Comparison of accuracy and precision of various types of photo-curing printing technology

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Abstract. Light-cured 3D printing technology has always had a series of advantages such as high precision, fast forming speed and low cost compared with other printing technologies. Since the invention of Stereo lithography Appearance(SLA) printing technology in 1986, light-cured 3D printing has been developing rapidly, and has been derived into Digital Light Processing (DLP), Laser cladding deposition (LCD), Continuous Liquid Interface Production (CLIP), etc. Object: The roughness of the printed products of various photocurable printers was evaluated by the surface morphology of the printed products on the micro level, Compared with the original digital file model, the dimensional accuracy of printed products of various types of photo-curing printers is evaluated. Materials and Methods: A digital 3D model was obtained by scanning the adult maxillary teeth with a 3shape mouth scanner. Save the upper digital three-dimensional model as an STL file and print it as a physical model using three different 3D printers(UNIZ (LCD), Han’s laser SLA 6000 (SLA) and Han’s laser DLP (DLP)). Again, use 3shape to scan the physical model into a 3D digital model and use the Dental Cad to compare the accuracy. Test blocks (20mm*10mm*5mm) were printed using three different printers, and the surface topography was observed using a KEYENCE optical microscope, and data comparison was performed using DANTAL CAD for file fitting.

Results and Conclusion: On the Z direction, the surface bump SLA was 185.1 micron mum, the LCD 105.4 mum, and the DLP 95.2 mum. SLA<LCD<DLP. The model fit DLP was 0.07 mm, the LCD was 0.10 mm, and the SLA was 0.14 mm. In terms of print accuracy, DLP > LCD > SLA. The surface roughness of the test block was DLP>SLA>LCD. Conclusion: DLP performs well in all aspects.

1. Introduction
3D printing technology, also known as additive manufacturing technology, has developed rapidly since the invention of 3D printing technology in 1986. In the 2012 issue of the journal Nature Science, an article entitled "How a new manufacturing technology will change the world" was published.
Comparing 3D printing technology with the industrial revolution of the 18th century, it is believed that the emergence of 3D printing technology will have a profound impact on the entire world and is hailed as "the most iconic production technology of the third industrial revolution." From the 1980s to the present, light curing technology has become the most popular 3D printer because of its development and maturity. In 2015, Science published a technical result called Continuous Liquid Interface Production (CLIP) 3D printing. Subverting everyone's awareness of the speed and accuracy can not coexist, but also increase the printing speed by 10-100 times! According to statistics, there are more than 20 types of 3D printing technology till now, among which the most mature production technology and the most widely used are resin photopolymerization (SLA/DLP), laminated solid manufacturing (LOM), fused deposition molding (FDM), selective laser sintering (SLS), selective laser melting (SLM) and three-dimensional ink-jet technology (3DP)[1]. The biggest difference between various photopolymerizable printers is the molding way and the light source. SLA technology was proposed by Dr. Charles Hull in 1986. SLA technology can produce parts with high surface quality with micron fine resolution [2]. The molding process is the process of photopolymerization of resin materials. Usually, before printing the next layer, use a scraper to smooth the surface of the liquid for better molding. Because of its high precision, fast speed and relatively mature development process, it is considered to be the most popular 3D printing technology in the world[3] ([Paul f. Jacobs, Rapid prototyping & manufacturing: Fundamentals of stereolithography, Society of Manufacturing Engineers, 1992]). Both DLP technology and LCD technology are the development of SLA technology.

Raymund E. Rebong et al. used different 3D printers to print dental models, comparing the errors of different printers with the original plaster model, and comparing the overall printing accuracy of different printers. In the four types of light-cured printers, there are gaps in molding speed, light source, and molding accuracy. Niall P. Macdonald uses a Y-junction microfluidic device for direct experiments. Three 3D printing techniques, mainly for microfluidics, demonstrate that DLP-SLA is a forward structure (such as a soft lithography template) with a minimum channel size of 154±10 μm. And 94±7 μm with a roughness of 0.35 μm[4]. (Comparing microfluidic performance of 3D printing platforms). Witold Habrat et al. compared the parts manufactured by milling, the parts manufactured by the injection molding machine, and the accuracy of the 3D printed parts with the help of manual laser scanner analysis[5] (Comparison of Geometrical Accuracy of a Component Manufactured Using Additive and Conventional Methods).

However, the accuracy comparison of various types of photopolymerizable printing is not enough. This paper starts with 3D printer and compares the surface accuracy, overall fitting degree and various reasons affecting the accuracy of various printers in the printing molding.

2. Experimental methods and material

2.1. Experiment Apparatus

The printers used in this study are DLP desktop printers, SLA700 industrial printers and LCD SLASH printers from UNIZ Beijing. Use magics21.0 to slice the. STL file into 3D printing (hans laser), which is controlled by DLP printer (rui yi, China). Set printing parameters according to machining accuracy. Surface topography by high power optical microscope (Keyence VHK6000 and VHK2000).

2.2. Experimental Methods

Print test blocks. The test block is made by three methods: (I) DLP, (ii) SLA, and (iii) LCD. The printed size is set as the same: 20mm*10mm*5mm. Surface characterization of the printed test block. All structures are printed and analyzed in triplicate.

Tooth mold printing. There are three methods for making dental die: (I) DLP, (ii) SLA, and (iii) LCD. The source files used for printing are all the same. Perform surface fitting on the printed test block.

The SLA printing:
By Solidworks designed 3D solid model, using discrete program model slice, scanning path design, the data will be accurate control the movement of the laser scanner and lifting table, a laser beam through the scanner numerical control device, according to the design of scanning path radiation to the surface of a liquid photosensitive resin, the specific surface area of a layer of resin after curing, when a layer is processed, generates a cross section of the parts, lifting platform fell by a certain distance, covered in another layer of liquid resin solidified layer, and then to the second scan, the second layer bonded firmly in the previous solidifying layer, These layers form a three-dimensional prototype of the workpiece, which is taken out of the resin for final curing.

LCD printing: the light source is distributed evenly through the condenser. Fresnel mirrors cause light to fall vertically onto the LCD screen. The image is illuminated by a liquid crystal screen on a light cured resin. The thin resin liquid between the support plate and the bottom film solidifies under the light of the liquid crystal screen. The tray lifts the cured part and lets the liquid in. The tray drops again and the thin layer between the tray and the substrate is exposed again.

After the printing was completed, the surface roughness and surface morphology were observed by the two optical microscopes, namely, keens VHK-6000 and keens VHK-2000.

After the measurement of test block was completed, three different printers were used to print the Dental model, and the accuracy of Dental Cad was compared.

Scan the printed tooth model with the 3shape instrument, and we will get a 3D file of the printed tooth model.

Utilizing the fitting function in the Dental Cad, Then input the source file and the scanned file after printing (select 5 points in order to match) .The results obtained are compared with the original precision color bars in the Dental Cad, which can detect the accuracy of the overall accuracy and the accuracy of the locally printed product and the source file.

3. Results and discussion
SLA, LCD, and DLP 3D printing were respectively 185.1, 105.4, and 95.2 microns in Z direction. So in terms of accuracy, SLA < LCD < DLP.
Fig 2. The surface topography of the LCD in the Z direction

Fig 3. The Surface morphology of SLA in the Z direction

The model fit DLP is 0.07 mm, the LCD is 0.10 mm, and the SLA is 0.14 mm. In terms of model fitting accuracy, DLP>LCD>SLA.

Fig 4. Original scan model
3D printing technology is a new solid model manufacturing technology based on 3D digital imaging technology and multi-level continuous printing technology, it is based on computer numerical control technology, laser technology, computer-aided design, computer-aided manufacture (CAD/CAM) technology, and new material technology. The light curing in the application field of 3D printing, dental is a very important application field, because of its extremely strict with precision, so the light curing accuracy is higher and higher demands are proposed too. Through comparative experiments, this study explored the difference in accuracy of teeth molds made by different photocurable 3D printing, and found that the 3D printing technology based on DLP was superior to the printing technology based on SLA and the printing technology based on LCD. In the figure above, we can see that the surface roughness and overall accuracy of the three printing technologies based on light curing are different after molding. Generally, the higher the surface roughness, the greater the accuracy. The surface roughness and overall accuracy of the three printing technologies based on light curing are different after molding.
From a single machine, when the print file is sliced, the design layer thickness is consistent, and the natural exposure rate reaches the lowest critical state, the exposure and exposure time affecting the overall printing accuracy. On the basis of a certain exposure time, the greater the exposure, the area of influence shown in the figure will increase as the exposure increases. As a result, the dimension in the XY direction is larger than the originally designed size, resulting in a precision deviation. On the other hand, in the case where the exposure amount is constant, the exposure degree and the exposure time have a certain inverse relationship. When the exposure reaches the lowest critical state, the greater the exposure time, the greater the tendency of the affected area to expand outward, and finally reaches a threshold. Therefore, different photo-curing printing processes as shown in the above figure show different bumps on the connection between layers. From Figure 1,2 and 3, we can see that on the 3D printed XY plane, there is not much difference between the DLP and the LCD on the molding surface, and the SLA has obvious bumps in the Z direction. This is because of the three printing processes, DLP and LCD are formed by surface molding, while SLA is formed by laser from point to line to surface. Because the SLA inherent light source is too bright, or the small bright spot scanning time is too long, the affected area shown in the above figure3 is too wide, and the final product is printed as the peak in the Z direction is too high. Due to the laser irradiation molding, there are rows of small bumps that are difficult to observe on the X-Y molding plane. In the Z direction, it can be seen that due to the combination of the faces, the lamination is combined, the layer is cured by photocuring between the layers, and the dimensional accuracy on the XY plane is due to the obvious linearity under the microscope. relationship. The DLP-based 3D printing process is more accurate than the SLA and LCD fit in dental model accuracy fit.

4. Conclusion
On the Z direction, the surface bump SLA was 185.1 micron mum, the LCD 105.4 mum, and the DLP 95.2 mum. SLA<LCD<DLP. The model fit DLP was 0.07 mm, the LCD was 0.10 mm, and the SLA was 0.14 mm. In terms of print accuracy, DLP > LCD > SLA. The surface roughness of the test block was DLP>SLA>LCD. Therefore DLP performs well in all aspects.

Acknowledgments
This work was financially supported by 2019 Shenzhen Technology University of Pioneer Park Innovation and Entrepreneurship Fund Project.
This work was financially supported by 2019 Shenzhen Technology University of Graduate School-Enterprise Cooperation Project fund.

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