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History of Three-Dimensional Printing (3D)-Review

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Abstract

Although the idea of 3D printing was originally presented before the 1980s, the technology's basis was not established until the beginning of 1980s through patents. Since then, different methods have been created to imprint a vast assortment of materials. In recent years, the restorative dentistry field has profited considerably from the quick and automated three-dimensional (3D) archetypes of dental materials and restorations. Unquestionably, digital dentistry has forward actually in the last ten years, particularly with the introduction of CAD/CAM imaging and milling equipment, that have practically invented a different clinical dental procedure.

3 D printing is central to the most current technical advancement in digital dentistry. This has been especially true because major privileges that had protected miscellaneous 3D printing companies and methods for several years have expired.

They are now more reasonably priced, making them accessible to a larger range of makers and end users. Due to their rapid growth, new 3D printing techniques and commercially accessible goods are popping up in the marketplace and in academic journals.

Introduction:

It has been acknowledged that 3D printing will disrupt advanced industrial processes in the future. Considerable progress has been achieved in 3D printing approach in terms of materials, printers, and techniques. these advancements have the possible to critically modify everything from our daily lives to the widespread economy(1).

The process of turning a computer-generated model into an actual, tangible thing is known as 3D printing. The model is initially translated into a set of printer-readable triangulated coordinates, after which it is changed into a set of successive layers. Then, using either an ink-based printhead or laser optics to follow the intended pattern, a computer-controlled translation stage fabricates items one layer at a time(2). Four historical periods may be distinguished in the chronological evolution of curing procedures Figure(1). In "The Early Years (2000–2010)", digital light processing (DLP) technique is introduced. The technique of layer-by-layer printing with accuracy was introduced using this mechanism. High resolution dental models were highlighted in the second phase, "Advancements in Materials and Technologies (2011–2015)," which made use of the stereolithography (SLA) technology. The advent of the DLP 3D printer signaled the start of the subsequent phase, "Expansion of Applications (2016–2020)," which increased the number of dental uses(3).

Simplifying the definition of more widely used 3D printing technologies might lead to a classification of printing systems based on how they are made(4).

Categories Of 3D Printing Techniques

Extrusion Printing

Because of its low cost of manufacturing and straightforward printing technique, extrusion-based printing is frequently employed. Materials are extruded via a spout using a mechanical force as the initial stage in this process. After being extruded and placed, the polymer solidifies via a variety of processes, including chemical interdependence, restore of noncovalent bonds, crystallization, and Reorder the series(2).

A three-axis stage is moved by a computer to discharge a substance from a spout(5)

A second name of Fused Deposition Modeling (FDM) is Fused Filament Fabrication (FFF)(6).

Figure (2) is a thermoplastic material extrusion printing process that involves melting thermoplastic materials to create filaments that are deposited to create the required products(7).

There is less detail in the rendering when using this less expensive process, however the plastic filament (thermoplastic) is heated and placed on a moving platform before being polymerized (8).

Because the filament polymer may be heated to a semi-solid state and then placed immediately onto the print bed, FDM is the most practical method(6).

Apart from the build material, which endorses the overhanging structures throughout the procedure and aids in preserving the integrity of the structural part till it is reinforced before the upholding material is eliminated by breaching or by disintegrate via the proper solvents, FDM uses support material to create complex shaped parts(10).

Using UV light and photoinitiators based on free radicals, photo-crosslinking is one of the most used solidification techniques. Temperature changes, adjustments to pH or ion concentration, as well as combinations or other curing techniques, can all be used to cure scaffolds. However, for bioinks, crosslinking usually takes place in the presence of cells, therefore strategies that reduce adverse survival circumstances while simultaneously maximizing mechanical qualities, simulating surface design, and preserving other physical traits have gained widespread traction(11).

Various Parameters In FDM

The literature analysis reveals that several criteria have an impact on the level of excellence of the FDM prototype created(12). explains these parameters in the following way

1- Direction : direction of construction, also known as orientation, describes how inclined the part is On the construction platform with regard to the X, Y, and Z axes, where the Z axis runs along the direction of the part construction and the X and Y axes are believed to be parallel to building platform .

2- Thickness of the layer: This is pointed to the layer thickness that a spout deposits and is dependent on the kind of spout that is being utilized .
3- Raster angle: This is the raster's orintation with respect to the costruction table's X-axis .
4- Raster to raster void (air void):It is the void among two neighboring raster on the same layer.
5- Part raster width: This is the raster pattern width that is used to fill in the interior spaces between part curves .
6- Spout speed and temperature (6).

Because the spout in FDM prints directly onto the substance layer by layer, it is a contact printing technique. As such, the spout and bed should be spaced uniformly apart across the bed. Inaccurate bed calibration results in warpage and the printer striking the bed and prints at two or more separate locations on the platform/bed of printing due to an unequal distance among the spout and the bed(6).

Although the 3D printing spout's diameter may be altered or replaced, doing so affects the part's quality and manufacturing time.Utilizing a spout with a wide hole diameter speeds up the process of producing an item(13).

Additionally, it has been shown that in FDM 3D printing, raising the spout diameter improves the mechanical qualities and product quality(14).

The acceleration at which the spout travels when depositing or printing melted filament

onto the build platform is known as the spout speed. Despite a shorter print time, it has a considerable influence on the printed items' dimensional precision.For instance, it is stated that when the spout velocity is increased from 30 mm/s to 90 mm/s, the wall thickness of the ring-shaped design increases from 2.00 mm to 2.17 mm(15).

The level of heat at which a substance melts and extrudes from a spout is known as the spout temperature. It greatly impacts the framework and buildup characteristics of the 3D printed items.(Triyono et al.,2020). For example, it is claimed that changing in the spout heating degree from 370 ◦C to 390 ◦C, the associated intensity will raised up (from 89.9% to 92.8% for PEEK)(16).

Injekt Printing

For liquid phase materials, the use of inkjet printers is a material-conserving deposition method(17).

The process of inkjet printing produces fluid droplets, or ink, that are deposited in a predetermined pattern onto a substrate. A picture is produced when colorants are present in the fluid. With time, inkjet technology for printing has developed into a crucial tool for the graphics printing sector as well as a plethora of recently developed industrial and medicinal uses(18).

The idea behind it is very much the same as with a traditional inkjet printer. For photopolymer jetting, a liquid photo monomer is utilized instead of ink droplets, while for material jetting, wax is employed. The wax then hardens thermally on the construction platform or the resin monomer is solidified in layers by UV light. The building platform descends by one Z grade after each layer, in line with the other printing operations, and the subsequent layer may then be applied. Multiple print heads can operate at the same time thanks to this procedure. Consequently, it is possible to create things with various compositions, hues, and attribute gradients(19).

The procedure basically uses piezoelectric action to rapidly and quasi-adiabatically reduce the chamber capacity in order to expel a set amount of ink out a spout. When applying an extrinsic voltage, a liquid-filled chamber shrinks, creating a shockwave in the liquid, which leads to shoot out a drop of liquid out of the spout(17).

Piezo inkjet technology is unusual in that it can deposit a broad range of materials in precisely defined patterns on a variety of surfaces. In order to meet the ever-increasing and ever-changing specifications for today's inkjet technology, it is imperative to have a basic awareness of the main procedure. The physics underlying the sequence of events in the inkjet printhead operation include the pairing of vocal field through the ink tubes to covert the defects into pressure wave, the pairing to the fluid dynamic field in the spout to change the vocal power into the moving and surface energy of the droplet formation method, and the two-way pairing from the electrical to the process of digestion domain by the piezo electric actuator(20).

Printheads And Drop Formation

Drop-on-demand (DOD) methods and ongoing inkjet printing are the two basic tenets of droplet generation. In DOD process, the droplets are formed on the need and flowing towards the center, in contrast to continuous inkjet printing where drops are created continuously due to the instability of the Rayleigh-Plateau of the jet and sorted afterwards by shifting them and return back just a small of them into the substrate and recycling the rest(21). It is necessary to precisely deposit each and every droplet in order to achieve the desired 3D microstructure(22).

Numerous optical techniques are used to measure the drops that emerge from the spout. The laser-induced fluorescent stroboscopic recording device or Ultra high speed cameras (up to 25 Mfps) are used to measure the droplet creation with pl-sized particles at elevated duplicated rhythm (up to 100 kHz). Numerical simulations using the way of fluid bulk, greasing theory, and lattice Boltzmann indicate an excellent association with the investigations and supply further details about the breakup mechanisms and the distribution of mass and velocity(17).

Drop size modulation is a crucial inkjet printing method. Using the same printhead and ink, up to eight methods are found to vary the jetted drop volume. First, by altering the fill-before-fire level and pulse width, drop size modulation may be accomplished. Next, by pre-actuating the meniscus motion or by firing bursts of numerous drops in synchronization with the channel acoustics, increasing the bulk of drops can be achieved by acoustic resonances. Break pulses can be used to minimize droplet size, particularly in conjunction with a satellite drop production process. Lastly, drop formation resonances and meniscus resonances can be applied(23).

The performance of the printhead can be adversely affected by air bubbles and spout plate wetting. In a prototype silicon-based printhead with a glass spout plate, high-speed imaging triggered by alterations in the ink channel acoustics was used to observe the bubble formation, translation, and growth.It is evident that an ink impurity interacts with the oscillating meniscus to cause the bubble to nucleate(24).

However, an ink film, which typically has a thickness of around 10 nm, on the spout plate (also known as spout plate wetting), can also be important. The spout plate's inkophilic properties facilitate its emergence. On this film, a flow may form, carrying dirt particles in the direction of the meniscus before distorting it and perhaps causing bubble entrainment. The spout plate flow may originate from several sources. One is just air-induced flow from ink jetting. Since it creates a Marangoni flow, a concentration gradient in the film may also be the source of this kind of flow.These gradients may arise from the selective absorption of one or more ink components, or they may arise between nearby spouts that jet distinct inks(21). Below is the steps of events and physical process of inkjet printing figure (3). From the ink–piezo generator reaction (left), by means of ink puffing (midst), to the reaction between the ink and the collecting base (right). Each number refers to the seven prime dynamics of fluid provocation pointed in the sections of this article: (1) the course and acoustics in the inkjet printhead; (2) vesicles that are trapped into the spout and interrupt the printing procedure; (3) the wetting dynamics on the spout plate, including the meniscus, drips, and film dynamics; (4) the buffing procedure, involve satellite formation; (5) the droplet effect and spreading on the substrate; (6) droplet coherent, drop–film reaction, and ink–paper interaction; and (7) the vaporization and solidification of the ink(21).

Selective Laser Melting/Sintering(SLM/SLS)

As seen in Figure(4), the SLM technique is intended for melting and fusing the metallic powders together using a high-power density laser. SLM and SLS share a similar technique, and SLM is regarded as a subset of SLS. SLM can completely melt metal into a solid three-dimensional structure, unlike SLS. But the SLM process usually calls for the support structure addition, whose primary purpose is to stop internal shrinkage stress development, which can cause issues like part wrapping by joining the molded and unformed parts. This can effectively reduce the shrinkage and preserve the molded part's stress balance(25).

After that, the fused particles is going to be solidified to create a three-dimensional structure. The three primary parts of the laser melting/sintering system are the powder bed, the spreading platform, and the laser system (laser and scanner). A slot feeder and a roller/scraper blade are used in the spreading system to evenly distribute the powder onto the construction platform. The system's three-dimensional component is processed as planes, with each plane standing in for a vector, which is the fundamental component of laser scanning(26).

Similar to FDM, the G-code produced by the slicer controls the laser's movement. The component is removed from the platform once the felting process is finished and the unfelt powder is eliminated(6).

In SLS, the energy density is one of the extreme important parameter that determines the whole process and component property Equation (1). The quantity of energy per unit volume is stored in a certain system or area of space(27).

$$ED = p/vh \times d/h \quad \text{-----}> 1$$

where v is the velocity of scanning, h is the hatch spacing, d is the diameter of the laser beam, P is the laser power, and ED is the energy density. Therefore, the defining process factors accountable for the component are the hatch distance, laser scanning speed, laser power, and preheat temperature(28).

Stereolithography Approach (SLA)

The first 3D printing technique to be sold commercially was stereolithography (SLA) as shown in figure (5). Utilizing highly cross-linked polymers and photoinduced polymerization, this fast manufacturing process produces multilayer structures(30).

The first essential stereo lithography (now commonly known as SLA) AM work was introduced in the 1970s. First, Swainson provided a patent for a technique that uses two intersecting radiation beams creating 3D structures by photochemically cross-linking or degradation of polymers. Next, Herbert presented a method for building solid objects layer by layer using photosensitive polymers. although, most people believe that Charles Hull's contributions initiated the current era of stereolithography(31).

SLA stands for localized photopolymerization, a process that occurs in a bath of liquid monomers, oligomers, and photo-initiators and is initiated by ultraviolet (UV) light(32).

Vat polymerization, in which layers of a fluid precursor in a vat are successively subjected to ultraviolet (UV) light and then selectively solidified, is another definition of SLA(33).

The platform motion and laser movement types may lead to distinct classifications for this technology. Regardless of these classifications, the process of printing involves three primary stages: exposure to light or laser, shifting of the platform, and replenishment of resin(34).

The capacity of stereolithography printers to generate structures with resolutions as low as 10 microns has contributed to their increasing popularity in recent years. SLA monomers begin to form polymer chains when they come into contact with UV light. In the resin layer, polymerization produces a pattern that forms the foundation for later layers(35).

Digital Light Processing (DLP)

DLP is a type of 3D printing that use UV light to polymerize materials and build pre-designed structures(35). Digital light processing (DLP) creates 3D structures by selectively photopolymerizing resin layer by layer, using the same principles as SLA as shown in figure (6), It has many of the same benefits and drawbacks(37).

The prime distinction among SLA and DLP is the source of light; the cross-sectional image is formed by either an arc lamp or a semiconductor chip having a matrix of small mirrors, called as digital micromirror device. every mirror stand for one or more pixels from the projected image. The count of mirrors represent the projected image's resolution. Under safelight circumstances, light from the DLP projector flows via a UV clear glass, projecting the image into a liquid photopolymer tank. In this technique, the physical item is return upward from the liquid resin instead of down and deeper into the liquid photopolymer, this technique is carried on until the 3D item is finished(38).

Because the printing procedure occurs in a liquid medium, this technique terminates the demand for the use of any support materials in the manufacture of porous or cavity structures, and has thus been used to produce lattice metamaterials, pneumatically actuated soft robots, and many other parts and devices constructed with trusses or cavities(39).

The advantage of adopting DLP technology is that it only requires a single laser irradiation to produce a full layer, in contrast to the SLA technology, which requires progressively scanning the layer using a laser beam(40).

This light-curing approach addresses the trouble of slower rates in SLA printing by curing a whole layer with a single flash of light. The main downside of this technique, however, is the dimension of each voxel, which is basically what a "pixel" is to resolution, but in a 3D perspective result, it has a unique way in translate the voxel, when they voxel increase in their size its get less resolution in contrast to smaller size which is give a higher resolution.

DLP printing is yet producing clinically accepted interim and constant restorations of crowns, removable prosthetic devices, and fixed partial dentures. Overall, DLP printing provides practitioners with novel time-saving options and more predictable treatment outcomes(3).

Running two DLP projectors together with HD quality in tandem creates a seam or "joint" on the construction podium because of use of two source of light. This combined inhibits the printing of items thats extend over the Progression field(41).

Because stereolithography is multilateral enough to produce a diversity of highly complex 3D structures with high accuracy and at an affordable price, more and many substances that developed for a wide zone of applications, like smooth robotic actuators, sensors, medical implants, microfluidics devices, in addition to energy storage components(32).

Because it contains more than 50% filler, 3D printed material may now be utilized for permanent reconstruction. The resins applied in vat polymerization should achieve the rheological and light permeation criteria from this production process. Increasing the filler content in resins will raise their glueyness and, hence,tardy the pace at which they level. Furthermore, filler particles may suck light, which lead to less amount of layer thickness can be polymerized(42).

Liquid Crystal Display (LCD)

The main difference between digital light processing(DLP) and liquid crystal display(LCD) is the image processing, In the LCD 3D printing technology, the liquid crystal screen serves like an picturing system. When an electric domain is given to a liquid crystal, will changes its molecular structure and prevents light from passing through(35).

On the display, each pixel represents a tiny cell containing particles in a liquid-crystal state. To create a veil, each pixel may be adjusted to either clear (passing) or masked (non-passing) by altering the direction of the particles. The resin in LCD is in frontal contact with the screen,

which makes it easier to fit the printed pixels to the form of the beam profile(43).
Figure (7) depicts the conventional construction of an LCD SLA 3D printing method and the processing phases. It includes an LCD screen for presenting sliced pictures, a non-adhesive vat for storing uncured resins, and a motorized metal construction plate for holding printed prototypes. LCD stereolithographic (SLA) printing is a bottom-up 3D printing technique that offers various benefits over the top-down digital light processing (DLP) SLA 3D printing technology. including the reduced amount of resin needed through manufacturing and the ability to achieve precise vertical resolution and a quicker curing time, due to the fact that the base of the resin is an oxygen free layer, which enhance the photocuring process(44).
In LCD 3D printers, light is emitted in parallel via the LCD screens and onto the build area. Furthermore, the light is not magnified by any lens or other technology. As a result, using an LCD 3D printer does not cause pixel distortion. LCD printers vary from Laser-SLA printers primarily in their speed. LCD printers are as fast as DLP printers, but they are less expensive due to the cheap manufacturing cost of the materials required to make them. This represents the key reason why these printers are getting more popular(45).

Conclusion

This is a brief history about 3D printing technique and their process in miscellaneous life needs still we needs to clarify their pros and cons and also their applications and limitations.
3D printer may lead to a revolution in the worldwide due to their duarability, cheap, time saving and light weight. Also its gives wide area for resin lover to generate 3D printing objects from their imagination depending on Computer aided design-computer aided manufacture (CAD-CAM).

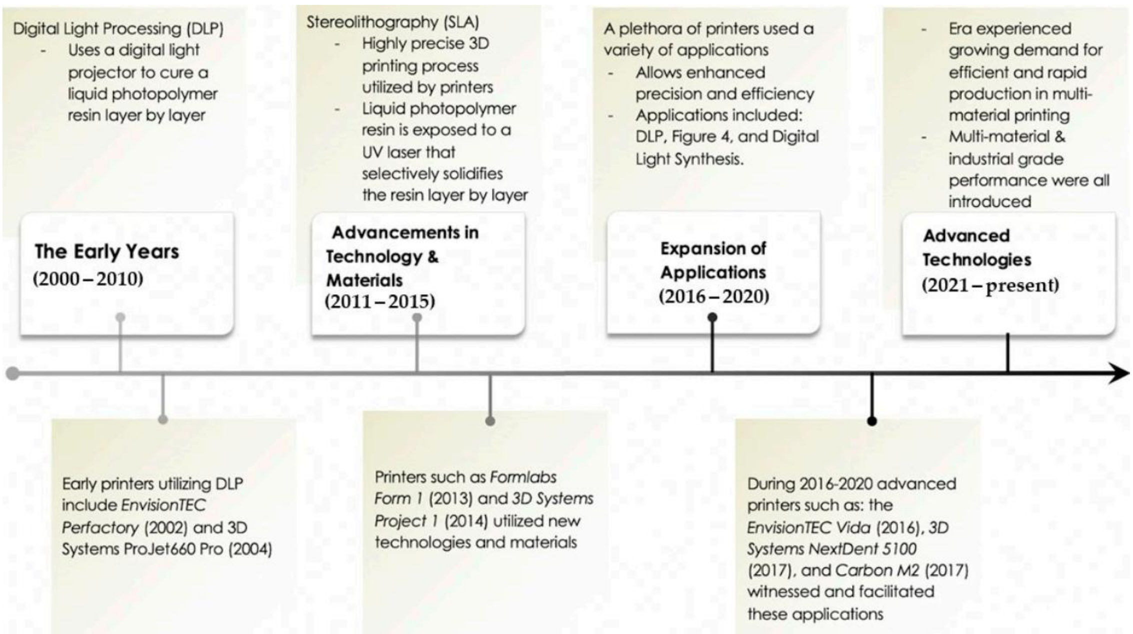

Figure 1 : chronical timeline of 3D printing(3)

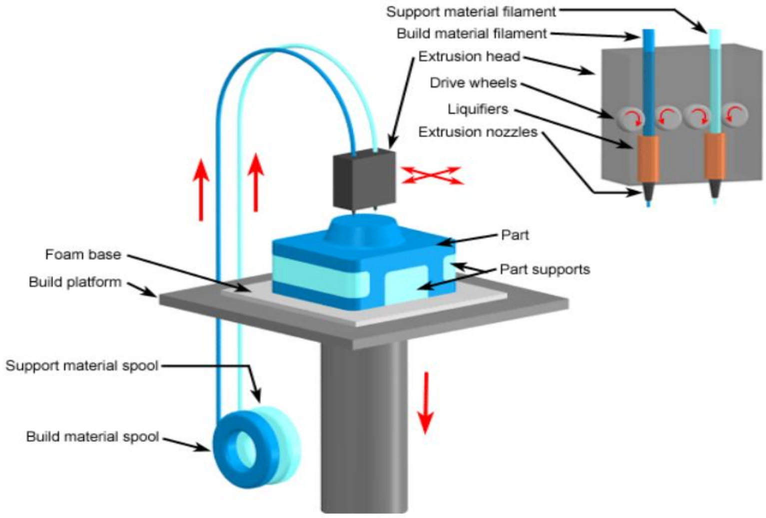

Figure2: Schematic Representation of FDM Process(9).

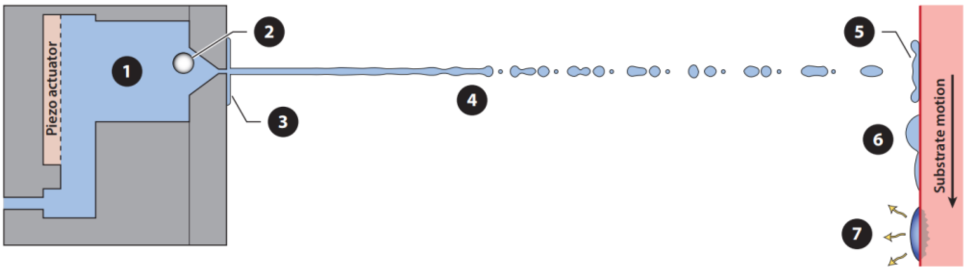

Figure3: scheme of the sequence of episods and physical performance in inkjet printing,

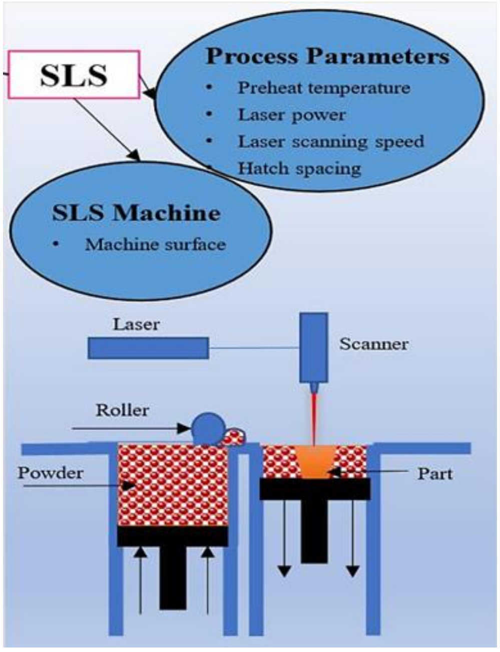

Figure 4 :Overview of the process parameters of SLS printing methods(6).

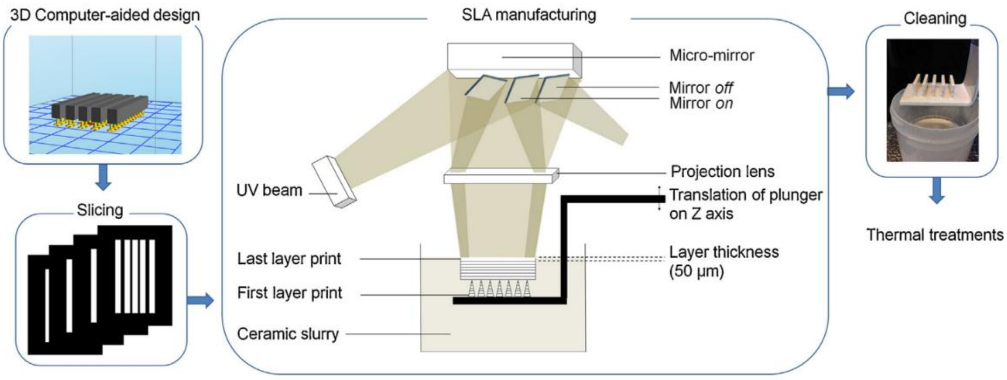

Figure 5: full steps of stereolithography 3D printer process(29).

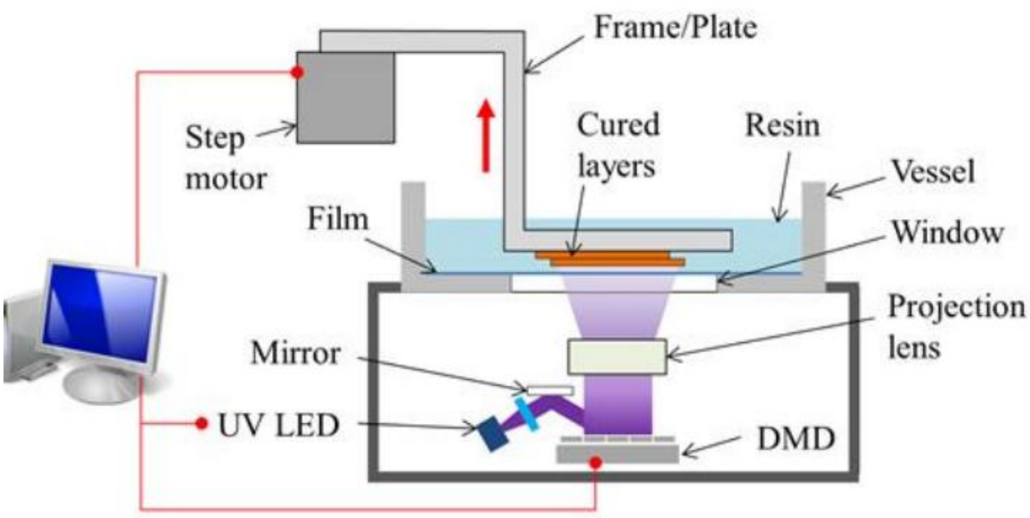

Figure 6 : scheme of DLP 3D printer parts (35)

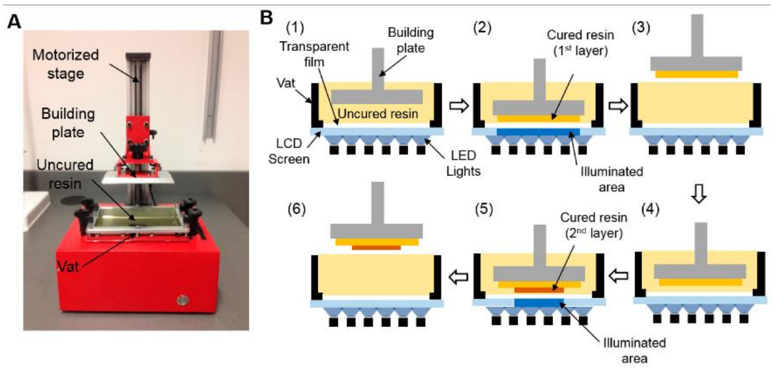

Figure 7: machine and Workflow of LCD sterolethography (A) picture of a specially-built LCD SLA 3D printer. (B)workflow sequence of the LCD SLA 3D printer(42).

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