The Application of 3D Printing in Dentistry

Shikha Parashar, Aishwary Awasthi

SOMC, Sanskriti University, Mathura, Uttar Pradesh, India

Email Id- shikha.soet@sanskriti.edu.in

ABSTRACT: ***3D printing has been heralded as a game-changing technology that will revolutionize the industrial industry. 3D printing is becoming more popular in the fields of aerospace, defense, art, and design. It is also becoming increasingly popular in the field of surgery. As 3D imaging and modelling technologies such as cone beam computed tomography and intraoral scanning continue to develop, as well as the relatively lengthy history of the usage of CAD CAM technologies in dentistry, this technology will continue to gain in significance. In dentistry, 3D printing is used for a variety of purposes, including the creation of drill guides for dental implants, the creation of physical models for prosthodontics, orthodontics and surgery, the manufacture of dental, craniomaxilolofacial and orthopedic implants, and the fabrication of copings, frameworks and other components for implant and dental restorations. This article examines the different kinds of 3D printing technologies that are now accessible, as well as their varied uses in dentistry and maxillofacial surgery, among other fields.***

KEYWORDS: ***3D Printing, Cone Beam Computed Tomography (CBCT), Computer-Aided Design, Dental, Orthodontic.***

1. INTRODUCTION

Generally speaking, the word 3D printing is used to describe a manufacturing process that creates things one layer at a time, adding many layers to construct an object. It is more accurately characterized as additive manufacturing, although it is sometimes referred to as fast prototyping in certain circles. 3D printing technologies are not entirely new; many of the modalities that are now in use were originally developed and utilized in the late 1980s and early 1990s. The author was the first to treat a patient with 3D printing technology in 1999. The phrase "3D printing," on the other hand, is relatively new, and it has piqued the interest of the general public. A tremendous lot of excitement surrounds the usage of 3D printing, which is being heralded as a revolutionary technology that will permanently alter the manufacturing industry. International news outlets have carried stories on 3D printing being used to create anything from fashion apparel and architectural models to guns. We have also seen articles about 3D printing being used to manufacture armaments. The truth, on the other hand, is that 3D printed undergarments would be uncomfortable today, and 3D printed weapons are hazardous — at least to the person who fires them. In spite of the fact that we are still many years away from seeing the production of viable 3D printed organs, the fields of dentistry and oral and maxillofacial surgery have been utilizing 3D printing for years and have enthusiastically embraced digital manufacturing technologies, particularly the use of computer-aided design and manufacturing. The purpose of this essay is to investigate why 3D printing is essential in dentistry, as well as why dentistry is a driving force behind the development of 3D printing applications[1].

1.1 Technology for 3d Printing:

3D printers are typically very basic robotic machines when viewed from a mechanical point of view. In the absence of computer-aided design (CAD) software, the equipment would be incomprehensible; this programme enables items, and even whole assemblies, to be created in a virtual environment. CAD software is ubiquitous in industrial design, engineering, and manufacturing settings, and it is also popular in the dental laboratory; it is even becoming a standard part of many dental operations in the United States and Europe. The advancement of computer technology and software applications has played a significant role in the groundswell of technical change that has brought 3D printing to the point where it is at this time. It is necessary to be able to create objects for 3D printing before it can be considered valuable; CAD software allows us to create objects from scratch, but in dentistry and surgery, we also have ready access to volumetric data in the form of computed tomography (CT) data, cone beam computed tomography (CBCT) data, and intraoral or laboratory optical surface scan data. In particular, recent advancements in cone beam computed tomography (CBCT) and optical scan technologies have revolutionized, and continue to revolutionize, many areas of restorative and implant dentistry. The use of these powerful technological tools is at the disposal of a class of individuals – dentists and dental technicians – who are frequently polymaths, possessing a broad

level of creativity and understanding of technology, as well as engineering and materials skills that are far superior to those possessed by many others working in individual fields of endeavor[2].

Dentistry has a long history of collaboration with subtractive manufacturing, which is more often referred to as "milling." Subtractive manufacturing is the process of removing material from an item in order to create it. The use of computer-aided design and manufacturing (CAD/CAM) for the machining of crown copings and bridge frames has become associated with contemporary dentistry technology. Modern dentistry is acquainted with materials that are intended to operate with computer-aided design and manufacturing (CAD/CAM) systems and to replace for more conventional precious metal casting alloys, which have seen their prices rise at an exponential rate in recent years. This use of technology facilitates the use of materials that would otherwise be difficult to work with, as well as the elimination of labor-intensive artisanal production techniques, allowing the dental technician to concentrate his manual skills on more creative aspects of the manufacturing process, such as the aesthetic layering of porcelain, which would otherwise be impossible[3].

Of course, every time a dentist performs a restoration or reconstruction on a patient, the process is customized to that patient's specific needs, including the specific jaw, tooth, or implant being restored or rebuilt. In addition, the reconstruction or restoration will have inherent complexity, necessitating the replication of complicated geometry with a high degree of accuracy. This is possible with multi-axis CAD CAM milling techniques, but the process is slow and wasteful since the material is milled from a solid block, and precision is restricted by the intricacy of the object, the size of the tooling, and the characteristics of the material. While 3D printing is not a replacement for traditional methods of fabrication, it can provide advantages in the precise one-off creation of complicated structures in a range of materials with characteristics that are highly desired in dentistry and surgery. The use of 3D printing in dentistry, oral and maxillofacial surgery, and other fields is becoming more common[4].

1.2 Medical Field:

In the field of surgery, one of the first uses of 3D printing was in medical modelling, which may be thought of as the creation of an anatomical "study model." CBCT (contrast-enhanced computed tomography) has been widely available in dental offices in recent years, making this even more accessible; it has revolutionized diagnosis and treatment in implant dentistry and endodontics, for example. The availability of CT, which gives comparable data and is more common in a hospital environment, or CBCT, means that it is feasible to send volumetric ‘image' data to a 3D printer before surgery and to create detailed replicas of the patient's jaws before the operation takes place. This allows for a thorough examination of the anatomy, especially complicated, unique, or unfamiliar anatomy, as well as the planning and practice of a surgical approach prior to the procedure[5].

In turn, this has led to the creation of novel surgical techniques and approaches, which, when combined with the fabrication of drilling or cutting guides using 3D printed technology or traditional laboratory equipment, may result in surgery that is more predictable, less invasive, and faster[6].

When it comes to medical modelling, accuracy will often be limited by the original imaging modality as well as the presence of artefacts caused by metal structures such as teeth, restorations, or implants; however, the level of inaccuracy will not be clinically significant for many surgical applications. Medical models may be printed using a broad range of 3D printers and 3D printing materials, but since it is beneficial to have such replicas in the operating theatre, materials which can be sterilized, such as nylon, are especially intriguing. Figure 1 shows the process involved in 3D printing.

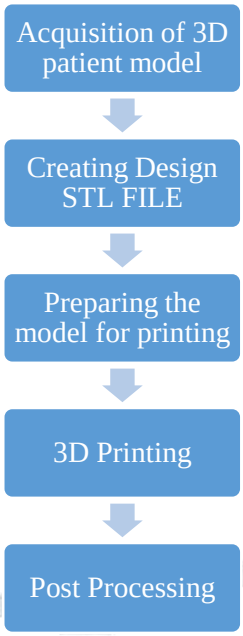

Figure 1: The process involved in 3D printing.

1.3 Manual Cutting and Drilling Guides:

Robust and accurate engineering instruments must be able to be sterilized or disinfected as they are utilized in surgical environments. Drilling guides are becoming more prevalent in implant dentistry, and orthopedics has adopted similar technique for knee surgery, for example. A virtual 3D plan, designed on the computer and then brought to the real world via the use of drill guides and cutting guides, may be considered an interface between the virtual plan and the actual patient.

A scanner's inaccuracies, software glitches, and the existence of any hardware issues may have an impact on the dental implant treatment, or on the correctness of prefabricated prostheses. While the finest materials for implant drill guides are not autoclavable, they must still be utilized with high-resolution printing methods and precise 3D printers[7].

1.4 Dental Fittings:

It is feasible to create a very detailed virtual model of the prepared tooth, implant location, and dental arch by using intraoral optical scanners or laboratory scanners. Fixed and removable prosthodontics both include the use of CAD software to plan and create restorations. The scan data and CAD design for these implants and dental structures may be utilized to mill or print crown and bridge copings, as well as bridge constructions.

Metal structures may be produced by using 3D printing techniques. The fabrication can be done in two ways: indirectly by using resins or waxes for a lost-wax process, or directly using metals or metal alloys. When utilizing conventional casting methods for resins/wax, there is less post-processing needed than with the direct 3D printing of metals. Casting facilities and alloys are also common and easily found. Printable metals are only available via more expensive technology, which has its own health and safety considerations, and is also an extensive post-processing step.

To provide a mechanical link to an implant through complicated bridge structures, 3D printing may be utilized in combination with milling/machining technologies to achieve the most accuracy while creating a minimal amount of waste. However, milling has the benefit of being waste-free in terms of materials utilized and may produce a material that is uniform, unaffected by the operation. The equipment is both less expensive and requires minimal post-processing[8].

1.5 Dental Model:

3D printing is necessary for dentists to produce a physical model of the scanned jaw, as the trend toward the usage of intraoral scanners continues.

It is not essential to print a master model today, but we are accustomed to seeing restorations displayed on a model, even if they have been created digitally. This is why 3D printed master models are still necessary for conventional aspects of the fabrication of a restoration, such as adding a veneering material. A digital archive of patient information may be created and only printed when required, thereby reducing storage needs.

1.6 Orthodontics:

In orthodontics, treatment planning and appliance fabrication may be done with the help of robots, with wires bent utilizing an optical process to collect patient data using either an intraoral or laboratory optical scanner. The Invisalign technology, which is digitally repositions patients' teeth in order to create a set of 3D printed models that will be used to create aligners, which move teeth over the course of months or years. 3D printing with both stiff and flexible materials was used to create bracket-bonding splints for orthodontic CAD software (3Shape).

Although data is travelling over the internet and smile design is occurring on software, the potential time savings are tremendous. Storing patient records digitally rather than in paper form will greatly reduce the space required for storing them[9].

1.7 Implants in The Mouth:

A porous or rough surface was created by manufacturers to be included into dental implants using 3D printing technology. However, we must not be tempted by the promise of a rough or porous surface, since we have seen that many dental implants whose surfaces are rough or porous have had difficulties after many years. However, because of its capacity to create complicated geometries, such as a bone-like morphology, 3D printing is more suited to manufacturing complex batches of dental implants than milling/machining is. Implants that have complicated geometry may also be created, although the traditional method of implanting a dental implant with a screw-type shape seems to be more reliable.

1.8 OMF Implants:

A lot of talk has been generated by the possibility of printing in titanium or implantable polymers (especially polyethylene terephthalate for the purpose of maxillofacial implants). However, despite 3D printing's capabilities, most OMF implants are basic in shape, with fast manufacturing and homogenous materials using less post-processing. The implanted structure may be printed directly using 3D printing, or indirectly using a traditional pressing method.

It's well known that dentists and surgeons are both famous for their innovation and inventiveness! The fast prototyping of instruments used by creative people to bring ideas to life is aided by 3D printing. One possible reason the public is more excited about 3D printing is that surgeons are able to move from concept to prototype product faster than they would with traditional rapid prototyping methods. However, while rapid prototyping processes are quicker and cheaper, they take a long time and are expensive to use for materials with better mechanical properties. The authors have printed several design prototypes for both inventive and commonplace items using 3D printing.

1.9 Powder Binder Print-Out (PBP) Machines:

Using an inkjet head adapted for the task, this equipment prints in liquid droplets, layer by layer, to inject powder into the overall structure. The powder, which is made of plaster of Paris, is often printed on using water-based colored liquid.

A fresh fine coating of powder is put over the surface and then a new layer of powder is placed over the surface of the previous one. This model is built on a foundation of uncontaminated powder; thus it does not need any supporting materials. If you want the printed model to be more durable and more hard-wearing, you should use a cyanoacrylate or epoxy resin for post-processing.

Models generated by this technique are good for serving as either study models or as preliminary models, but they lack in accuracy and are not very sturdy. From a surgical viewpoint, the disadvantage of this technique is that models may not be sterilized or physically handled during an operation.

Prosthodontic treatments are insufficient for accuracy. As you may have guessed, the equipment and materials are cheaper, but they're still not cheap. Because most of the material is plaster of Paris, the

equipment will likely be compatible with the surrounding environment in a dental laboratory, which is a plaster room[10].

2. DISCUSSION

A lot of the laboratory work that was formerly done by hand is now done digitally, so that only the finishing touches of dental restorations need to be done by hand. CAD CAM systems are already prevalent in dental laboratories, and will be used even more in dental surgeries. While centralized scanning and manufacturing had been used for decades to produce restorative dentistry, many labs today have their own scanning and milling equipment. Dentists are growing more reliant on intra oral and CBCT scanners. Dental professionals are getting more familiar with and skilled at using huge amounts of digital data. A third type of output device is available because to 3D printing, which enables the fabrication of complex components and objects in a range of materials. This kind of technology is best used for when the structures being scanned are unique, customized, and have complex geometry.

For dentistry, 3D printing is currently quite versatile, and it has significant potential to allow many novel and innovative dental restorative production methods. The national regulatory organizations have not addressed 3D printing usage in surgery or dentistry, but regulators will need to look into the technology in the future to establish standards. Though 3D printing equipment and technologies have been available for over a decade, the application of the technology has been made practical by recent developments in, and access to, scanner technology, computer-aided design software, and raw computational power. This has been accompanied by rising public and commercial interest.

The availability of new materials increased with the advent of milling, as did the possibility of using these materials for the manufacture of dental restorations. Furthermore, new generations of dental restorative materials for 3D printing are continually emerging. Considering dentistry's lengthy experience with scanning and milling technologies, together with the diverse variety of 3D printing applications in dentistry, it is conceivable that dentists and dental technicians are more familiar with 3D manufacturing technologies than any other profession.

The field of CAD software is still dominated by educated and computer literate experts, but new generations of users are unperturbed by this, and the software is also getting “smarter” and more user-friendly. Of course, the technology we use will advance further in the next years. This includes our ability to 3D print in ceramic materials, the reduced post-processing required for metal parts, and how we can integrate machining/milling of 3D printed metal parts into the metal printing workflow. The authors assert that it is not just the early acceptance of digital technologies in dentistry that has picked up pace, but that the technology has advanced enough that the time for the widespread use of 3D printing in orthodontics and in dental laboratories has arrived. It is vital to emphasize the entire integration of equipment with planning and design software to produce a seamless, rigorous, and efficient workflow, as this will help to ensure that these disruptive technologies are widely accepted.

The difficulty we confront is not to look at 3D printing as a new tool to accomplish what we have always done but to see it as a technology which allows us to be more creative, to create more predictable, less intrusive and less expensive for our patients. The second issue is that since it is digital, we may be lured into believing that it is superior. That study must be done to make sure that the devices that are entering our labs and operating rooms are equal to or better than existing analogue procedures.

3. CONCLUSION

3D imaging and modelling, and computer-aided design methods have a significant effect on all facets of dentistry. Digital data that describes complicated geometrical shapes may be translated into real objects through 3D printing, which can be created locally or in industry. While 3D printing is helping us today, no one technology is adequate for our patients' requirements. Orthodontics, which employs high-resolution printing in resin, has been using the technique, and comparable methods are used to print models for restorative dentistry and patterns for the lost wax process, which is becoming more prevalent with the increase in intraoral scanning devices. As more and more complicated procedures in maxillofacial and implant surgery are being done, it is becoming a need to utilize anatomical models produced by any number of various 3D printing methods to help with planning. Many people believe that using surgical guides printed

in resins (or autoclavable nylon) allows surgeries to be less intrusive and more predictable. For a few of people, the true fun is in producing metal-based dentures and implants in the dental laboratory, although this isn't yet common in the UK.

Although the cost of 3D printers is falling, it is necessary to consider the related expenses, such as operating, materials, maintenance, and trained operators. Also, post-processing and health and safety regulations must be taken into account. Despite these issues, it is certain that 3D printing in dentistry will play an ever more significant role. This is an extremely exciting moment to be in dentistry due to the convergence of scanning, visualization, CAD, milling, and 3D printing technology as well as the professional's natural curiosity and inventiveness.

REFERENCES:

[1] G. Oberoi, S. Nitsch, M. Edelmayer, K. Janjic, A. S. Müller, and H. Agis, "3D printing-Encompassing the facets of dentistry," *Frontiers in Bioengineering and Biotechnology*. 2018, doi: 10.3389/fbioe.2018.00172.

[2] A. Dawood, B. M. Marti, V. Sauret-Jackson, and A. Darwood, "3D printing in dentistry," *Br. Dent. J.*, 2015, doi: 10.1038/sj.bdj.2015.914.

[3] P. Papaspyridakos *et al.*, "3D Printing in Dentistry - Sculpting the Way It Is," *J. Sci. Tech. Res.*, 2018.

[4] S. Prasad, N. A. Kader, G. Sujatha, T. Raj, and S. Patil, "3D printing in dentistry," *J. 3D Print. Med.*, 2018, doi: 10.2217/3dp-2018-0012.

[5] E. Anadioti, B. Kane, and E. Soulas, "Current and Emerging Applications of 3D Printing in Restorative Dentistry," *Current Oral Health Reports*. 2018, doi: 10.1007/s40496-018-0181-3.

[6] M. Revilla-León and M. Özcan, "Additive Manufacturing Technologies Used for 3D Metal Printing in Dentistry," *Current Oral Health Reports*. 2017, doi: 10.1007/s40496-017-0152-0.

[7] N. Moser, P. Santander, and A. Quast, "From 3D imaging to 3D printing in dentistry - a practical guide.," *Int. J. Comput. Dent.*, 2018.

[8] A. Konidena, "3D Printing: Future of dentistry?," *Journal of Indian Academy of Oral Medicine and Radiology*. 2016, doi: 10.4103/0972-1363.195081.

[9] L. S. Zhu, Y. M. Chen, H. F. Li, and H. Kang, "Photosensitive resin used for 3D printing and its application in dentistry," *Chinese Journal of Tissue Engineering Research*. 2018, doi: 10.3969/j.issn.2095-4344.0078.

[10] C. Zaharia *et al.*, "Digital Dentistry — 3D Printing Applications," *J. Interdiscip. Med.*, 2017, doi: 10.1515/jim-2017-0032.