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APPLICATIONS OF 3D PRINTING IN DENTISTRY

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Abstract

Three dimensional printing is a rapidly developing technology that has gained widespread acceptance in dentistry. Compared to conventional and subtractive computer numeric controlled methods, 3D printing offers process engineering advantages. Materials such as plastics, metals and ceramics can be manufactured using various techniques. The aim of this work is to provide an overview of different printing techniques and the materials used in dentistry and their clinical applications.

Keywords – 3D printing, Additive manufacturing, Dentistry, Tissue engineering.

1.Introduction

The use of 3D printing in the fields of medicine and dentistry is one of the trends that is emerging to this era.The term "additive manufacturing," was first used by Sir Charles Hull in the 1980's. He holds the title of "Father of 3D Printing". Instead of subtractive manufacturing, material is "printed" in 3D printing by building up layers at a time. With 3D printing, complex structures may be quickly created. It is more cost-effective than subtractive manufacturing methods and does not waste the material during the process.[1]

Due to their widespread availability, somewhat stable printing quality, ease of installation, and cost, fused deposition modelling (FDM) printers are most frequently employed in medical and dental settings. Thermoplastic polymers including polylactic acid (PLA), acrylonitrile butadiene styrene (ABS), polycarbonate (PC), and PEEK etc are some of the materials which are commonly used.[2]

Adopting this technology makes it popular for the creation of new medical equipment, gadgets, and other surgical instruments, boosting the capabilities, precision, and reducing the cost and time in the medical and the dental industry.[1]

2.Discussion

With 3D printing specifically made for dental applications, dentists can now provide patients more individualised care at a far cheaper cost and also streamline the intricate production procedures for dental appliances. The demand for 3D printing in the dentistry business has increased as a result of technological breakthroughs that allow dentists to execute dental operations with excellent accuracy, high efficiency, and less trauma to patients.

3D-printed objects have been successfully used in different branches
of dentistry that includes;

- Prosthodontics
- Orthodontics
- Endodontics
- Periodontics
- Oral implantology
- Oral And Maxillofacial surgery

2.1 PROSTHODONTICS

2.1.1 CROWNS AND BRIDGES

Restorations using crowns and bridges are among the common clinical procedures in prosthodontics. Traditionally, they were fabricated using the lost-wax technique, which is labour intensive and prone to human errors. Understandably, comparative studies for evaluating various dental restorations parameters like crowns and bridges have been performed in light of the current popularity of 3D printing technologies to predict their reliability.

It has been reported that milling and additive manufacturing showed more accurate results regarding marginal fit compared with manual techniques. Moreover, 3D printed crowns had the most accurate occlusal fit and least internal discrepancies.[3]

2.1.2 FABRICATION OF 3D PRINTED DENTURES

The exponential growth of using digital technologies in the field of prosthetic dentistry can be mainly attributed to their application in the fabrication of removable prosthesis, such as complete and partial dentures. **Figure 1**

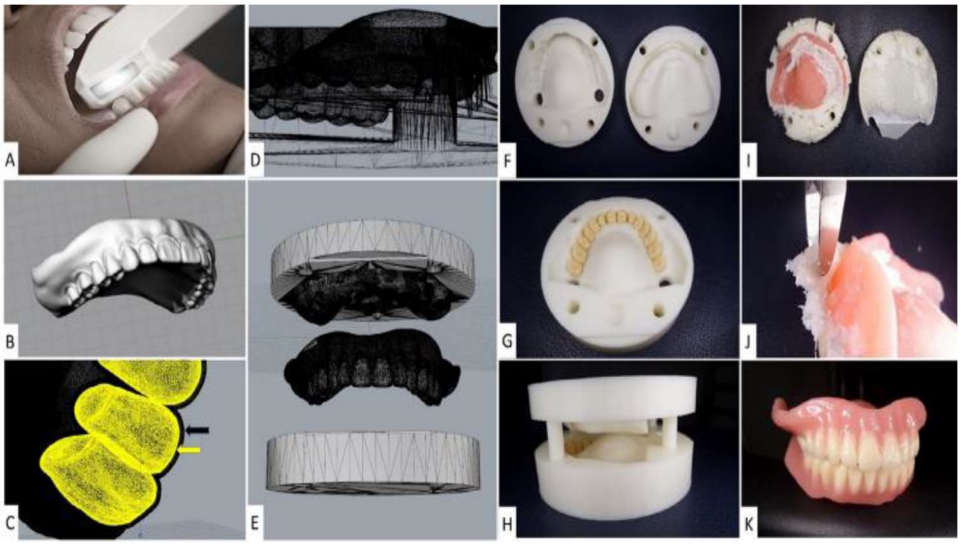

Figure 1 – 3D PRINTED DENTURES

In recent years, dentures fabricated by digital techniques have become increasingly popular. Because there is a variety of different CAD/CAM programs and protocols, the procedures for the digital manufacturing of dentures can vary, with some requiring only two appointments with the dentist.[4]

2.1.3 REMOVABLE PARTIAL DENTURE

The rapid manufacture of the RPD is more feasible with the development of oral scanning and 3D printing technology, which shows acceptable fit and satisfactory for clinical outcome. Teeth are supposed to keep appearance and performance for various physiological functions like masticating. swallowing, and speaking.[4] **Figure 2**

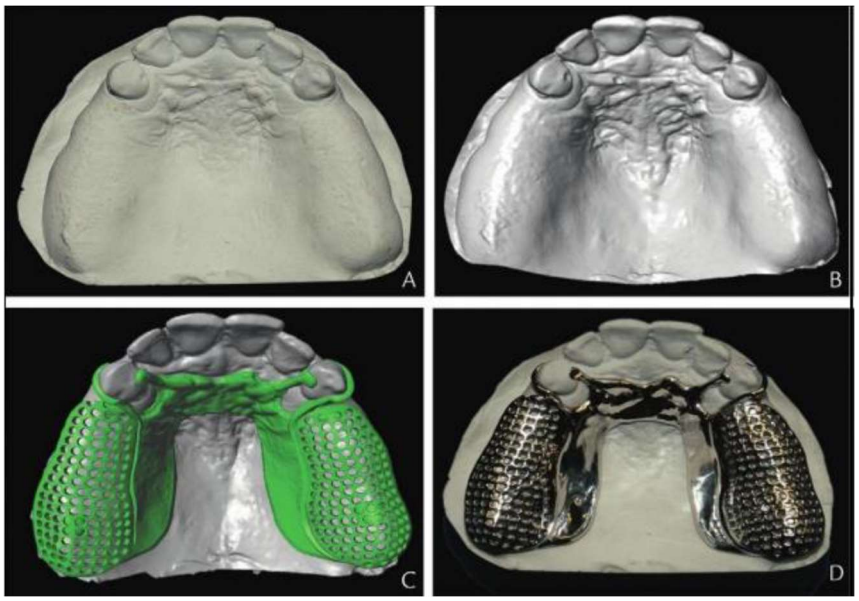

Figure 2 – Sequential fabrication of Cast partial Denture

A- Cast taken from the patient
B- 3D image of the cast
C- 3D image of partial denture framework
D- Completed 3D model

2.1.4 ORTHODONTICS

In Orthodontics, treatment may be planned and appliances created, or wires bent robotically based upon a digital workflow using an intra oral or laboratory optical scanning or even CBCT to capture patient data. The Invisalign®, system digitally realigns tie patient's teeth to make a series of 3D printed models for the manufacture of 'aligners', which progressively reposition the teeth over a period of months/years. **Figure 3**

Figure 3- Clear aligners

Various removable appliances (like Hawley's retainer, splints), functional appliances, arch expansion appliances, clear aligners, retainers, arch wires, brackets, auxiliaries, trays for indirect bonding, set up models which will make lingual orthodontics and mock surgeries fast and easy, also study models.[4]

2.1.5 ENDODONTICS OR RESTORATIVE DENTISTRY

Endodontics too benefits from 3D printing technology-in the fabrication of precise guides for application in surgical as well as nonsurgical endodontic procedures. 3D printed surgical guides help in a guided apicoectomy procedure. Guides in nonsurgical endodontic procedures are especially beneficial for access cavity preparation in cases of calcified canals.
Use of 3D printing enables creation of tooth models with realistic anatomical root canal structures by using CT Images; thereby providing dental students an opportunity to deal with realistic procedures, rather than usage of ideal typhodont teeth.[5]

2.1.6 GUIDED ENDODONTIC ACCESS

Pulp canal obliteration is insinuated in up to 75% of perforations during attempted location and negotiation of calcified canals. In these cases, canals must be located in more apical portions of

progressively narrowing roots. The risk of perforation can be reduced by producing a true path of canal access and instrumentation.[5] **Figure 4**

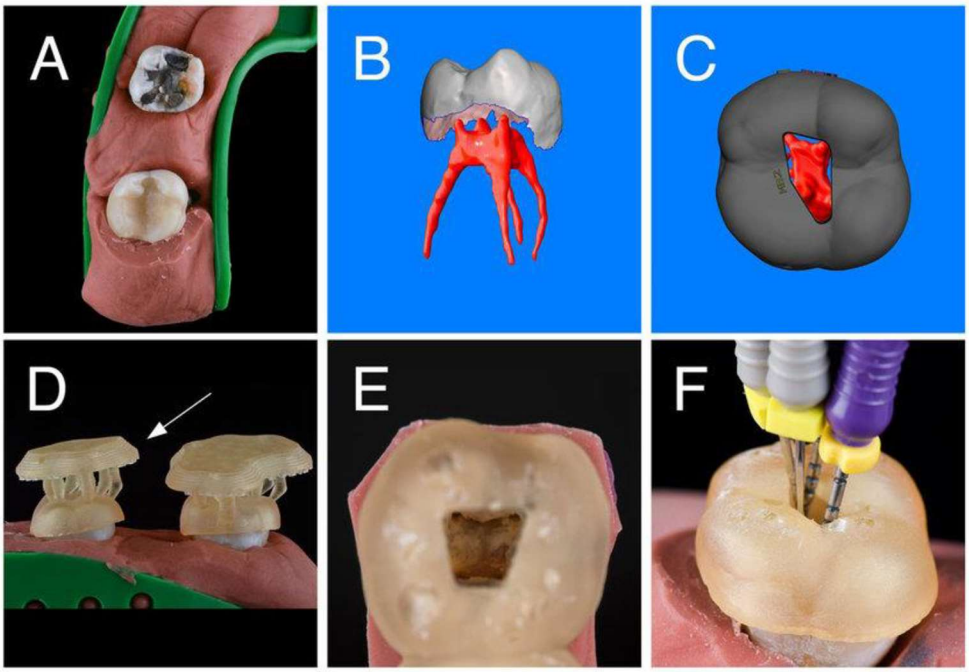

Figure 4 - 3D printed guide for endodontic access

2.1.7 SURGICAL GUIDES

In CBCT, the use of CAD/CAM has leveraged the data regarding the objects used in surgical or nonsurgical endodontics. The anatomically challenging cases have also been defined using targeted endodontic microsurgery (EMS) using 3D printed guides, and trephine burs.[6]

2.1.8 PERIODONTICS

Recent advancement in the field of tissue engineering has led to the development of ―3D printed" scaffolds. **Figure 5**

Figure 5 - Surgical guide in position for gingivectomy

With the increasing demand for tissue regeneration, these scaffolds have been investigated in different periodontal procedures such as socket preservation, guided tissue and bone regeneration, sinus, and vertical bone augmentation and crown lengthening procedures as well.[7]

2.1.9 ORAL IMPLANTOLOGY

3-D printing along with digital technology have made significant improvements to rate of success and have transformed work process and practices in standards of care in dental implants. Advanced thinking clinicians and the dental laboratories have harnessed benefits of the digital technology for ensuring best outcomes for the patients as well as providing versatility and savings in time and cost Implants offer a viable solution for replacing missing teeth with no need to do away with surrounding healthy dentition.[8]

2.1.10 GUIDED IMPLANT SURGERY WORKFLOW

The digital imaging and communications in medicine (DICOM) file or rendering of the anatomy of the patient is integrated to yield guided surgery software. In this software program clinician and dental technician is able to virtually place the implant and run number of test for ensuring best location outcomes.

The impression of the mouth of the patient is captured with an analog PVS method or with a digital intraoral scanner from which model is prepared and scanned. This generates an optical scan providing a scan to 3D print (STL) file which can be simply and quickly overlaid onto DICOM (cone beam) file and generate a comprehensive STL file for importing in to guided surgery software program. **Figure 6**

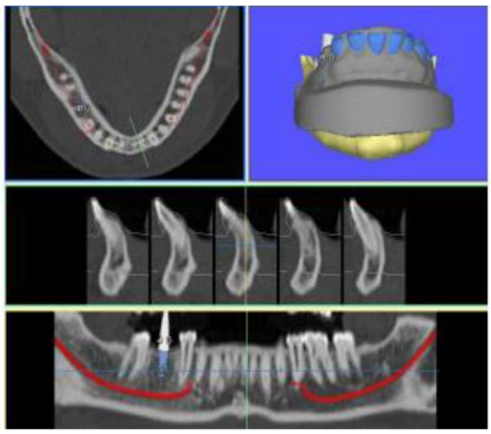

Figure 6 – Guided implant surgery planning software

After the implant and the location are in line with intraoral scan or with the optically scanned model, they are overlaid and integrated into one open source concise STL file. This file may be now manipulated for designing a surgical guide.

After the design of implant surgery guide, it is a simple task to export comprehensive STL file to 3D printer for obtaining quickly a seamless surgical guide. The guide gets printed in biocompatible

material for contacting with oral environment for short duration. The material is specifically approved contact with mucosal membrane for short-term period up to 24 hour duration.
The hole is to accept either a metal sleeve glued to the guide or predesigned hole is 3-D printed and used with drill guided sleeve which fits on dental drill and guides clinician to location and depth of the implant placement.[8]

2.1.11 ORAL AND MAXILLOFACIAL SURGERY

3D printers provide a good educational tool for doing mock surgeries and getting
familiarized with the anatomy and instrumentation for aspiring surgeons. 3D models are very effective in preoperative surgical planning, especially for fields like vascular surgery, for endovascular aneurysm repair; in cardiac surgery for tumor resections and repair of congenital defects; in neurosurgery for navigation training; and in orthopedic surgeries for tumor resections and treatment of trauma injuries.
Nowadays, many oral surgeons are using virtual planning and 3D printing technology to provide better care and treatment outcomes to their patients. Four categories of 3D printing models uses for craniomaxillofacial surgery in patients, which includes[9]
• Contour Models (Type 1),
• Surgical Guides (Type II),
• Splints (Type III) And
• Implants (Type IV)

2.1.12 REGENERATIVE DENTISTRY

Polymer-based materials that are used in biomedical applications are classified into hard and soft polymers. They are further classified into two types namely biodegradable and non-biodegradable polymers. However, non-biodegradable polymers are used as structural implants. Some of the hard-synthetic biodegradable polymers that are used in biomedical applications include polylactic acid (PLA), polycaprolactone (PCL), polyglycolic acid (PGA), and polydioxanone (PDO).[10]

3. CONCLUSION

All facets of dentistry are being significantly impacted by 3D imaging and modelling, as well as CAD technologies. From this digital data, one of the intricate mathematical structures can be made precisely locally or in industrial facilities using a range of materials.
Similar technology is being used to print models for restorative dentistry and patterns for the lost wax process, which is becoming more significant with the rise of intraoral scanning systems. The technology is already widely used in orthodontics, where high resolution printing in resin is already an entirely practical proposition.
Utilising 3D printing techniques to aid in the planning of difficult treatments. The use of surgical guides printed in resins (usually) or autoclavable nylon is widely accepted to make surgery less intrusive and more predictable. Although 3D printers are getting more economical, other costs such as operating expenses, material costs, maintenance costs, and the requirement for qualified

operators must also be carefully considered. Post-processing is also necessary, and strict health and safety regulations must be followed.3D printing is a manufacturing technology that is increasingly used in medical applications.

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