAD) model, by successive addition of material layer by layer thus it is also known as additive manufacturing. During 1990's, the technique of 3D printing was only applied for the manufacture of aesthetic or functional prototypes and was suitably named as rapid prototyping. The following descriptive review presents with an overview about contemporary 3D printing technologies and their use in various specialties of dentistry and largely focusing on the applications of this technology in the endodontics.

KEYWORDS

3d printing, endodontic problems

INTRODUCTION

The main and important motivation for having endodontic treatment completed is likely to simply put an end to pain and discomfort that the patient experienced. Thus the 3D printing is modifying the medical as well as dental devices in terms of personalization and customization as it digitizes the entire manufacturing process.

The term 3D printing used to describe manufacturing approach which builds objects one layer at a time, and then adding multiple layers, forming object. Due to its additive manufacturing process, it is also known as "rapid prototyping".¹

3D printing adoption has significantly increases the success rate; improve the quality and precision of dental work.² Since, from last few years application of 3D printing for medical and dental has increased remarkably. The drive behind this advancement may be because of possibility of individualized products, savings on small scale productions, eased sharing and processing of patient image data.³

For the Success of endodontic treatment full understanding of internal tooth morphology including the root canal system is required on which endodontic procedures such as access opening, shaping and cleaning, and obturation of canal are based. With the advantage of acquiring 3D information, a variety of CT scans such as cone-beam computed tomographic (CBCT) imaging, peripheral quantitative CT imaging, and spiral CT imaging have been increasingly used in the management of endodontic problems. But, additional training is necessary to understand the 3D structures of internal root canal morphology and to interpret CT scans.

Now days, 3D scans using CT imaging helps in visualization of an object as well as for the generation of physical model. Rapid prototyping technology (also known as 3D printing) which is used for making physical model, hand over new possibilities for diagnosis, surgical planning, prosthesis designs in dentistry. However, according to some previous studies the use of physical tooth model limited to

reconstruction of the external teeth shape.⁴

Currently, 3D printing applications in endodontic literature highlighted the possible paradigm shift in the way challenging surgical and non surgical endodontic treatment. Thus, the aim of this article is to review the application of 3D printing in management of different endodontic problems.

History

3D printing started in 1980s by Charles Hull. He printed three dimensional objects in 1983.

He then created the first 3D printer based on the technique of stereolithography which was used in the field of architecture, aeronautics and telecommunications.²

1960s	Computer-aided design and manufacturing (CAD/CAM) applications emerged
1970s	CAD/ CAM first employed by large aerospace and automotive companies
Duret & Preston (1991)	demonstrated first dental application of CAD/CAM for fabrication of fixed restorations ⁵

Methods for printing 3D models:

Following common technical type classifications can be adopted for dental application:

1. Stereolithography apparatus (SLA): Earliest and most commonly used in dentistry.⁶ Invented by Charles Hull.² It directs the UV laser onto the surface of vat of photosensitive resin. During a sequential curing process layers bind together to form a solid mass, beginning from the bottom of the object and building upward.
2. Fused Deposition Modeling (FDM): In this, layers of molten material deposited from filamentous nozzle, then solidify within 0.1 s.
3. Multijet Printing (MJP): In this jetting of photopolymer material in

ultra-thin layers and curing of each layer after deposition onto build tray.

4. Photopolymer Jetting (PPJ): Same as in MJP. There is difference only in their support structures and post-processing requirements

5. Colorjet Printing (CJP): It uses a print head disperses binder onto layers of powder; the build platform lowers with each subsequent layer.

There is extensive documentation of dental applications of CJP, PPJ and MJP.

6. Digital Light Processing (DLP): Consists of projector which exposes vat of photosensitive resin to a two-dimensional image after that printing occurs sequentially in layers as the supporting platform is manipulated to incrementally produce the object.⁶

7. Selective laser sintering (SLS)/ selective laser melting (SLM):² It uses computer-directed laser and roller that distribute the layers of powdered material on the top of preceding layer; a solid object takes shape as each new layer is sintered (SLS) or melted (SLM).⁶

Processing of 3D objects

Steps from image acquisition to 3D rapid prototype models are as follows: Image acquisition, Image post-processing and 3D printing.

1. Image acquisition

This step is very crucial as it decides the quality of object because it depends on data quality. Ultra-high spatial resolutions (400–600 microns) are now available for image acquisition. Various imaging modalities like MDCT and MRI can be used for data. MDCT is widely used for rapid prototyping because its image post-processing is less complex. Several other non-invasive imaging modalities can also be used like Cone Beam Computed Tomography (CBCT), Positron Emission Tomography (PET), Single Photon Emission Computed Tomography (SPECT) and Ultrasonography (US). The acquired data is saved in the DICOM format (Digital Imaging and Communications in Medicine).

2. Image post-processing

The 3D post-processing tools consisting of

- a. segmentation tools (based on simple region growing)
- b. Visualization tools (surface/volume rendering, maximal/minimal intensity projection and multiplanar reformation).

These tools are commonly used for vascular surgery, orthopedic surgery, and pediatric surgery.

3. 3D printing/ rapid prototyping

It is a technique for generating 3D haptic physical model using 3D CAD data sets.

The principle behind this technique is to use 3D computer models for the reconstruction of a 3D physical model by the addition of material layers. The machine first reads in data from a CAD drawing, afterwards lays down successive layers of liquid, powder, or the sheet material. This way builds up the model from a series of cross sections; this process is known as additive fabrication. The advantages of additive fabrication process are its capacity to create any complex shape or geometric feature, produce models in few hours (contemporary methods can take from several hours to days).⁷

Application of 3D printing in Endodontics

1. Preclinical Training

Help the student discover and improve clinical skills via instrumentation with printed teeth in contrast to the extracted teeth used for learning purposes. Due to the limited availability of the extracted teeth, copies of multiple model tooth can be printed from selected micro CT scan for use. Moreover, these 3D printed models help to recreate pathological conditions like they can mimic pulp stones, internal and external root resorptive defects, dens-in-dente etc.

2. Assist Endodontic Treatment of Atypical Anterior Tooth

According to some previous studies, where physical tooth model made to guide the treatment procedure. A translucent tooth model was built which carry information about the internal root canal structure. For obtaining accurate working path to root canal a customized guide jig was fabricated. Complete healing without any clinical signs and

symptoms was reported on follow up visit after few months. Therefore, fabrication of such 3D models help to analyze the anomalous defects better.

3. Guided Endodontics

2 types of guided endodontics are there:

a. Guided surgical endodontics

Used for surgical endodontics for determining the osteotomy site by positioning the guide sleeve cortical plate and level of root resection in complex cases.

During osteotomy depth calibrated drills or piezoelectric instruments must maintain parallelism with the guide sleeve, thereby limiting its size to 4 mm.

According to Strbac et al. the potential advantages of guided surgical endodontics include shortened operation time, improved accuracy and reduced post-operative discomfort. As surgical endodontics is not frequently indicated and performed, there is a need to encourage skill acquisition, and facilitate management of complicated cases using guided surgical endodontics.

b. Guided non-surgical endodontics

It can be used for canal location, especially when there is risk for procedural errors like root perforation etc.⁸ For guided access cavity preparation, 3D printed templates can be used, especially when the clinicians faced with challenging canal morphologies. A 3D guided access could pave the way to minimally invasive endodontic access stent (digitally designed to fit each particular tooth).⁹

According to Thomas Connert et al., Microguided endodontics gives accurate and fast technique for the preparation of apically extended access cavities in teeth with narrow roots.¹⁰

In cases of Pulp canal obliteration produces root canals must be located in more apical portions because of progressively narrowing of roots due to age related apposition of dentine, caries, systemic disease and conditions or trauma. Risk of perforation due to pulp canal obliteration is mitigated by measures that produce a true path of canal access and instrumentation.⁶

Teeth with multiple orifices or root canal systems in dens invaginatus: in such cases directional guides should be fabricated individually for every canal orifice. 3D printed directional guides reduce chair side operating time, reduce excessive loss of tooth structure risk of perforation should be avoided. This procedure is also safe, cost effective.⁷

Mena-alvarez et al.,(2017), concluded that CBCT was a useful diagnostic tool for detecting the internal anatomy of tooth with anatomic malformations and virtual osseointegrated implant planning software was an effective method for planning the root canal treatment and for designing stereolithographed splints which helps to create a guided and conservative access cavity on teeth.¹¹

Y. Yahata et al.(2017), found that incisal-shifted access was useful for maintaining the apical configuration that uses 3D printed tooth models instrumented by K-file.¹²

Zehnder et al. (2015), evaluated accuracy of a novel method for gaining access to root canals by utilizing 3D printed templates. Their study showed that deviations of planned and prepared access cavities were low.¹³

4. Effective Tool in Tooth Autotransplantation Procedures

For tooth transplantation computer aided rapid prototyping works by fabrication of a duplicate form of the donor tooth (obtained prior to the extraction) with a 3D image with real dimensions of the donor tooth from Computed Tomography high speed scan.

This help in reducing the extra oral time during the surgical procedure, maintains healthy periodontal ligament cells in the donor tooth for successful tooth transplantation.⁹

Verweij et al.(2017), discussed various advantages of 3D autotransplantation such as:

a. Neo-alveolus preparation with a 3D-printed replica of the donor tooth: reduces the extra-alveolar time of the donor tooth.

b. Multiple fitting trials for donor tooth placement can be avoided because the size and shape of the neoalveolus are accurately replicated in the 3D model.

c. Helps to determine the placement, location, and angulation of the transplant with the replica without damaging the transplant.¹⁴

Strbac et.al.(2016), presented a innovative technique which offers fully implemented digital work flow for pretreatment planning and guided osteotomy during autotransplantation. It utilizes superimposition of Digital Imaging and Communications in Medicine files and 3D data sets of the jaws in order to predesign 3D printed templates with the aid of a fully digital workflow.¹⁵

5. As an Effective Tool in Dental Pulp Regeneration

To replace the pulp tissue we can utilize the 3D cell printing technique. For this process an ink jet device can be used to recreate the structure of pulp tissue. This helps in precisely positioning of the cells. For mimicking the pulp of natural tooth a systematic positioning of cells is required that includes positioning of the odontoblastic cells at the periphery and fibroblasts within the core with a supportive network of vascular and neural cells.⁹

6. As an effective tool in assessing root canal anatomy and its variation

Lee et al. (2006) studied the anatomy of 3 distal roots of mandibular first molar with 3D digital reconstruction and computer-aided rapid prototyping (CARP) model and demonstrated that CARP was a useful imaging technology to document unusual root anatomy in clinical dentistry.¹⁶

7. As an effective tool in assessing root resorption

Kim et al. (2003) studied the application of computed tomography (CT) and a rapid prototyping model in an effort to produce better visualization of the extracanal invasive resorption. They found that CT was very useful in diagnosing the exact size and location of resorption. In the serial cross-sectional view helpful in localization of resorption area.¹⁷

8. As an effective tool for periapical surgeries

Primary aim of Periapical is to treat endodontic pathosis unresolved with conventional root canal therapy and the adequate surgical access is necessary to visualize, instrument, and seal the apex. In the success of periapical surgeries the main hurdles are anatomical landmarks like inferior alveolar nerve, mental foramen, adjacent root tips, maxillary sinus etc. other difficulties are visualization requirements, root end preparation depth, and equipment size (ultrasound, surgical mirror, etc.), require complex presurgical planning to ensure adequate access. Pinsky HM et al. (2007), introduced the application of computer-generated surgical guides for periapical surgery. Their results showed that the apex was more consistently localized utilizing computer guidance. This may be partly due to the CT measurements.¹⁸

Aldowaisan (2016) utilizes CAD software to design a soft tissue retractor which was used during the patient's surgery. A custom retractor fabricated using a 3D printer. This custom-made retractor enhances the visualisation and soft tissue handling during the patient's surgery.¹⁹

9. As an effective tool for endodontic retreatment

Sanchez et al, (2020) Studied the use of 3D printed guide for negotiating the calcified canal during endodontic retreatment. They fabricate 3D printed guide according to CBCT images and intraoral STL files which helps to locate the unobdured root canal.²⁰

Advantages

3D printing minimizes high wastage which is the main drawback of Conventional subtractive manufacturing techniques like milling.

It is highly efficient, passive, flexible and utilizes superior material. This makes it distinct from other techniques.

Along with this, it saves the time, less technique sensitive and many models can be prepared using this technique.

Disadvantages

Its main drawback is its high cost

The staircase effect (created by layered deposition), inconsistent reproduction and requirement of support materials difficult to remove

post processing. Requirement of trained person and there is no gold standard and no ethical and legal clearance as of now are the other limitations.²

CONCLUSION

With growing advancements in 3D techniques like imaging, printing and planning, improves the success rate of treatment outcomes and also improves the patient comfort. Management of Endodontic problems can be very challenging. By utilizing 3D technologies the treatment of compromised cases can be performed more accurately. In addition, when using the developed tool, its use may reduce the treatment time for the clinician meanwhile increasing the predictability and success of the treatment.

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