Egyptian Prosthodontic Association
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3D Printing in Fixed Prosthodontics

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The application of CAD/CAM in dentistry has progressed strongly. It has led to the development of novel materials and to the digitization of different work processes. CAM process includes both the subtractive and additive manufacturing [1].

For years subtractive manufacturing (milling) has been the most successful method for production of fixed dental restorations. However, it has the disadvantage that the surface resolution is limited by the smallest tool radius. There is high material waste. Furthermore, the tools used show signs of wear after repeated use, which can lead to cracks in the objects produced [1].

In Additive manufacturing (rapid prototyping, 3D printing) the physical object is built up by the sequential application of thin layers of material. In contrast to subtractive methods, additive processes can save material and produce more complex geometries (Figure 1). However, it still has several disadvantages, such as high cost of processing and material, and time-consuming postprocessing [1].

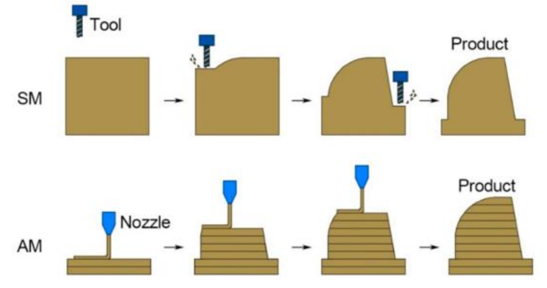
- **Steps of 3D Printing [2]:**

Step 1 Preparation of a 3D CAD model
Step 2 Creation of STL/OBJ file
Step 3 Slicing software to break up the CAD model into layers
Step 4 Transfer of files and determination of the path of the tool to print the object
Step 5 Additive Manufacturing process/3D Printing
Step 6 Post-processing of 3D printed object

- **Categories of 3D Printing Technologies:**

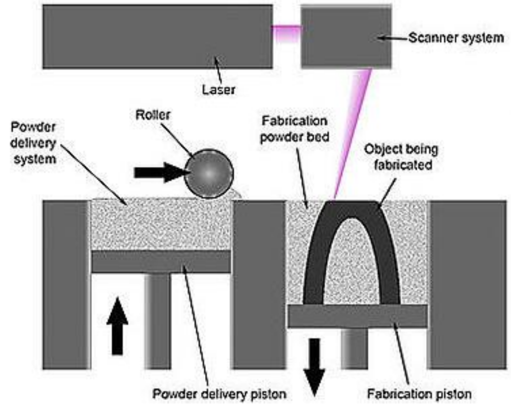
1. Powder Bed Fusion (PBF) [3, 4]

Powdered material, which can be sintered or fused by laser radiation and solidified by cooling, could be suitable for laser sintering or fusion technologies.
PBF includes selective laser melting (SLM), selective laser sintering (SLS) (Figure 2), electron beam melting (EBM), and direct metal laser sintering (DMLS).
In Fixed Prosthetic field, PBF is used to manufacture all kinds of metal products including titanium dental implants, metal frameworks, crowns and bridges. In addition to, ceramic restorations. PBF has the advantage of being suitable to metal and requires no binding process.



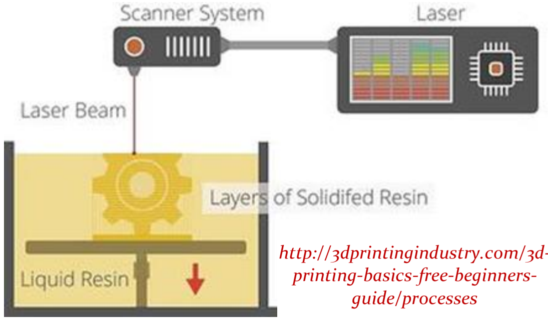
Courtesy of Tao et al.[5]

Figure 1: Subtractive and Additive Manufacturing.



https://en.wikipedia.org/wiki/selective_laser_sintering

Figure 2: Selective Laser Sintering.



http://3dprintingindustry.com/3d-printing-basics-free-beginners-guide/processes

Figure 3: Stereolithography.

2. Light Curing [3,4]

Light curing technology is a general term for a type of 3D printing technologies using photosensitive resin materials that are cured and molded under light irradiation.

It consists of three main technologies: Stereolithography (SLA), digital light processing (DLP), and photo jet (PJ). The printing process in SLA and DLP technologies can be divided into three discrete procedures: light exposure, building platform movement, and resin refilling.

SLA is one of the earliest 3D printing technologies, and its device consists of a reservoir for the material supplier of photosensitive liquid resin, a model build platform, and an ultraviolet (UV) laser to cure the resin (Figure 3). In the case of ceramics, SLA incorporates ceramic particles into a curing resin that selectively cures a ceramic slurry.

DLP technology microsystem consists of a rectangular arrangement of mirrors, called a digital microreflector device. Compared to scanning the layer sequentially using a laser in SLA technology, the advantage of DLP is that the entire layer can be constructed by single laser irradiation in just a couple seconds, making it significantly faster (Figure 4). Another advantage that DLP has over SLA, and most other forms of 3d printing, is that it wastes very little material. DLP printing is currently being utilized for creating Models, castable restorations, surgical guides, splints, and even short-term temporaries.

PJ is a photopolymerizable inkjet. During the printing process, the printhead moves along the X/Y-axis, and the photopolymer is sprayed on the table, while an ultraviolet lamp emits light along the direction of movement of the printhead to cure the photopolymer on the building surface to complete one layer of printing (Figure 5). The distinctive feature of this technology is the diversity of materials, from thermoplastics to resins and ceramics, even zirconia paste. Moreover, inkjet-based 3D printing allows for the blending of materials by printing different materials in the same position, by which it can form objects with a variety of properties. The surface quality and print resolution are particularly high.

The disadvantages with inkjet printing are: wasted expenses due to the mandatory support material, difficult post processing, slower print time, and high initial purchase price.

3. Fused Deposition Modeling [3,4]

FDM is cheap 3D printing technologies in dentistry. The filamentous thermoplastic material is heated and melted by the nozzle. is the process of building an object from the bottom up by heating and ejecting a thermoplastic filament layer by layer (Figure 6). Unfortunately, this style of printer does not print in a high enough accuracy and resolution for the dental industry.

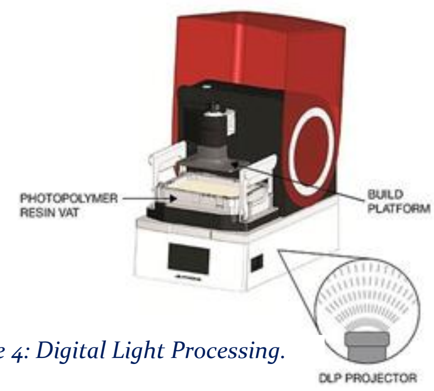
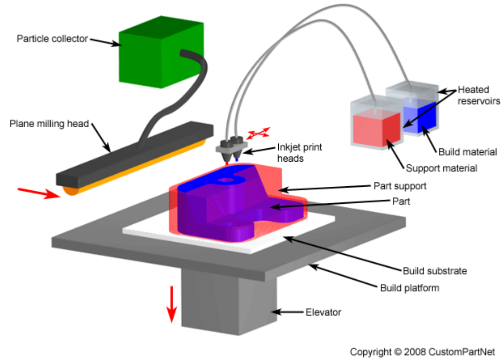
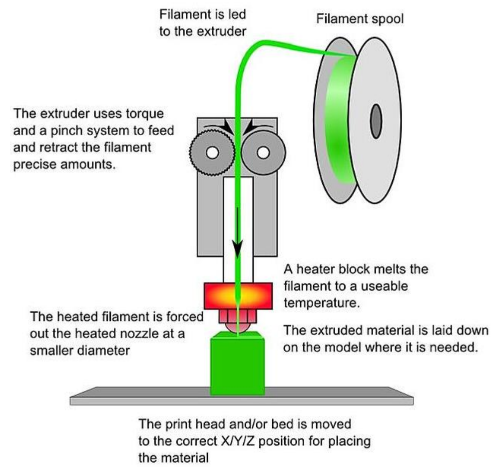


Figure 4: Digital Light Processing.



http://www.custompartnet.com/wu/ink-jet-printing

Figure 5: Photopolymerizable Inkjet.



http://reprap.org/wiki/Fused_filament_fabrication

Figure 6: Fused Deposition Modeling

- **Postprocessing**

Proper postprocessing can improve the performance of printed samples with higher cost and more time consumption. The shrinkage and deformation of resin materials have limited the development of SLA; however, the postcuring process evades this disadvantage. After curing indicates that the cured resin object is exposed to either curing temperature or above for a long time, UV and microwave postcuring can improve elastic modulus and ultimate strength of samples [3].

▪ 3D printing applications in Fixed Prosthodontics [2, 3]:

Casts and Dies

The 3D printed casts or dies are resistant to deformation and overcome the shortcomings of gypsum cast and also provide the possibility of fabrication of multiple replicas simultaneously. (Figure 7)

Figure 7: 3D printed model with removable die

Surgical Guides

These include surgical guides, pilot drill guides, and drilling templates. (Figures 8,9)

Figure 8: Surgical guide for crown lengthening

Figure 9: Implant surgical guide

Metal Frameworks of Tooth-Supported and Implant-Borne FDPs

Metal frameworks can either be fabricated by direct metal printing or by burnout and casting of the 3D printed wax/plastic pattern. Mechanical properties of metal frameworks fabricated using AM are comparable to those that are milled and better than those that are fabricated through conventional casting techniques. (Figure 10)

Figure 10: 3D printed metal framework

Prosthesis Fabricated in Ceramics and Zirconia

AM used for fabrication of ceramic structures are still evolving.

Provisional Crowns/Bridges

3D printed provisional restorations have clinically acceptable flexural strength, hardness, dimensional accuracy, surface roughness and marginal fit. (Figure 11)

Figure 11: Provisional crown and bridge

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