ORIGINAL RESEARCH PAPER

Endodontics

APPLICATIONS OF 3D PRINTING IN ENDODONTICS

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ABSTRACT

Thanks to technology, it is now possible to print three-dimensional (3D) solid objects from a digital file. Additive manufacturing has found several applications in dentistry. In endodontics, it can be of aid in fabricating indirect restorations, guided access with pulp canal obliteration, auto-transplantation, regenerative therapy, study models, custom trays etc. Although it is still in its early phase of development, it holds the potential to transform our clinical practice entirely.

"We pay attention to the things that violate our expectations of the world."

As futuristic as it may sound to someone who has not witnessed it yet, 3D PRINTING is no longer just a concept or a theory. It is an advancing technology that has developed strikingly over the past decade.

Background

In 1983, Charles Hull printed the first 3D object using stereolithography. Francois Duret in 1970s introduced digital dentistry which was not easily welcomed and took its time to get accepted into the current practices. 3D printing was first used as dental implants and custom prosthetics in the 1990s. As recently as 2012, there was a 3D printed jaw by a manufacturing company in Holland. Today 3D printing has changed the landscape of how we see and do things.

How Does 3d Printing Work?

3D printing is part of a process known as ADDITIVE MANUFACTURING where an object is created by adding material layer by layer. The entire process is quite straightforward and can be narrowed down to 3 basic steps-

1. Acquisition of digital data using a scanner.
2. Data processing & design using a software application.
3. Printing the 3D product layer by layer.

Different mechanisms can be used to create and print 3D objects. These include stereolithography apparatus (SLA), fused deposition modelling (FDM), MultiJet printing (MJP), PolyJet printing, ColorJet printing (CJP), digital light processing (DLP) and selective laser sintering (SLS) also known as selective laser melting (SLM).

Stereolithography is the most common one. Here, resin polymer is added in increments and cured by UV light.

Applications

3D printing is gaining rapid potential in all dental fields. Endodontics has not been left untouched by its magic either. Better diagnosis, possibility of unlimited customization with faster and more accurate results are few of the many benefits of this technology.

Fabrication of Restorations

Printing tooth fillings with 3-D technology may be a novel way for restoring decayed teeth with a potential to reduce treatment costs and technique-sensitivity of the placement of restorative material compared to conventional indirect tooth restorations. Restorations can be produced a lot faster through rapid prototyping than those created by laboratory technicians.

The process involves preparing the tooth for an inlay/onlay restoration, digital image of the prepared cavity can be acquired and 3D restoration designed followed by printing the restoration with a proper material and finally cementation of the 3D printed filling in the cavity using adhesive systems.

3d Printed Models and Custom Trays

In patients with severe gag reflex, TMJ disorders, reduced mouth opening or any oral defect, obtaining accurate impressions can be a task. In such cases, 3D scanners can be a good alternative tool. 3D printed models can be made from the scans, which help in fabrication of different types of prostheses for such patients. This also eliminates human error and produces more accurate results.

3D printed custom trays can also be used to reduce errors and for better fit, enhancing the overall quality of the final impression.

Guided Endodontic Access

Calcified canals often carry some risk of perforation while attempting canal location and negotiation. The risk of perforation and other iatrogenic errors can be reduced manifold with the use of measures that ensure a true path of canal access and instrumentation. For this, 3D access guides can be printed using digital impressions and CBCT data. These guides help to target burs to elusive canal spaces without perforation. Investigations suggest that designed targeted access guides may be more efficient and safer for the treatment of teeth with pulp canal obliteration, extensive restoration, or malposition.

Surgical Endodontics

Sometimes, it can be difficult to identify an osteotomy site or the correct level of root resection due to proximity of anatomical structures, root apex orientation, thickness of cortical plates or tooth position. To overcome such situations, 3D printed guides based on the principles of guided implant surgery can be used.

The guide sleeve contains a prefabricated customized cylinder, made using CAD/CAM devices. The guide positioned over the cortical bone helps to determine the exact osteotomy site. During the operative procedure, depth calibrated drills and piezoelectric instruments maintain parallelism with the guide sleeve while performing the osteotomy ensuring a more predictable, less invasive, and safer outcome.

Soft Tissue Retraction in Microsurgery

Adequate and atraumatic soft tissue handling plays a key role in the aesthetic outcome of endodontic surgery, also increases the likelihood of successful healing. Better access

and soft tissue handling also provides enhanced visibility and ultimately improves the overall efficiency of the treatment.

Patel S, et al in 2016 published a case report introducing a novel method for soft tissue retraction during periapical surgery of a maxillary central incisor using 3D technology. After raising a full thickness mucoperiosteal flap with distal releasing incisions, the autoclaved custom retractor clipped onto the incisal edges of the teeth and was used to hold the flap into place and keep it away from the operating area. Sintered nylon was selected as the material of choice, as it is robust, flexible, and autoclavable, but other options might include titanium, stainless steel, and other plastic materials.

Fabrication of such retractors provide surgeons better vision and more stable soft tissue retraction during surgical treatment, prevent soft tissue trauma and damage to adjacent sensory nerves. Also, they may be customized to suit the nature of their intended purpose.

Education and Training

Instrumentation practice with various printed teeth would enhance clinical skills. Current use of extracted teeth may not be ideal due to inconsistent supply, lack of availability of teeth with critical anatomies etc. *3D printed tooth models* can be duplicated and used for simulation exercises to assess the skill development of individual students with standardized exercises.

Also, the use of conventional plaster models as an educational aid to students and patients, for treatment planning, potential difficulty assessment, fabrication of custom guides and splints etc continues till date. However, the plaster models fail to represent the accurate internal anatomic structures. Additional storage space requirement and proper disposal is also a concern with plaster models.

3D printing eliminates all these limitations. Not only do they replicate the exact details of the anatomical structures, but also offer convenience while record keeping as the digital file that holds the data for the 3D model can be easily stored, reproduced when needed and shared electronically.

Another advantage of 3D models is that they can be printed in multiple colors, and textures which helps in differentiating tissue types. This makes them a better teaching aid for students. They can also be used as a management tool for treatment planning when unusual root canal anatomy or proximity to delicate anatomical structures is anticipated.

Regenerative Endodontics

3D printing offers stimulating possibilities in the field of regenerative endodontics as well.

Anatomically shaped *human molar scaffolds* have been fabricated by 3D bioprinting using a hybrid of poly--caprolactone & hydroxyapatite to overcome the hurdles associated with cell delivery in tooth regeneration.

Calcium sulphate, calcium phosphate and composite powders can also be printed which act as augmentation materials.

Researchers have also produced a *dentin pulp complex* having a patient specific shape. For bioprinting, a fibrin-based bio ink laden with human dental pulp stem cells was designed. Co-printing was done using this bio ink with caprolactone which is a bio thermoplastic material. The use of bio inks for printing the outer dentin region of the 3D construct promotes active odontogenic differentiation.

Future studies are aimed at developing a printing process for cementum and periodontal ligament tissue to regenerate a whole tooth.

Autotransplantation

Conventionally, the transplant tooth is used as a template for preparation of the recipient site, which may require multiple attempts with adjustments to the alveolar bone that increase extra-oral time and risk damage to the PDL. Computer aided rapid prototyping (CARP) can be used to print replicas of teeth such that manipulation of the recipient bone sites could be completed prior to extraction of the transplanted teeth without PDL damage from repeated insertion and removal.

Other uses

In case of fractured anterior teeth, **3D printed templates** can be used for easier and more convenient placement of composite restoration. At present, **3D printed instruments** are being used in medical field. So, dental instrument fabrication can also be anticipated in near future.

Why Choose 3d Printing?

Traditional technology (subtractive manufacturing) uses a block of material to cut the object out. This generates surplus waste of cut material. In contrast, 3D printing or additive manufacturing process only "prints" what is needed. In time, 3D printing will have a significantly positive impact on the environment as it helps the manufacturing industry to go green by reducing waste.

It also offers better accuracy, customization possibilities, reduced technique sensitivity and better material utilization. 3D printing is also more cost-effective and time saving than many conventional techniques.

Limitations

Despite all the benefits and hype, 3D printing in dentistry is still in its earlier phase of development. Limited printable materials, difficulty in post-processing removal of support material, and the need of trained technicians are some of the hurdles that need to be crossed for this technology to be accepted more widely.

CONCLUSION

3D printing technology, although still evolving, is here to stay. It is transforming our dental practices by creating continuous opportunities in diagnosis, treatment, and education. The potential benefits to the profession and patients are equally ground-breaking. However, the freedom offered by 3D printing is not limitless. We must take time to understand the true parameters of this technology.

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