

3D Printing in Dentistry

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ABSTRACT

3D printing is a technology to produce a certain structure in a short period of time using additive manufacturing of data obtained through CAD (Computer Aided Design). It involves layering a filament material onto labeled points of support in order to build up complex forms. It is a seamless manufacturing solution to get customized items for all areas. One growth area for 3D printing technology is digital dentistry, where dentists use 3D printers to produce models, dentures, braces, and implants. 3D printing has been an ally among dental practices worldwide. This process allows for custom-fitted dental implants with minimal waste and maximum patient comfort. This paper examines the use of 3D printing technology in dentistry.

KEYWORDS: 3D printing (3DP), additive manufacturing (AM), 3D printing in dentistry, dental implants

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INTRODUCTION

Traditionally, a printer is used at home or in the office to print out text and images on paper. This conventional printer prints in a flat two-dimensional (2D) space using the dimensions length and width. A three-dimensional (3D) printer uses length and width but also adds depth to the print. A 3D printer has more manufacturing capacity than a traditional manufacturing machine. It is regarded as a disruptive technology that will change manufacturing. It has been used for decades in the automotive and aerospace industries. The 3D printer is also used by hobbyists, small businesses, creatives, manufacturers, architects, and most importantly contractors to instantly create a variety of products.

3D printing applications in the dental industry are rapidly advancing. It has emerged as an innovative method for dental implant manufacturing. One of the earliest adopters of digital dentistry was 3D printing giant Stratasys, with headquarters in Israel. In 2012, it merged with Israel's Objet 3D, another major manufacturer of 3D printers. The Israeli lab has been producing new products to enable dentists to take advantage of 3D printing techniques. With digital

files, they are stored electronically and models can be 3D printed on demand if necessary [1]. There is a growing use of 3D printing in the dental industry. It can be used to prepare tools, prostheses, dental implants, etc.

WHAT IS 3D PRINTING?

3D printing (also known as additive manufacturing (AM) or rapid prototyping (RP)) was invented in the early 1980s by Charles Hull, who is regarded as the father of 3D printing. Since then it has been used in manufacturing, automotive, electronics, aviation, aerospace, aeronautics, engineering, architecture, pharmaceuticals, consumer products, education, entertainment, medicine, space missions, the military, chemical industry, maritime industry, printing industry, and jewelry industry [2]

A 3D printer works by "printing" objects. Instead of using ink, it uses more substantive materials—plastics, metal, rubber, and the like. It scans an object—or takes an existing scan of an object—and slices it into layers, which can then convert into a physical object. Layer by layer, the 3D printer can replicate images created

in CAD programs. In other words, 3D printing instructs a computer to apply layer upon layer of a specific material (such as plastic or metal) until the final product is built. This is distinct from conventional manufacturing methods, which often rely on removal (by cutting, drilling, chopping, grinding, forging, etc.) instead of addition. Models can be multi-colored to highlight important features, such as tumors, cavities, and vascular tracks. 3DP technology can build a 3D object in almost any shape imaginable as defined in a computer-aided design (CAD) file. It is additive technology as distinct from traditional manufacturing techniques, which are subtractive processes in which material is removed by cutting or drilling [3].

3D printing has started breaking through into the mainstream in recent years, with some models becoming affordable enough for home use. Many industries and professions around the world now use 3D printing. It plays a key role in making companies more competitive. The gap between industry and graduating students can be bridged by including the same cutting-edge tools, such as 3D printing, professionals use every day into the curriculum. There are 3D printed homes, prosthetics, surgical devices, educator, and church minister in Nigeria, United Kingdom, Canada, and United States.

She is a co-author of some papers and books.

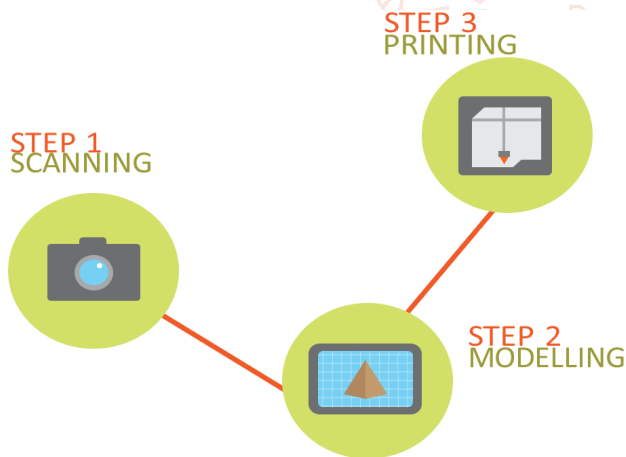


Figure 1 3D printing involves three steps [4].

drones, hearing aids, and electric engine components. As shown in Figure 1, 3D printing involves three steps [4]. A typical 3D printer is shown in Figure 2 [5].

3D PRINTING IN DENTISTRY

Due to increased life expectancy and greater concern on oral health problems and aesthetics, there has been a growing demand for dental structures and devices to replace/restore missing/damaged teeth in recent years. Traditional production methods are mainly based on handcrafted fabrication techniques that are time-

consuming and require great amounts of labor. However, production methods have started to be overtaken digital dentistry, which is about half a century old, around 1971. Digital technologies such as 3D printing has allowed for high levels of customization that make practices more efficient and improve patient treatment outcomes. 3D printing in dentistry is helping doctors diagnose better and faster, and making patients heal earlier too. More dental care professionals than ever are having a 3D printer in house. Patients get their 3D printed teeth at a very low cost and quickly too [6]. Figure 3 displays a 3D printing dentist lab [7].

Depending on the application, different printers are used in dentistry. Probably the most common 3D printing technologies in dentistry are stereolithography (SLA) and digital light processing (DLP). (Charles Hull in the US officially developed a SLA system in 1984.) Both use similar technologies but differ mainly in the type of light source. Using these printing techniques, we can create highly accurate 3D models that help us plan and visualize your custom denture design. With 3D printing technologies such as Selective Laser Sintering (SLS), Stereolithography (SLA), and Digital Light Processing (DLP), 3D printed crowns and alike can be produced in various volumes in-house.

Not all materials used in 3D printing are equal in strength and durability, so it is important to select one that will stand up to use inside the body. 3D printing of dental implants utilizes various advanced dental-grade materials such as stainless steel, titanium, titanium alloys, and cobalt chromium. Of these materials, titanium is often the most favorable due to affordability and biocompatibility. The materials have been used to replace metal components when combined with other materials in order to reduce the weight of the final prosthesis. Biomaterials used in dental implants include metals such as titanium and its alloys, ceramics, and polymers. The choice of biomaterials used in dental implants depends on the patient's particular [8].

DENTAL APPLICATIONS

Three-dimensional (3D) printing has a variety of uses and is becoming an integral part of dentistry, oral surgery, and dental lab workflows. Its use in dentistry is the natural progression from computer-aided design (CAD) and computer-aided manufacturing (CAM) technology which has been used for years by dental labs to create crowns, veneers, bridges, and implants. There are a number of applications for 3D printed dentistry. Common applications include the following [9]:

1. **3D Dental Implants:** Dental implants are a universally employed common treatment approach for the loss of teeth. Implants are usually the most feared dental procedure. Traditional implants are made from metal and other materials that can be difficult to replace or adjust. **3D Dental implants** are made from various materials, including plastic, and can be printed in any desired shape or size. They are dental prosthesis including crowns, bridges, and dentures. The most common type of 3D printed dental implants are abutments, which is used to attach a prosthetic crown or bridge to the jawbone and used to replace missing teeth. Dental implants are made of titanium or other bio-compatible materials, which have been proven to be safe and effective for use in dental applications. They are created using additive manufacturing techniques that enable the creation of complex designs with greater precision and accuracy than is possible with traditional manufacturing methods. Because they are surgically placed into the jawbone, dental implants decide both the medical and cosmetic outcomes of dental procedures. In earlier days, the conventional machines and mechanisms used could not accurately factor in the unique teeth size, locations and condition of patients. Today, dental implants have improved dramatically, thanks a lot to the accurate results of scans. After a digital scan 3D, a dentist will be able to virtually begin printing the required implant immediately. Figure 4 displays customized dental implants using 3D printing [10].
2. **3D Dentures:** 3D printed dentures, whether complete dentures, gums and teeth, must be printed with biocompatible materials. Although custom-made dentures were available, but they had their own limitations. Today, 3D printing equipment has become reliable and made dentures more affordable. In-house 3D printing dental facilities for hospitals or clinics makes it cost-effective. As a result, more and more patients are both willing and able to access dental treatment. Figure 5 shows a 3D printed dentures [11].
3. **3D Printed Crowns:** Dental crowns are essentially the hat your teeth wears on the top. They cover and protect your teeth. Because they do not need any special care after fitment, they are an important component of dental fittings. You can actually 3D print a crown in-house. Doctors in Japan have been printing dental crowns with lasers for years. As a result, custom-made crowns for each individual's teeth can be replaced much more easily than traditional crowns, which can become loose over time. Figure 6 portrays golden 3D-printed crowns [12].
4. **3D Aligners:** As an alternative to traditional braces, clear aligners can be created with the help of 3D printed dentition models and thermoforming. Clear aligners are transparent, nearly invisible devices used to adjust your teeth at a spacing that is suggested by your dentist and agreed upon by you. Using a specialized scanner, your doctor will take a swift but accurate 3D digital scan of your teeth. The aligners are printed once the dentist decides what is the best treatment. This 3D printing in dentistry can be completed in under an hour.
5. **3D Printed Teeth:** A dentist may be keen to use 3D printed teeth for their patients. A question most non-professionals miss is whether these artificial teeth will look natural. All these printed teeth, whether a single-unit or multi-unit replacement, exhibit all the aesthetic, medical, and engineering features you want. Figure 7 show typical 3D printed teeth [13].
6. **Dental Surgery:** 3D printers play an important role in dental implant surgery. 3D printed models can actually be created to replace missing teeth. 3D printing allows obtaining replacement teeth faster and more accurately than traditional methods. Dental implant surgery requires extensive measuring and planning to ensure an accurate and successful outcome. You can use your 3D printer to create precise anatomical models that can be used as intelligent surgical guides in conjunction with digital models and scans.
7. **Orthodontic 3D Printing:** 3D printing has various useful applications in orthodontics, such as the creation of orthodontic models, retainers, bonding trays, and splints. The use of a 3D printer helps optimize production workflow and create precise and individualized finished products.

BENEFITS

3D printing technology has gained popularity due to its ability to produce highly customized devices with intricate details that would otherwise be difficult or impossible to achieve in traditional manufacturing processes. A major advantage that 3D printing offers is that it is accurate to within a tenth of a millimeter. 3D printed implants offer a great deal of potential, presenting opportunities for customization, reduced time to market, and increased cost efficiency. They are more durable, customizable, and easier to replace. The printed models can be used to design patient specific pre-surgical guides, drill templates, and

dental appliances such as crowns and bridges which are then produced on the same device. Other benefits of 3D-printed dental implants include the following [11,14]:

1. *More Durable*: They are much more durable than traditional implants. This is due to the fact that they are made from a solid material, so there is no chance of them breaking or becoming loose over time.
2. *More Affordable*: They are more affordable than traditional ones, making them an attractive option for dentists who want to offer their patients quality dentistry at an affordable price. With affordable prices and more compact sizes of 3D printers, they are an accessible option for many dental practices. Advancements in additive manufacturing technology have not only improved printer size, capabilities, and affordability but also a range of printable materials.
3. *Less Likely to Fail*: They are also less likely to fail than traditional implants. This is because they are made from a solid material, which means they cannot become damaged or corrupted over time.
4. *Cheaper to Replicate*: They are also cheaper to replicate than traditional implant materials. They can be produced in large quantities quickly and easily using modern technology.
5. *Less Painful*: Traditional dental implants are metal and are often associated with more pain, discomfort, and a longer recovery time. 3D-printed dental implants are made from plastic and can be fabricated using various methods, including 3D printing.
6. *Less Risky*: The 3D-printed implants are less invasive than traditional implants, requiring only local anesthetic rather than general anesthesia. It makes them more comfortable for patients and reduces the risk of complications.
7. *Shorter Recovery Time*: They also have a shorter recovery time, meaning that patients can return to work sooner after surgery than traditional implants. In-house 3D printing has been shown to reduce a patient's overall treatment time. 3D-printed dental implants are safe, efficient, and precise type of implantations in the patient, serving to replace missing teeth.
8. *Customization*: In-house 3D printer allows for the customization and precision required for dental implant applications. Since you have the ability to view and edit CAD files before printing, you consequently have the ability to completely

customize your patient's finished product. By utilizing digital treatment planning data, we can produce patient-specific surgical guides and temporary restorations that precisely fit the individual's anatomy, ensuring accurate and predictable implant placement.

9. *High Speed*: 3D printing dentistry gets faster and faster. Depending on the size, 3D printers can produce high-detail parts without sacrificing quality in a few hours or a day. The ability to reproduce a tooth while you wait in the dental chair.
10. *Improved Efficiency*: With the combined use of an intraoral scanner and 3D printer, the entirety of the planning and creation of dental prosthetics can be done quickly and efficiently in your practice and you can rely on incredible accuracy in your finished products.
11. *Cost Effectiveness*: While the initial cost of purchasing a 3D printer may be a bit high, you will find that operations are much more cost-effective in the long run.

CHALLENGES

Just like any other promising technology, dental 3D printing too has its own set of challenges. These challenges need to be faced when using 3D printing technologies. These include the following [9]:

1. *Side-Effects*: One of the biggest questions was the side-effects of 3D printing resins in dental devices. Research shows 3D printing can negatively impact the reproductive health of patients.
2. *High Cost*: 3D printing machine for most dental practices and laboratories is expensive. Initial purchase cost for equipment and supplies may be high. However, today, 3D printers are far more compact and affordable than they were twenty years ago, making them more viable for private practices and labs.
3. *Expertise*: The average dental practitioner needs a solid amount of experience to operate the 3D printing machinery involved. Training staff members to fully understand how to use and maintain the equipment is necessary. In spite of the automation involved in the actual printing process, there is a learning curve for the average dental practitioner in understanding how to operate a 3D printer effectively.

CONCLUSION

The medical applications of 3D printing technology are widening daily due the fact that an increasing number of people are becoming concerned about their

dental health. The technology has revolutionized dentistry in recent years, providing novel opportunities to tailor both orthodontic and surgical treatments more accurately and efficiently than ever before.

Dental 3D printing is crucial to modern dentistry. Dentists, orthodontists, and oral surgeons are using 3D printing technology in patient care as well as in research and testing. The future of dentistry is here with 3D-printed implants. This groundbreaking technology allows for faster, more precise implant placement, resulting in a more comfortable and efficient patient process. Studies predict that in the future, dentists would be able to print you a newly 3D printed artificial tooth in 6.5 minutes.

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Figure 2 A typical 3D printer [5].



Figure 3 A 3D printing dentist lab [7].

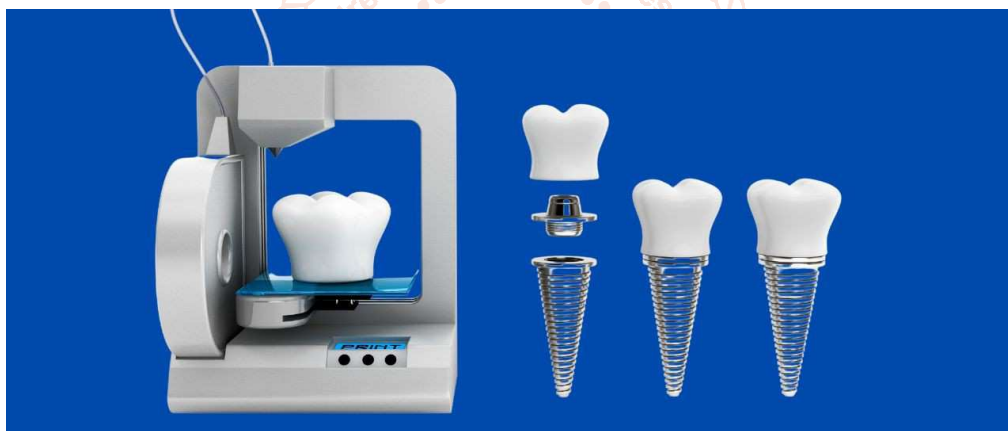


Figure 4 Customized dental implants using 3D printing [10].



Figure 5 3D printed dentures [11].

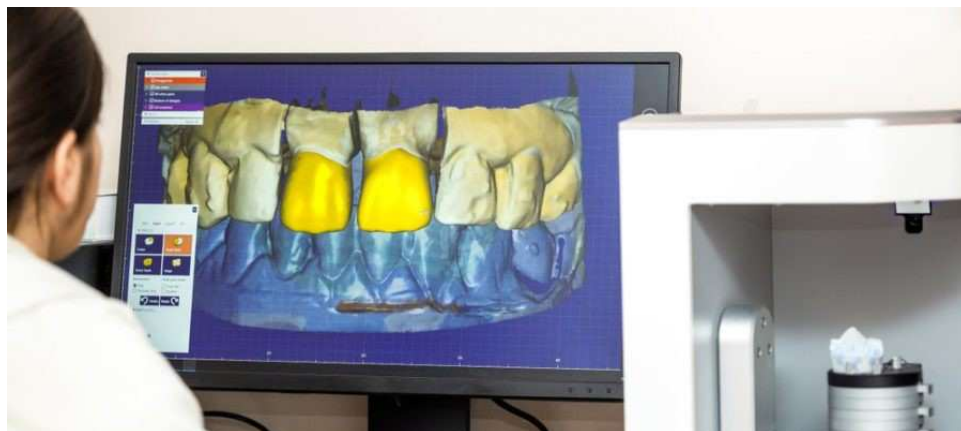


Figure 6 3D-printed dental crowns [12].

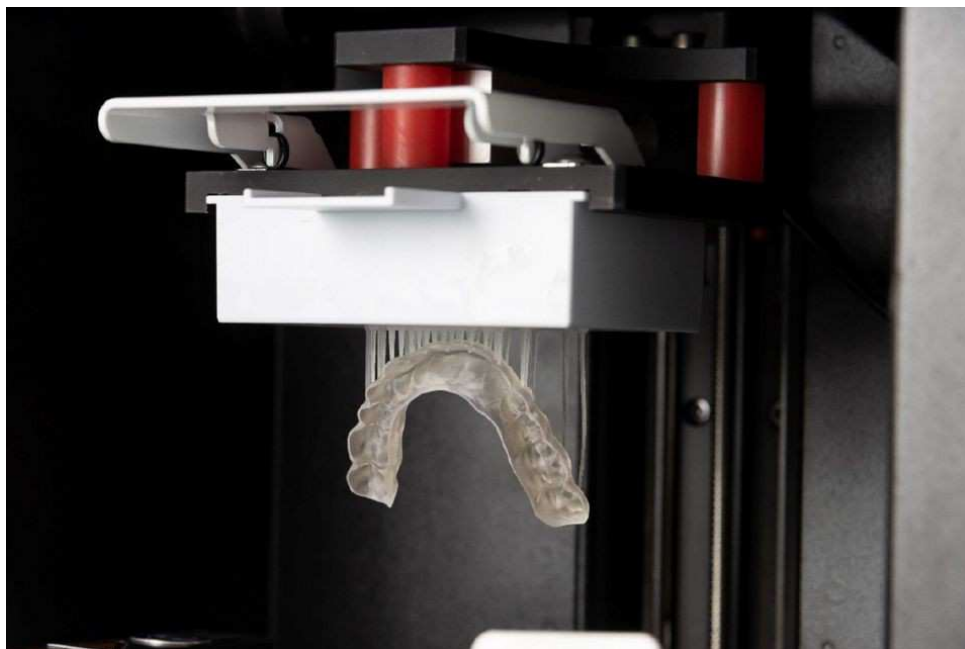


Figure 7 Typical 3D printed teeth [13].