



A Review of the Stereo lithography 3D Printing Process and the Effect of Parameters on Quality

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Abstract

Stereo lithography (SLA) three-dimensional (3D) printing process is a type of additive manufacturing techniques that uses digital models from computer-aided design to automatically produce customized 3D objects. Around 30 years, it has been widely utilized in the manufacturing, design, engineering, industrial sectors and its applications in dentistry for manufacturing prosthodontics are very important. The stereo lithography technology is highly regarded because it can produce items with excellent precision especially when selecting the best process parameters. This review article offers a useful and scientific summary of SLA three-dimensional printing technology and its brief history. The specific type of 3D printers which is SLA type based on light curing resin and material overview is also presented. Moreover, the survey was conducted to gain substantial knowledge of the various advantages and disadvantages of SLA 3D printing. According to this study, a summary has been specified on the accuracy of SLA 3D printers and various factors that affected its accuracy and dimension measurement namely layer thickness, normal exposure time, bottom or top exposure time, post processing and room temperature. The majority of works in the literatures conducted till date are on improving the physical part attributes like dimensional accuracy and surface roughness but the improving of the mechanical properties have received less attention and need more focusing in the future works.

Keywords: Additive manufacturing, bottom or top exposure time, 3d printing, normal exposure time, resin, stereo lithography, UV.

1. Introduction

Additive manufacturing (AM) technologies are generally called three-dimensional (3D) rapid prototyping printing processes. Based on computer-aided design (CAD) digital model, a group of techniques that permit the layer by layer construction of complex 3D shapes out of a variety of standardized materials, including solid, liquid, and powder [1, 2]. The flexible design of such a process increases its capacity for manufacturing a wide range of functional products [3]. Additionally, it can quickly produce one-off and small-batch components, fresh samples, and goods with complicated shapes, molds, and models [4].

Stereo lithography is recognized as the first commercial rapid prototyping device for what is commonly known today as 3D printing. The 1970s saw the introduction of the first significant stereo lithography (now popularly known as SLA) AM work. Swainson [5] offered a patent for a technique that makes use of two intersecting radiation beams to photochemically cross-link or degrade polymers to create 3D structures. Then Herbert [6] presented a method for layer-by-layer construction of solid things using photosensitive polymers. However, the majority of individuals consider that Charles Hull's [7] work marked the beginning of modern stereo lithography. His theory (Figure 1) proposes that photosensitive liquid materials that ultraviolet

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(UV) light can cure are used to layer by layer create 3D creations [1]. Hull invented a 3D printing technology and obtained a patent for stereo lithography (SLA). Hull then formed the company 3D systems, which presented the first 3D printer (SLA-250) to be sold commercially, in 1988 [4, 8]. Today, over 75% of dental applications for 3D printing employ light-curing technology, and light-curing resins are often used as fillers and restorative materials in dentistry. The global standard for dental prostheses is moving toward digital dental medical technology [9]. The use of SLA 3D printing in dentistry can aid in the provision of more inexpensive dental equipment. Since stereo lithography is adaptable enough to produce several very complex 3D objects with great precision and a low costs. An increasing number of materials have been created by SLA for a wide variety of applications, including soft robotic actuators, sensors, microfluidics devices and energy storage components [1, 10]. Medical implants are the most important applications of SLA such as dental prostheses [11]. This review discusses the stereo lithography process including its technology, material overview, advantages, disadvantages, SLA printer parameters. The accuracy of SLA printing process and the factors affecting will be discussed in detail.

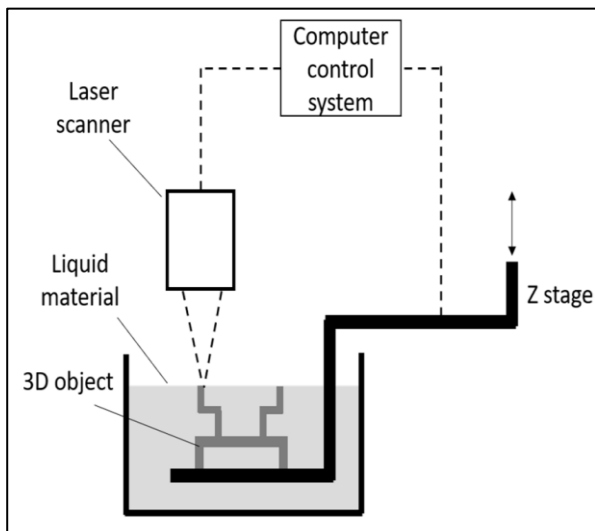


Fig. 1. Stereo lithography setup [1].

2. Stereo Lithography (SLA) 3D Printing Technology

Stereo lithography has made significant progress, and many methodologies for stereo lithography systems have been developed. Huang et al. [1] categorized the described technologies

into four generations, with Hull's work being the first generation stereo lithography, which creates 3D items by scanning a laser beam over liquid materials. To overcome the limitations of poor efficiency, the second generation technique was used, also known as projection stereo lithography, uses photo mask technology to cure each layer concurrently. Tumbleston et al. [12] developed third generation stereo lithography in 2015. They developed a continuous liquid interface production (CLIP) technology that allows for far faster print speeds than earlier approaches, allowing them to make components in minutes rather than hours. Recently, a volumetric stereo lithography technique was developed, also regarded as the fourth generation. [1].

An extrudable thermoplastic filament is substituted by a vat of a liquid UV curable photopolymer in the somewhat more sophisticated additive manufacturing technique known as SLA. At the moment, SLA method is the primary foundation for big industrial photocuring 3D printing machines [13]. The SLA three dimension (3D) printer uses an ultraviolet laser beam to solidify an acrylic photopolymer at a specific previously predetermined spot [14]. Figure (2) shows the stereo lithography apparatus which consists of the following components: (A) low UV radiation laser source, (B) when the laser beam hardens bottom layers to top layers during manufacturing, an elevator raises the construction platform (illustrated in G), (C) for the purpose of treating the liquid photopolymer's surface, lenses focus an intense laser beam from a UV source, (D) the beam is redirected by the X-Y scanning mirror so that it descends vertically into the liquid photopolymer instead of traveling horizontally (the deflection of the mirror depends on the desired 3D model), (E) photosensitive polymers harden when they come into touch with the laser beam, leaving untreated polymers liquid, (F) a big container called a "vat" that holds photosensitive liquid, (G) build platform is each layer of photosensitive polymers represents a cross section of the final 3D object and is created layer-by-layer from bottom to top, (H) liquid photopolymer, (I) layered part is a combination of solidified photopolymer layers, (J) the sweeper is recoats the stacked part's surface with a liquid photopolymer resin as the build platform (in G) descends after the solidification of each layer, (K,L) the sweeper moves to the right and left (in K) while the construction platform moves up and down (in L) [15].

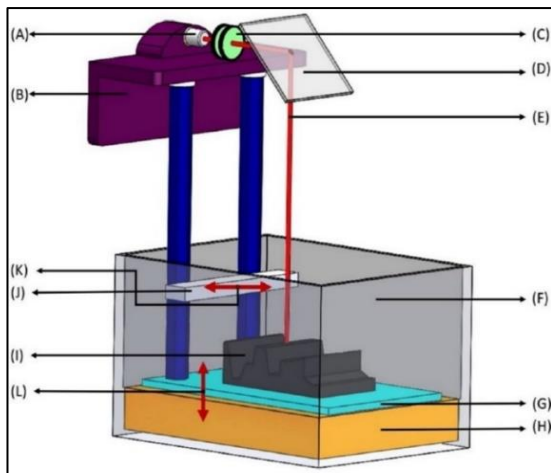


Fig. 2. Stereo lithography apparatus. [15]

Typically, the liquid resin is scanned by the laser beam employed by SLA machines, which causes it to harden. Usually, the laser beam is visible from the top above the resin tank. When the platform is lowered into resin, the resin's surface is covered by a thick layer of the platform's surface. After the layer of resin has dried and solidified, the platform falls a certain distance. Layer by layer, the solidification procedure is performed to produce a solid 3D part. The laser beam then fills up a two-dimensional cross section of the model by following its edges. The fabrication process of stereo lithography is shown in Figure (3) [1]. The model is completely cured in a UV oven after printing in order to completely eliminate resin residues [14].

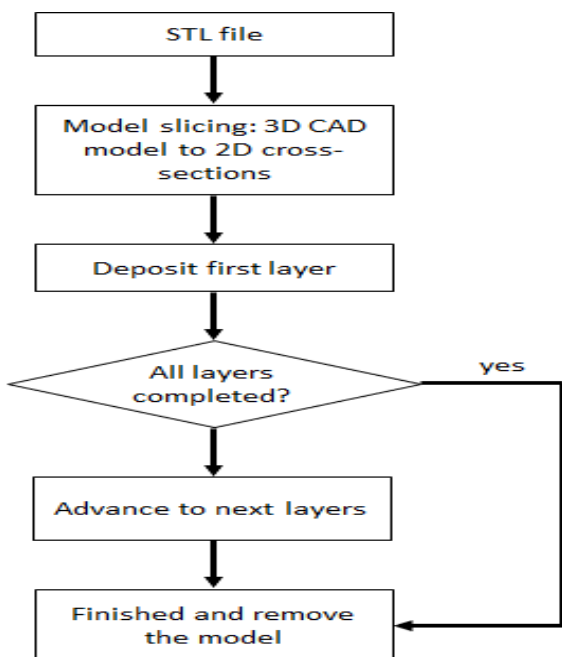


Fig. 3. Fabrication process of stereo lithography [1].

3. SLA Material Overview

SLA uses a variation of materials with a wide range of characteristics including soft, transparent, very stable, and even heat resistant materials [14]. Photosensitive resin is the substance utilized in the photocuring process for 3D printing. The light wavelength and the method of printing would determine the photo curing procedure [13]. Conventional epoxy, acrylate resins, or thermoplastic elastomers make up the majority of the materials utilized in SLA. First monomers were blends of multipurpose acrylates that resulted in cross-linked resins. The low viscosity of this composition helps the liquid spread smoothly. It also has high photosensitivity, oxygen inhibition, low critical energy, controlled mechanical properties, and is relatively insensitive to changes in temperature and humidity [16]. Polymers make up the majority of the 3D printing materials used in dental restorations, which replace lost teeth and tooth structure. In contrast to ceramics and metals, the chemical and physical properties of polymers are characterized by elasticity and tensile strength, which may offer the high-performance and long-lasting qualities required for use as a dental restorative material [11]. The transverse strength and elastic modulus of the resin were both significantly impacted by a change in the polymerization temperature [17]. The environment to which resin is exposed affects its mechanical properties, which is why they may degrade in the oral environment in addition to being affected by their chemical composition [18]. Three-dimensional printing technology have created a variety of dental prosthesis using polymer materials in orthodontic treatment, including denture bases, fake teeth, temporary crowns, bridge and crown facings, and implant caps. Studies have shown that polymers are used in 3D printing technology for dental applications, such as the manufacturing and intervention of implant fixtures, maxillofacial reconstruction, and metal bridges [11]. The majority of resin compositions contain inert dyes, which absorb incoming light and improve polymerization control. Additional additives like surfactants and diluents or other stabilizers may be added, particularly when employing filled resins. The Photo curable resins for SLA all have the same essential components (Figure (4)) and they are summarized as follows [19]:

1. Precursors: The SLA precursors are liquid molecules that, when exposed to light, may link

together (i.e., polymerize) to create a solid three-dimensional network.

2. Photoinitiators (PIs): it is a resin component reacts to light. When the appropriate wavelength of radiation is applied, it gets activated and prepared to initiate the curing reaction. A suitable PI must be chosen depending on the kind of precursor being employed. The kind and amount of PI employed can have a major influence on the reaction's kinetics, the amount of light used, conversion, cross-linking density, and, to a certain degree, the mechanical properties of the printed components.
3. Absorbers: A light absorber, which lowers light's penetration into the resin and restricts the depth to which the resin can be cured, is another element that is important to the majority of SLA processes.
4. Filled resins: SLA has been used to fabricate metal or ceramic materials by mixing resins with powder, printing the parts, and then sintering and debinding the printed specimens. The organic resin components are dissolved by pyrolysis during the debinding process, and the presence of a high filler content prevents defects like cracks and shrinkage from occurring.
5. Additives: For slurries to have a longer shelf life and to remain stable throughout longer printing processes, rheological additives and stabilizers are required.

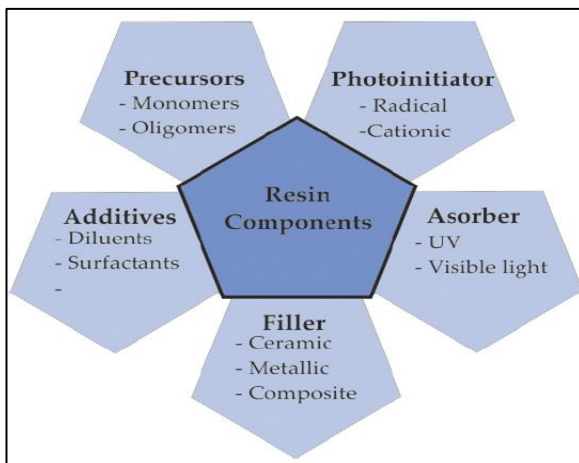


Fig. 4. Materials of Resin in SLA [19]

4. SLA 3D Printing Advantages and Disadvantages

4.1. SLA 3D Printing Advantages

The followings are typical advantages of SLA process:

- SLA has a well-developed, reliable printing process, and a wide range of equipment providers [13].
- SLA 3D printers can produce complex forms with fine details at reduced material costs when utilized in large quantities [10].
- SLA is adaptable to variable material selection, highest resolution, accuracy, suitable for fine details and functional prototyping and highly versatile material selection [14, 20].
- SLA offers great material utilization, significant cost advantages, the ability to produce specific goods at scale on demand, and relatively quick technological advancements [4, 21].

4.2. SLA 3D Printing Disadvantages

The followings are the limitations of SLA process:

- Resin has a limited shelf life, a short vat life, can't be heat sterilized, dirty, can cause skin sensitization, and requires expensive technology [10].
- Since the curing rate depends on how rapidly the laser beam moves and the size of the model affects that speed [13].
- SLA is presently the only photo curing three dimensional printing technique that can print big scale models, however, it has a low printing rate [13].
- Volume shrinking is a drawback of photocuring 3D printing, and researchers are working to eliminate it [13].
- The difficulties in handling liquid resin due to its sensitivity to extensive UV light exposure and its poor mechanical qualities as a result of brittle material and curling [14].

5. SLA 3D Printers Parameters

Although SLA technology has advanced quickly and attracted a lot of attention lately, it is still in the early stages of development, where several academics have discovered answers to challenging real-world issues. Specifying, assessing, and managing process factors to produce precise, high-quality products has been the major focus of research efforts. Because of the interrelations between variables and nonlinear relationships between final outputs and parameters, determining and optimizing process parameters is a very difficult procedure [22].

5.1. Layer Thickness.

Thickness of each slice of the portion that builds on the preceding layer is known as the layer thickness [23]. The most suitable layer thickness setting affects SLA process accuracy and performance. The building time decreases with the number of slices (and layer thickness), but accuracy decreases [24]. It has been shown that when printing samples with low layer thickness using SLA technology, the accuracy and strength of the sample improves [25]. Figure (5) shows the built layer thickness of a printed part.

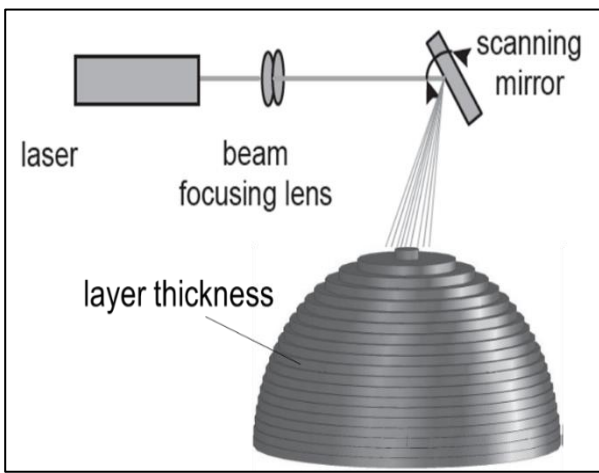


Fig. 5. Layer thickness in SLA.

5.2. Normal exposure time

The normal exposure time is the precise amount of time that each layer is exposed to UV. The bending strength and chemical bonding of the printed resin were modified by the exposure duration. When exposed to UV radiation, printed

items' surface roughness is also impacted, leading to two surface impacts. On the one hand, the formation of cracks is affected by the UV exposure time [26]. Also, the shrinkage of the photo curable resins is affected by exposure time, which increases with the increasing of curing time leading to less accuracy [27].

5.3. Bottom or Top exposure time

They are the UV exposure time of the first layer thickness at the first layer fabrication between the platform and the bottom or top of the resin container Figure (6). Bottom or top exposure time are similar to exposure time, but only applying to the first few layers of 3D prints. The bottom or top layers of the print require more focus because they form the foundation for the whole print. The bottom or top surfaces of the exposed and curing layer bond with the previously cured layer during the manufacturing process of the free surface SLA technology [28, 29].

5.4. Build Orientation or Angle

The choice of construction angle is crucial since it influences the amount of support structures required, which may have an impact on the precision of the created components. Rotation of the crown from a 90 degree build angle to a build angle of 180 degree increases the self-support surfaces and therefore decrease the number of support structures [30]. The construction angle setting has an effect on the biocompatibility, product accuracy, and material qualities [4]. Figure (7) shows the orientation of 3d printing of different building angle of prosthesis.

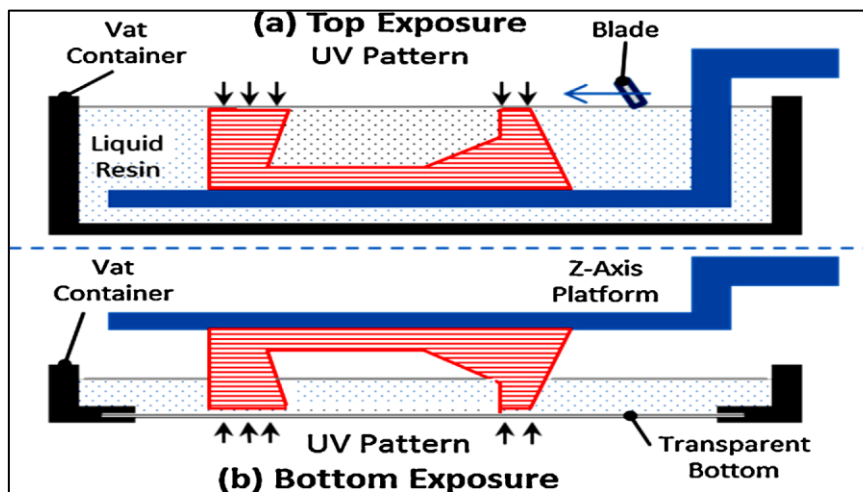


Fig. 6. (a) Top exposure vs. (b) bottom exposure [29]

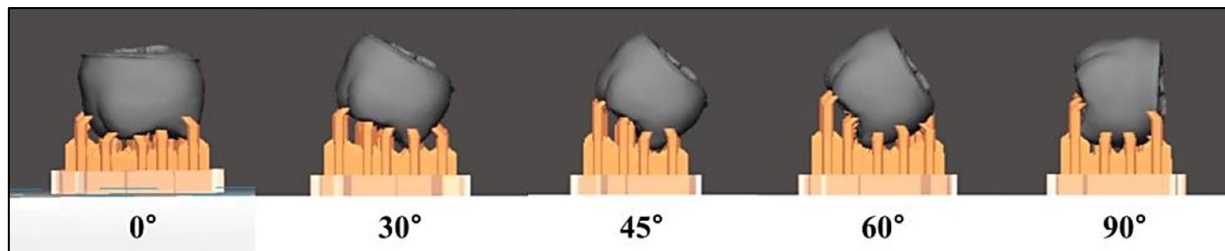


Fig. 7. Different 3d printing angles [30]

5.5. Post Processing

The performance of printed samples can be improved with proper post-processing, but it will cost more and take more time. The development of SLA has been constrained by the shrinkage and distortion of resin materials. However, the post-curing procedure gets around this defect [28]. After curing, the resin item has been subjected to temperatures above curing temperature for a considerable amount of time. Enhancing the elastic modulus and ultimate strength of samples can be achieved by using UV and microwave post-curing. The strength of the sample can also increase concurrently with the expansion in laser power [4, 26].

6. Effect of SLA 3D Printers parameters on Accuracy, surface integrity and strength

Several researchers have attempted to enhance the dimensional accuracy and surface integrity of SLA printing. One of the primary sources of inaccuracy in the SL process is the significant amount of shrinkage experienced during the post-curing phase [27]. As a result, the extended light exposure might result in a local temperature rise or local polymerization, which could lead to local stress or defects. Also, according to a research by Kavin Kowsari et al. [31] solidified layers' breadth and height rose less linearly as exposure duration increased. Dimensional accuracy in 3D printing is complex and is influenced by a number of variables, including printing technology, post processing techniques, the use of support material, and part orientation [32]. However, one of the main reasons why the prototype was not accurate enough was the resin's volume shrinkage during photopolymerization [28]. Also, the model is forced to change as a result of the peeling process, which involves removing the resin from the vat's bottom. Additionally, the total number of errors made at each stage of the manufacturing process,

containing radiological imaging, image segmentation, the STL file generation, the STL post processing, STL file slicing for the printer control file, 3D printing, and post-processing, affects the accuracy of a functional 3D model. All these steps are strongly reliant on machine, software, ultimately and user [14]. Additionally, as the stereo lithography apparatus (SLA) printer's build platform descended into the resin tank to create a fresh layer, the cup could trap air and resin, resulting in structural flaws that jeopardize dimensional accuracy [33]. The SLA technique's accuracy is sufficient to print items with complicated structures and small sizes [13]. However, the selection of the SLA process variables to accomplish the desired results established by users is still a challenging work. The selection of the process parameters is also known as the establishment of the building strategies or building setups. The qualities of the parts produced by the SLA printing machine, such as the dimensional accuracy, the surface finish, the tensile strength and the build time are often impacted by these process parameters [34]. The development of SLA's accuracy has always been a fascinating case for researchers. Different strategies and techniques have been employed to discover a successful solution to advance SLA dimensional accuracy. Jayanthi et al. [35] explored the impact of SLA process parameters, as well as two alternative writing techniques (the hatch and the weave), on the curl distortion of produced components. A twin-cantilever test piece was also proposed. They came to the conclusion that the four key factors are the layer thickness, the hatch spacing, the fill cure depth, and the hatch over cure. Additionally, they discovered that the weave style distortion is significantly larger than hatch type. Diane A Schaub et al. [36] listed the numerous stereo lithography process controls and determined that the four following factors are the most important ones that affect the end part's dimensional accuracy namely layer thickness, spot overlap, boundary over cure, and part orientation.

Additionally, they examined their impact and relative importance on dimensional accuracy and came to the conclusion that layer thickness and component orientation play a substantial role in dimensional error. Onuh and Hon [37] tried to adjust build settings for better stereo lithography surface finish. In their experiments, the following construct characteristics were taken into account, namely, layer thickness, hatch spacing, hatch style, hatch over cure, and fill cure depth. In order to identify key process factors (Layer thickness, Hatch spacing, Overcure, Blade gap, Position on the build plane), Zhou et al. [23] managed an experiment utilizing specially designed components produced by SLA 250. in SLA dimensional accuracy. The results suggest medium layer thickness for good reduction of the dimensional error. Lee et al. [38] created 140 of samples using various setup settings (layer thickness, hatch overcure, and hatch spacing), produced customized H-shaped pieces using SLA 250, and measured 5 points. Also, they suggested combining input parameters and output measurement data to train a neural network to forecast the dimensional accuracy of SLA components. The trained network can predict the dimensional errors with a respectable level of accuracy, according to test findings on its performance. K. Chockalingam et. al. [39] Studies on the stereo lithography process that are listed focus on identifying the variables, namely the layer thickness, the hatch spacing, the hatch style, the hatch over cure and the fill cure depth that might influence the shrinkage rate. K. Chockalingam et al. [40] made an effort to discover the process variables such as layer thickness, post-curing, and orientation that affect the strength of components created using the SL method, optimizing the parameter values, and developing an empirical regression equation between the tensile strength and their influencing parameters. The findings showed that orientation, post-curing time, and layer thickness have a significant impact on the part strength. The process parameter like orientation has the biggest impact on the part's strength. Additionally, layer thickness of 0.1 mm, post curing time of 60 min, and vertical orientation are the optimum combinations of process parameters. Campanelli et al. [41] tried to find the factors namely, layer thickness, hatch overcure, hatch spacing, border overcure, fill spacing and fill cure depth that lead to the best accuracy of the printed parts in the SLA process and found that best accuracy was gain with low value of layer thickness. Chockalingam et al. [42] studied the effect of layer thickness, orientation, and post

curing time on strength of part parts made by SLA. They showed that layer thickness has the major contributing factor on strength. The ideal layer thickness was 100 μm under the conditions of 60 min of post curing time and vertical construction. Lee et al. for a SLA 5000 type machine, layer thickness and component quality were examined by Raju et al. [43]. They concluded that small layer thickness gave good mechanical qualities, high accuracy and good surface finish. Guangshen Xu et al. [44] carried out an experimental analysis to identify the Taguchi method's ideal construction parameters like the shrinkage compensation factor of resin, the liquid surface waiting time, the exposure time and the light intensity for an integrated stereo lithography (SLA) system. It was discovered that the dimensions accuracy was strongly impacted by the build settings, including the resin's shrinkage correction factor, waiting time for liquid surfaces, exposure time, and light intensity. Khorasani and Baseri [45] showed that layer thickness is one of the stereo lithography (SLA) process factors (Layer thickness, hatch overcure and hatch spacing) that has been offered as a model for optimization in order to achieve the least amount of the shrinkage and the distortion of H-shaped products. To link the input parameters to the dimensional inaccuracy of the SLA-produced parts, a neural network was created. Results showed less layer thickness led to minimum shrinkage with good accuracy. S. Rahmati and F. Ghadami [46] suggested a neural network model to identify and improve important parameters like the layer thickness, the hatch overcure, the hatch spacing, the border, the overcure, fill spacing and the fill cure depth, in order to increase accuracy and predict dimensional accuracy using different parameter values. According to the results of the study, layer thickness was the most essential factor for dimensional accuracy. Multiple quality aspects of SLA fast prototyping machines had been improved by Raju et al. [47] by utilizing the process variables that affect the strength aspect of SLA and the Taguchi method-based Grey relational analysis. According to the results, the layer thickness and orientation parameters have a significant impact on the component strength of SLA parts other than hatch space. The optimal combinations of process parameters are 0.125 mm Layer thickness and 90 orientation for tensile strength of SLA parts by single quality characteristics. Loflin et al. [48] evaluated the effect of SLA print layer thickness on the clinical acceptability of 3D printed models. The outcomes showed that layer thickness of 100 μm was the best option. Munproma and Limtasiri [49] investigated

the process parameters namely, exposure resolution, layer thickness, exposure time, post-cure time, up speed lift and post-cure temperature that affect part qualities namely flexural stress, hardness and part dimension. The exposure resolution had a substantial impact on the flexural strength and hardness of the 3D-printed items, whereas the post cure temperature had a large impact on the width error. Ahmet Cekic et al. [50] investigated the process variables like layer thickness and temperature, in Stereo lithography (SLA) in order to produce a smooth surface product with minimize dimensional deviations relative to the CAD model. Experimental studies have shown smaller layer thickness gave lower the surface roughness with good accuracy. Khodaii and Rahimi [51] examined how the SLA process's surface roughness is affected by surface angle, hatch spacing, and postcuring time. The findings demonstrated that surface roughness increased as surface angles increased, while post-curing time had no impact. Katheng et al. [52] examined the grade of polymerization of a transparent photopolymer resin specimen produced by SLA for various post-polymerization times and temperatures and dimensional correctness was analyzed using an ANOVA. Lower temperatures result in enhanced accuracy and tissue surface accuracy, according to the study, which found that the polymerizing temperature had a bigger impact

than the polymerizing duration, 15 minutes and 40 °C are the suggested SLA polymerization parameters. N. Dhanunjayarao Borra [53] adjusted the printing parameters of the Masked Stereo lithography equipment by employing the Taguchi approach to ensure the dimensional accuracy of the 3D printed components. Layer thickness, orientation, and exposure time were the printing parameters that were chosen. According to the ANOVA results, exposure duration had a significant impact on accuracy. Dhanunjayarao et al. [54] examined the experimental findings regarding the dimensional accuracy of resin SLA 3D printed post cured objects. The study's goal was to use design of experiments to show the inaccuracies related to dimensional accuracy as well as the interactions between the process parameters of layer thickness, exposure duration, and x-orientation. It was found that the part's variations in size and form are what cause the dimensional inaccuracies. The investigation found that layer thickness of 0.06 mm and exposure times of 3 and 5 sec with 0° and 150° x-orientation always correspond to minimal deviation. The summary of related works on effect of SLA 3D printers' parameters on Accuracy, surface integrity and strength is given at Table (1).

Table 1,
Summary of related literature

Year and Authors	Parameters	Main Findings
Jayanthi et al. [35]	The four key factors are hatch spacing, layer thickness, fill cure depth, and hatch overcure.	They discovered that the weave style distortion was significantly higher than hatch type.
Diane A Schaub et al. [36]	Layer thickness, spot overlap, boundary over cure, and part orientation.	Layer thickness and component orientation played a substantial role in dimensional error.
Onuh and Hon [37]	Layer thickness, hatch spacing, hatch over, cure hatch style, and fill cure depth.	The optimum build parameters proposed in this study would build parts faster, cheaper and better
Zhou et al. [23]	Layer thickness, hatch spacing, overcure, blade gap, position on the build plane.	The results suggested medium layer thickness for good accuracy.
Lee et al. [38]	Layer thickness, hatch overcure, and hatch spacing.	Neural network could predict the dimensional errors with a respectable level of accuracy, according to test findings on its performance
K. Chockalingam et. al. [39]	Layer thickness, hatch style, hatch spacing, hatch over cure and fill cure depth.	Proposed a genetic algorithm (GA) to find the best process parameters and to predict process parameters for better dimensional accuracy in SLA process.

K. Chockalingam et al. [40]	Layer thickness, post-curing, and orientation.	Orientation had the biggest impact on the part's strength. Additionally, layer thickness of 0.1 mm, post curing time of 60 min, and vertical orientation are the optimum combinations of process parameters.
Campanelli et al. [41]	The Layer thickness, the hatch spacing, the hatch overcure, the border overcure, the fill spacing and the fill cure depth.	Found that best accuracy was gain with low value of layer thickness.
Chockalingam et al. [42]	The Layer thickness, the orientation, the post curing time.	The Layer thickness had the significant contributing factor on strength.
Raju et al. [43]	Effect of the layer thickness on the part quality.	They concluded that low layer thickness equivalent to 0.1 mm is optimal at which the mechanical properties and accuracy are high.
Guangshen Xu et al. [44]	The Shrinkage compensation factor of resin, the liquid surface waiting time, the exposure time and light intensity.	It was discovered that the dimensions accuracy was strongly impacted by the build settings, including the resin's resin shrinkage correction factor, waiting time for liquid surfaces, exposure time, and light intensity.
Khorasani and Baseri [45]	Layer thickness, hatch overcure and hatch spacing.	Results showed less layer thickness led to minimum shrinkage with good accuracy.
S. Rahmati and F. Ghadami [46]	Layer thickness, hatch overcure, hatch spacing, border, overcure, fill spacing and fill cure depth.	According to the results of the study, the layer thickness was the most essential factor for dimensional accuracy.
Raju et al. [47]	Layer thickness, orientation and hatch space.	The layer thickness and orientation parameters had a significant impact on the component strength of SLA parts other than hatch space.
Loflin et al. [48]	Layer thickness.	Low value of layer thickness of 100 μm was the best option.
Munproma and Limtasiri [49]	The layer thickness, the exposure resolution, the exposure time, the post cure time, the up speed lift and the post-cure temperature.	The exposure resolution had a substantial impact on the flexural strength and hardness of the 3D-printed items, whereas the post cure temperature had a large impact on the dimensional error.
Ahmet Cekic et al. [50]	Layer thickness, printing temperature and print speed.	Smaller layer thickness gave lower the surface roughness with good accuracy.
Khodaii and Rahimi [51]	Surface angle, hatch spacing, and postcuring time.	The findings demonstrated that surface roughness increased as surface angles increased.
Katheng et al. [52]	Postpolymerizing times and temperatures.	The polymerizing temperature had a bigger impact than the polymerizing duration, 15 minutes and 40 °C are the suggested SLA polymerization parameters.
N. Dhanunjayarao Borra [53]	Layer thickness, orientation, and exposure time.	Exposure duration had a significant impact on accuracy.
Dhanunjayarao et al. [54]	Layer thickness, exposure duration, and x-orientation	The investigation found that layer thickness of 0.06 mm and exposure times of 3 and 5 sec with 0° and 150° x-orientation always correspond to minimal deviation for all output metrics.

7. Conclusion

This paper's objective was to review the current state of stereolithography 3D printing process and the effect of its parameters on part quality. The following conclusions can be reached from literature review:

1. SLA is a 3D printing for rapid prototyping flexible process and it is a form of additive manufacturing.
2. This process is a layer by layer method of producing objects from photosensitive polymers exposed to UV light.
3. The volume of the photosensitive materials is shrink and then distorted causing a change in dimensions leading to printed objects with less accuracy.
4. Conventional epoxy, acrylate resins, or thermoplastic elastomers make up the majority of the materials utilized in SLA.
5. The effect of UV light on surface changes the surface roughness. Although previous researches on stereo lithography provides information that explains how process parameter affect part quality (dimensional accuracy and surface integrity).
6. Dimensional accuracy in 3D SLA printing is complex and is influenced by a number of variables, including the printing technology, the post processing techniques, the use of support material, and part orientation.
7. None suggested any specific results regarding optimization efforts for the parameters that combine exposure time, bottom exposure time, and bottom layers. Additionally, the SLA user's systematic information on how to choose the process parameters to increase accuracy have not given in the prior studies.
8. Based on the researches that was presented in current study, the number of studies that dealt with the issue of exposure duration of UV radiation is generally rather limited.
9. Improvements to physical part attributes, such as the dimensional accuracy and the surface quality, have received the majority of attention in the literatures done to date but mechanical property improvements have received less attention.

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مراجعة لعملية الطباعة ثلاثية الأبعاد بالأشعة فوق البنفسجية وتأثير المتغيرات على النوعية

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الخلاصة

عملية الطباعة ثلاثية الأبعاد بالأشعة فوق البنفسجية هي نوع من تقنيات التصنيع بالإضافة والتي تستخدم نماذج رقمية من تصميم معان بالحاسوب لإنتاج اشياء مخصصة ثلاثية الأبعاد تلقائياً. منذ حوالي 30 عاماً، تم توظيفها على نطاق واسع في التصنيع، التصميم، الهندسة والقطاعات الصناعية وتطبيقاتها في طب الأسنان لتصنيع التعويضات مهمة جداً. تقدم مقالة المراجعة هذه ملخصاً مفيداً و علمياً لتقنية الطباعة ثلاثية الأبعاد بالأشعة فوق البنفسجية وتاريخ مختصر عنها. النوع المحدد من انواع الطابعات ثلاثية الأبعاد والمستند على معالجة راتنج بالضوء ونظرة عامة على المادة المستخدمة أيضاً تم التطرق لها. علاوة على ذلك، تم إجراء الاستطلاع لاكتساب معرفه كبيره حول مزايا و عيوب هذا النوع من الطباعة ثلاثية الأبعاد. من خلال هذه المراجعة، تم تحديد ملخص لدقة الطباعة ثلاثية الأبعاد بالأشعة فوق البنفسجية وعوامل مختلفة أثرت على دقتها وقياس الأبعاد مثل سماكة الطبقة ووقت التعرض ووقت التعرض الاسفل او الاعلى والمعالجة اللاحقة ودرجة حرارة الغرفة.