Determining the process parameters of two photopolymer resins for MSLA printing processes

B.Sc. Felix Ungar, M.Sc. Alina Kohler, Prof. Dr. Volker Bucher

***Abstract*— In the course of researching a bellows to encapsulation the mechanical unit of a moving active implant, two photopolymer resins were calibrated for further investigation as part of this research. This has been done using a masked stereolithography (MSLA) printer, cleaning steps followed by curing. The resins were one biocompatible and the other with special flexibility. The evaluation of the printing was carried out using a validation matrix for SLA printing processes. The time required for the process steps had been observed as well. Both resins were calibrated with respect to their exposure time and the process chain was evaluated. The results are meaningful, but additional factors had been identified that need to be considered too.**

I. Introduction

The main work was to find the process parameters of two photopolymer resins, in terms of their exposure time, to achieve the best possible printing result.

The far-sighted goal behind this constitutes the development of bellows to protect the mechanical components of an autarkic distractor. Bellows are highly deformable protective covers for axially movable push rods or joints to protect them against adverse factors [1]. Distractors are implantable surgical devices that are used in distraction osteogenesis for extension treatment. Distraction osteogenesis is a procedure in which autologous bone is created. The principle behind this is to create an osteotomy in a bone in order to drive those bone segments apart afterwards (Figure 1).

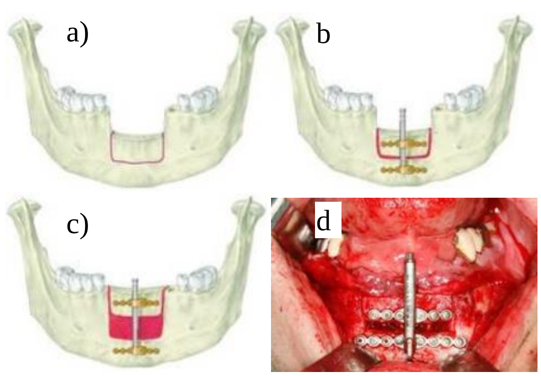

Figure 1: Distraction osteogenesis procedure on a mandible + surgical image [2]

After a certain amount of time, regeneration tissue, so-called callus (Figure 1, b) red area), forms in the osteotomy gap created (Figure 1, a) red line), which grows with the patient and restructures into bone in a stable state. This regeneration tissue can be stretched by means of a distractor and thus new bone can be created over a certain distance (Figure 1, c)). The autarkic distractor illustrates a prototype (Figure 3) which does not drive the bone segments apart like conventional distractors (Figure 1, d)) via a screw spindle extending from the soft tissue, hence it acts independently.

The advantage of the autarkic distractor is, that it gets implanted and therefore has no connection to the periphery out of the soft tissue and a resulting possibility of inflammation is prevented. In order to protect the mechanical unit of this distractor from the incorporation of cells, which can lead to a loss of function, a bellows is to be developed (Figure 3).

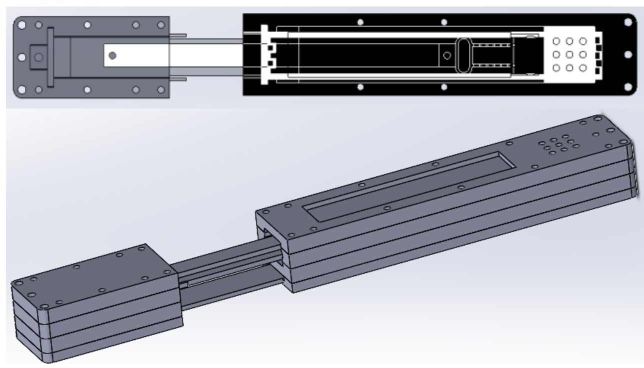

Figure 3: Prototype of an autarkic distractor

II. Materials and Methods

A. Devices

3D-Printr; curing/washing device; ultrasonic cleaning tank; validation matrix

Original Prusa SL1S SPEED (3D Printer) 5,96" Monochrom-LCD with a physical resolution of 2560×1620p

Original Prusa CW1S (curing and washing device) is used for the preparation and / or post-processing of printing.

Bandelin Sonorex (ultrasonic cleaning tank) for an additional cleaning process.

Validation matrix from the company Anycubic for adjusting photopolymer resins on a 3D-printer

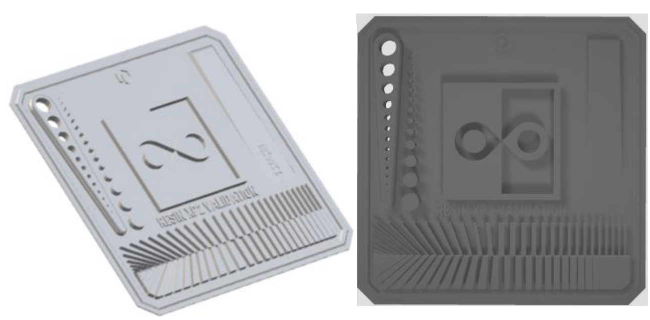

Figure 2 Validation matrix from the company Anycubic

B. Materials

Silicone like 3Dresyn Hard SR from 3Dresyns (SKU:P18756);

Elastic 50A form formlabs (SKU:RS-F2-ELCL-01)

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Hard SR: low viscosity; similar touch and resilience to conventional hard silicon rubber; shore hardness of A70; 100% foldable without breaking; resolution less than 20 microns; biocompatible; no monomers. [3]

Elastic 50A: Elongation at break 160%; bend, stretch, compress, and hold up to repeated cycles without tearing, not biocompatible. [4]

Hard SR is biocompatible, foldable without breaking and has a high resolution. This makes it suitable for smaller and more detailed structures. [3]

Elastic 50A, on the other hand, is not biocompatible but has the enormous advantage of expanding and contracting over repeated cycles without showing signs of fatigue. This can be a supporting advantage for the distractor prototype (Figure 3). [4]

Both materials need to be washed in Isopropanol to get rid of excess resin on the print before the curing process. [3, 4]

C. *Parameters*

The parameters for the printing processes:

Layer height: 0,025 mm; fading out layers 10; no supports were used; no base layer (pad) were used; gap closure radius: 0,005 mm; Tilting time of the basin: fast 2,5 s (for HARD SR) / high-viscosity 10 s (for Elastic 50A)
The exposure times were varied, as were the cleaning & curing process parameters.

D. Methods

To set the optimal exposure times for the photopolymer resins, a validation matrix from the company Anycubic has been used which was specially developed for the calibration of photopolymer resins. At the beginning, different exposure times must be set for the print in order to determine a tendency in which exposure times a resin moves. The evaluation of the print is assessed by several points, showed in

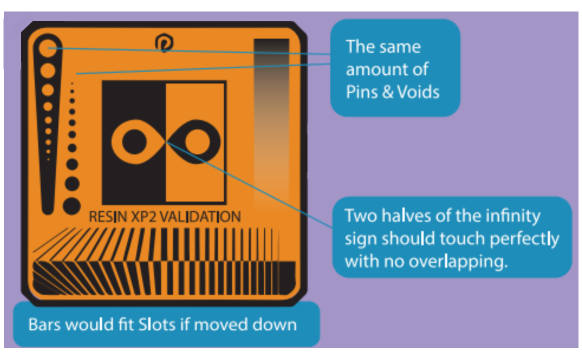

Figure 4: Validation matrix from the company Anycubic; evaluation points [5]

This matrix is designed to push a resin printer to its limits. This means that the exposure time of a resin can be optimally set, but smaller structures are still not able to be printed. The reason for this could be the printer as well as the resin, which means that not all structures have to be printed completely and perfectly on the matrix. [6]

III. Results

In the following, the results of the research work are presented pictorially and the best results for the exposure times and the washing & curing/drying time/temprature of the individual resins are shown.

The best result of exposure times for HARD SR describes an initial exposure time of 30 s and an exposure time of 15 s (Figure 5). The washing time, in isopropanol, for an optimal result is 20 min, with a curing&drying time of 12 min each at 55°C.

The best result of the exposure times for Elastic 50A represents an initial exposure time of 40 s and an exposure time of 28 s (Figure 5). The washing time for an optimal result is 1 min cleaning in the ultrasonic basin + 10 min in the original Prusa CW1S, with a curing time of 20 min and a drying time of 8 min at 60°C each.

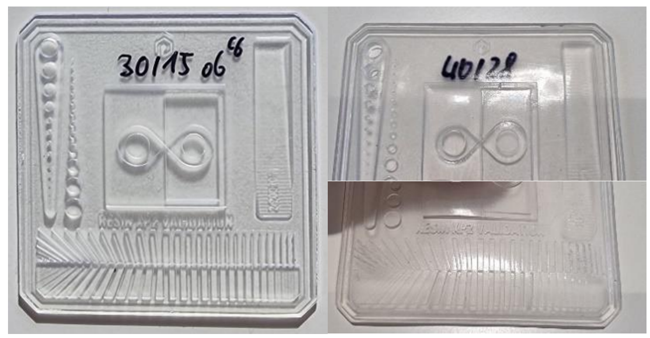

Figure 5: Best print results of HARD SR (left); Elastic 50A (right)

IV. Discussion

A. *Challenges*

Hard SR presented no challenges and was calibrated as written in chapter II. Materials and Methods

Elastic 50A has been challenging in several ways shown in the following.

First. With higher exposure times (Figure 6), layers up to three times thicker occurred. These excess thicknesses decreased from the first to the last layer. The structures of the validation matrix were nevertheless well imaged.

Figure 6: Thick layers of Elastic 50A

Second. If the initial exposure times were too low (less than 30 s), the print did not come off because the first layer did not stick to the print bed but to the resin tank.

Third. Due to the high viscosity of Elastic 50A, the tilting time of the resin tank had to be slowed down, which additionally prolonged the entire process. Secondly, the washing time had to be set to 40 min in the Original Prusa CW1S in isopropanol in order to wash off the resin sufficiently.

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Fourth. There was always tension within the print, which produced a bending.

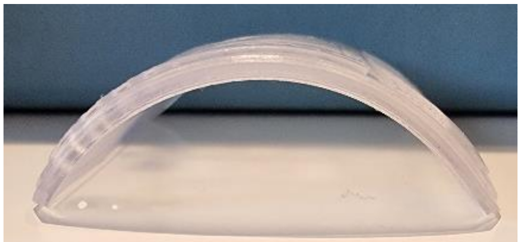

Figure 7: Bending of as Elastic 50A print

B. General Discussion

The process parameters regarding the exposure time, the cleaning process, as well as curing and dyring time /temperature could be determined to a large extent and sufficiently (Figure 5).

As mentioned in the subchapter "Challenges", Elastic 50A has several problem factors and, in contrast to HARD SR, it could not be optimally calibrated. With higher exposure times Elastic 50A increased the layers thickness enormously, but it could not be prevented even with lower exposure times and an oversize remained.

Due to the high viscosity of Elastic 50A, an additional cleaning step must be added, also slower tilting of the tank (10 s, normally 2,5 s) was needed as higher exposure times. Because of these points the process including a finished print, within Elastic 50A, took a process time around one and a half hour. With conventional cleaning in the original Prusa CW1S, a cleaning time of at least 40 minutes is required. This is an enormous expenditure of time and not economical in the long run. Therefore, the ultrasound had to be used to correct this economic factor. Insufficient cleaning not only holds the economic factor, but also leaves residues on the print during the drying & curing process. As both materials are cytotoxic, residues must be avoided at all costs.

Furthermore, it could be observed that tensions occurred within the pressure (Figure 7). This has been the case with Elastic 50A as well as with HARD SR, but with HARD SR the tensions were no longer present after a few days and with Elastic 50A they remained. This may be due to the curing & drying temperatures after the printing process. Probably in combination with the direct printing on the print bed without supports as the print bed, which is made of a metal alloy, extracts heat from the print. This should be a term of examination in the future.

The quality of the print details for both materials were almost identical, whereby HARD SR performed much better in a direct comparison regarding the entire process chain and the resolution of the print.

Many factors came together for Elastic 50A and, in contrast to Hard SR, it must be further investigated whether better parameters for the print or the processes must be set.

To achieve a perfect print result, there are other factors that need to be considered.

V. Conclusion & Outlook

The exposure times for the materials could be set, but there are some factors that must be regarded, which still need to be examined. A high viscosity with photopolymer resins can always be a certain disturbing factor and must be differentiated or considered differently for each resin. The resins could be preheated to influence the viscosity and thus improve the printing process. The temperature during the printing process is also a factor to be considered, so it depends on where the printer is located and whether there is a continuous ambient temperature. It is also important to check whether the temperature, and the preheating or process temperatures, have an influence on the material after printing. The programming of the printing process is versatile, and many settings could influence the print. Accordingly, it is still necessary to check whether the resins can be used for the large target and whether further print settings could optimize the print. The current state of knowledge regarding the research carried out here does not allow any conclusion to be drawn as to whether the materials are really sufficient for the bellows and the associated requirements.

VI. Acknowledgment

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VII. References

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