Trainers for Visually Impaired Students Introduce 3D Printing

Tutorial Module 7
Autonomous Utilisation of SLA Printers

Tutorial for the T4VIS-In3D trainer course

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Content

1 General

The technical development of 3D printers is proceeding rapidly. The machines are increasingly more user-friendly and convenient. Setting and adjustment functions are increasingly handled by the devices themselves. The more expensive the printer, the greater the range of functions available.

For the operation of a 3D printer, the corresponding operating manuals provide detailed instructions and safety information. In addition, every manufacturer offers online user forums where problems related to the device can usually be solved quicker than via a support hotline.

This tutorial will only describe the basic operation of SLA printers and the basics of a correct setup.

2 Commissioning SLA printers

The main steps in setting up an SLA printer can be described as follows:

1. Insert the data media with the print file into the printer
2. Adjust the building plate and check the exposure screen
3. Gill resin into the resin container (VAT)
4. Start printing
5. Check the print

2.1 Transferring print data

Like FDM printers, the print data is stored on a USB memory device or SD memory card. Some printers have difficulties reading memory media with a storage capacity higher than 32 GByte.

Modern models now also allow the transfer of print files via LAN or WLAN from the computer to the inserted data medium.

To avoid reading errors, the media should be connected before switching on the machine.

2.2 Adjusting the building plate and inspecting the exposure unit

After each printing process and transport, the exact distance of the building plate from the surface of the exposure screen must be adjusted.

If the distance is too large, the layers will not adhere to the building plate but to the glass or foil of the VAT. If the distance is too small, the exposure unit can be destroyed. In the best case, the resin is pressed out between the film or glass plate. Thus, no good printing result can be achieved.

To adjust the distance, the VAT must be removed from most printers. Depending on the manufacturer's specifications, the distance is measured with a sheet of paper. Again, depending on the manufacturer, this can be single or double folded. To do this, first loosen the screws securing the building plate (see red arrows in Figure 1).

Manual adjustment is called up via the printer menu and the building plate is moved to the top of the paper. The movement is stopped by a light barrier. A light pull on the paper checks the correct distance. It should be possible to pull the paper out with two fingers with only a slight resistance.

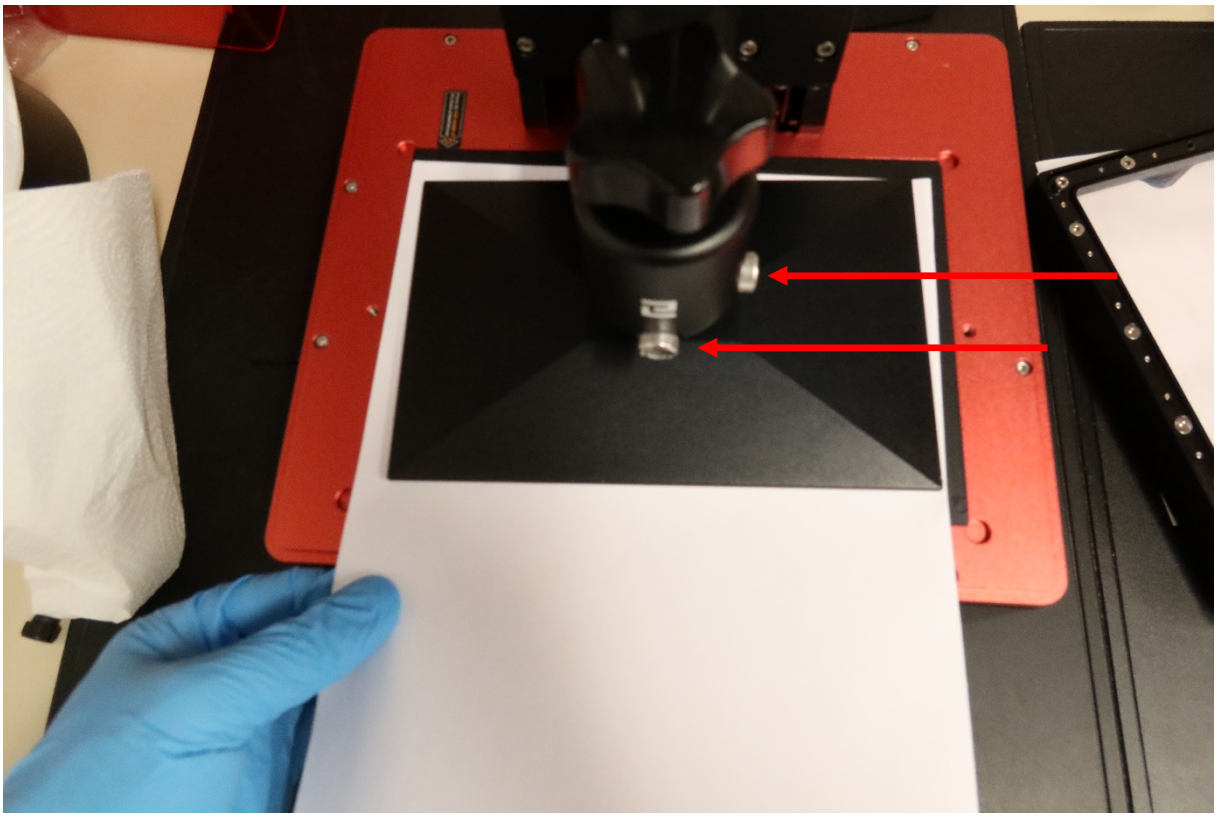

Figure 1 Checking the correct building plate distance

If the resistance is too high or too low, the plate must be moved up or down in 0.1 mm steps with the menu. If the resistance is correct, the adjustment is stored as the Z0 setting with the printer menu.

For printers where no adjustment is possible via the menu, a mechanical device may be present to change the light barrier activation to adjust the Z0 position.

Finally, the screws fixing the building plate are hand-tightened again. The building plate is then raised again via the printer menu.

Once the building plate has been raised, the exposure unit can be checked. Printer manufacturers also offer options for this in the printer menu. These are called

"Exposure" or "LCD Test". Here you can check whether the exposure unit is working without spots or errors.

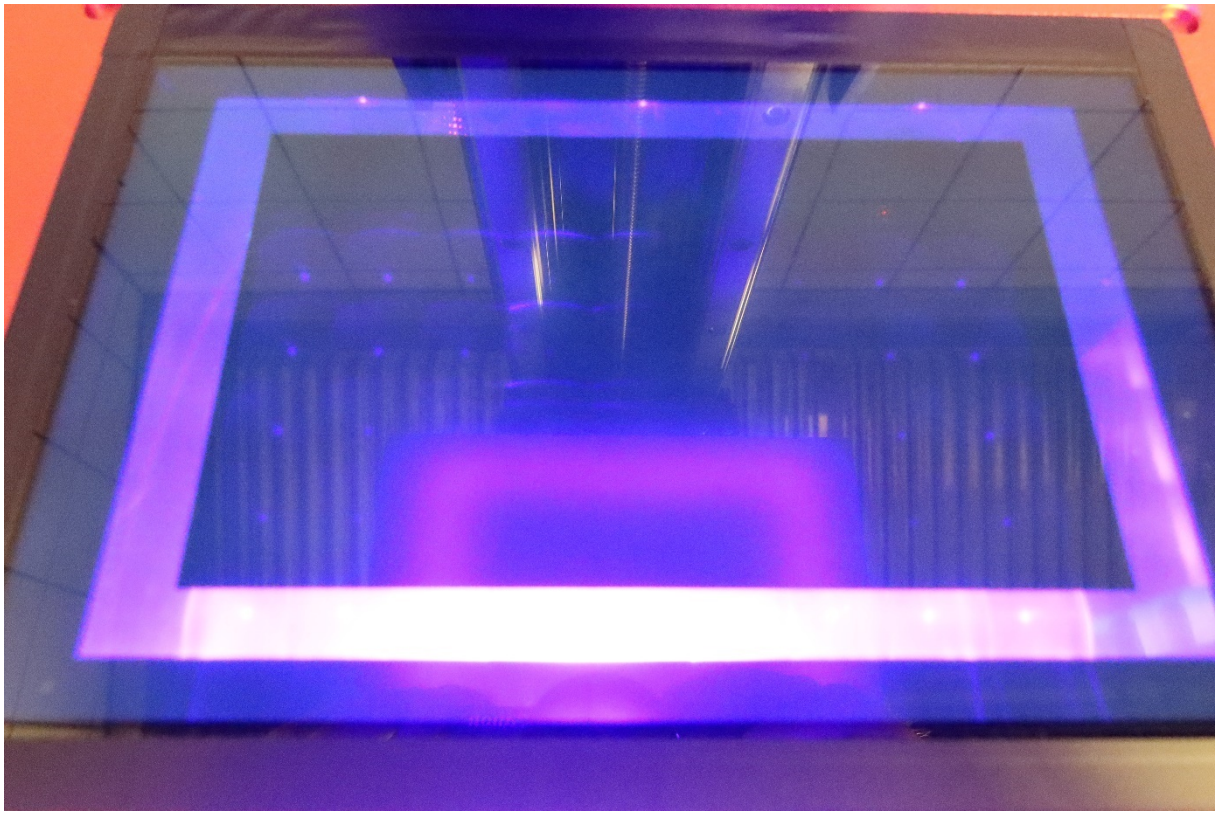

Figure 2 Test of the exposure unit (example Elegoo Saturn)

If the surface has stains or exposure failures, the resin cannot be exposed and cured in these areas. Stains can be caused by resin on the surface of the exposure unit. You can try to remove these stains with isopropanol (abbrev. IPA). However, in case of cured resin, this is not possible without leaving residues.

Exposure failures can be caused by penetrated resin or LED failures. The only solution in this case is to replace the exposure screen.

2.3 Filling in resin, starting and checking the printing process

After adjusting the building plate, the VAT can be reattached to the printer according to the manufacturer's instructions. The resin can then be poured in. **Prior to this, however, a respiratory mask FFP2 (or better yet an FFP3) and disposable nitrile gloves must be worn.** The usual silicone gloves are **not sufficient** for handling resin and isopropanol.

A lab coat can also be worn to protect clothing.
The resin must be shaken in the bottle before filling to loosen any deposits. Subsequently, fill the resin carefully into the VAT until it reaches the maximum mark. Here, that the maximum marking must not be exceeded, otherwise the resin gets onto

the exposure unit and into the printer when the building plate is immersed. Once the filling mark is reached, the bottle should be turned slightly to avoid drops on the bottle neck. These can also be wiped off with a paper towel.

After filling the resin, the bottle should be stored away and the light protection lid of the printer is closed. Now, the print can be started via the printer menu. To do so, first select the file and then start printing it.

During printing, repeatedly check that the print is carried out correctly and that the object adheres correctly to the building plate. This can be done by using the light protection lid. At the beginning of the print, however, the building plate is still too deep and hidden by the edges of the VAT. Therefore, the manufacturers offer a pause button. This allows for the building plate to be raised for a short time for checking.

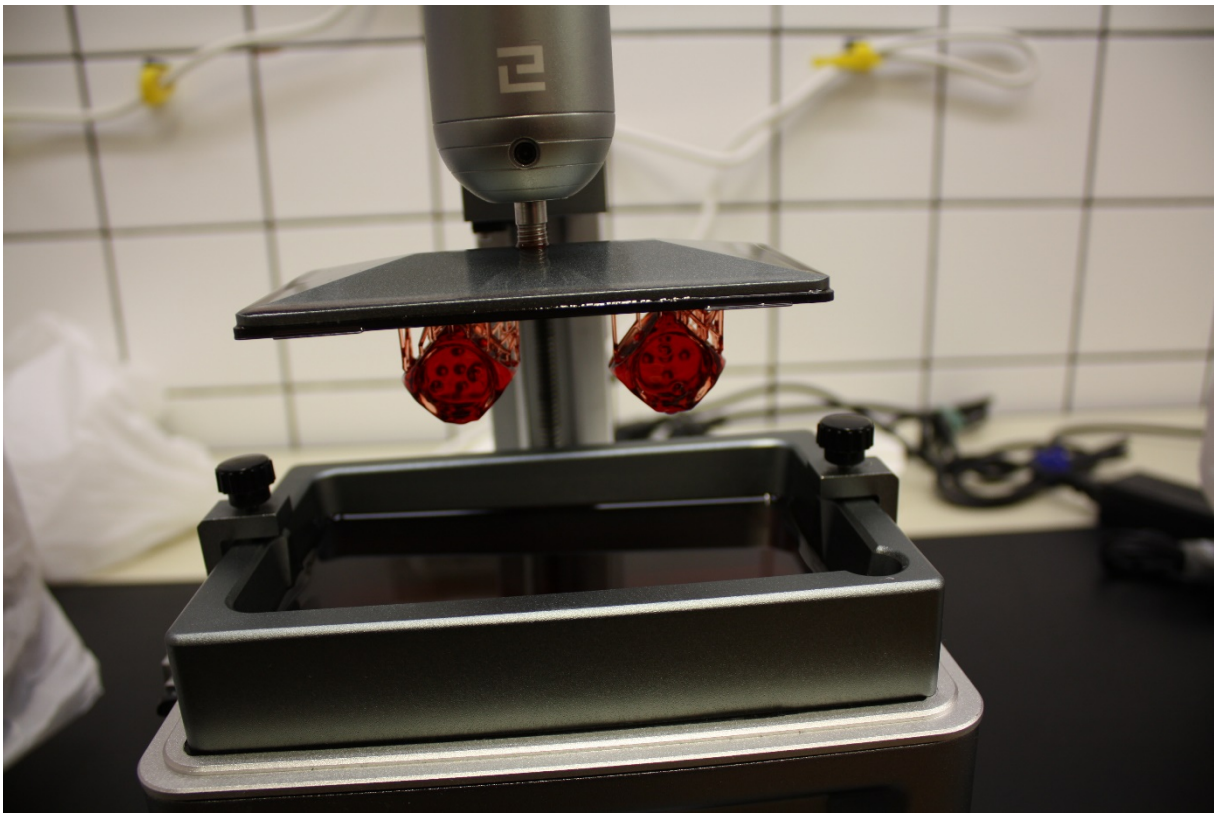

Figure 3 Controlling the print

When controlling, make sure that all parts of the component and the support structure are present. If individual parts are missing, the print must be cancelled.

3 Removing the components and decommissioning SLA printers

Regardless of the manufacturer, the essential steps for commissioning an SLA printer can be described as follows.

1. Remove the building plate
2. Remove, empty and clean the VAT
3. Remove the component from the building plate
4. Clean the building plate

3.1 Removing the building plate

Once the print is complete, the building plate can be removed from the printer immediately. However, it is recommended to wait about 5 minutes to allow excess resin to drip off the component. This reduces the amount of resin used and the contamination of the cleaning solution.

Prior to that, however, the same protective equipment as outlined in the previous chapter must be put on.

As a standard, the building plate is attached to the guide of the Z-axis with a knob. Loosen the knob and hold a tray under the building plate. This is to avoid contamination of the exposure unit by dripping resin. Then, place the building plate in a container with cleaning solution. Isopropanol of 99% alcohol is particularly suitable as a cleaning solution.

Figure 4 Placing the building plate in the cleaning bath

3.2 Removing and cleaning the VAT

As a next step, the connection of the VAT to the printer is loosened and removed from the printer. This may require some force and slight back and forth movement, as adhesive forces can cause the film of the VAT to stick to the exposure unit.

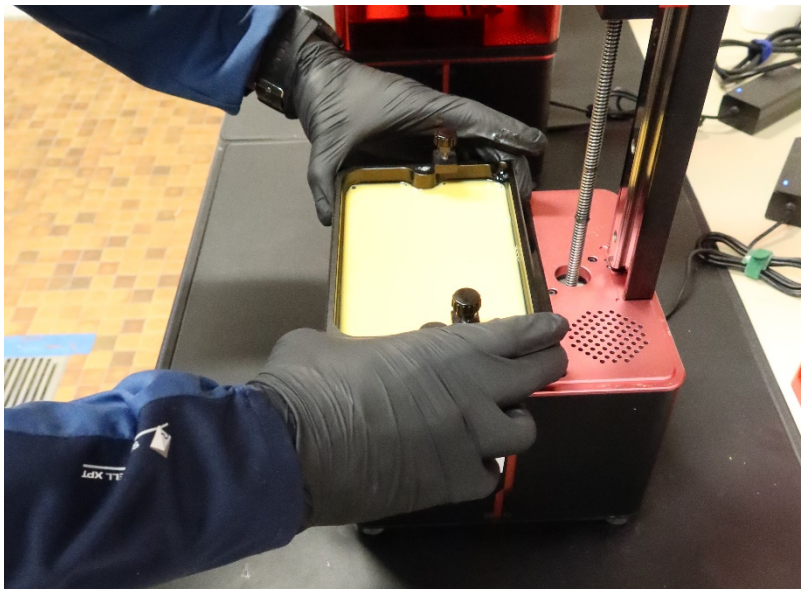

Figure 5 Removing the VAT

First place the VAT on a clean kitchen towel or a frame to protect the bottom from damage and contamination.

Then, open the resin bottle and insert a funnel with a paint filter. The filter is important to remove any hardened resin residues (e.g. from the support material). These could damage the VAT bottom when the new print is applied under the building plate. Slowly pour the resin back into the bottle.

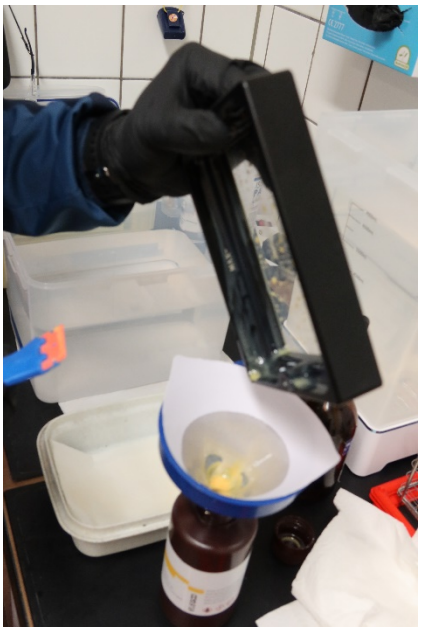

Figure 6 Refilling the resin

To collect the viscous resin from the VAT base faster, the resin can be pushed through a **soft** plastic spatula or a playing card.

Next, place the VAT back on the base and clean the inside and outside of the VAT with sufficient isopropanol, also paying attention to the bottom so that no resin residue can get into the exposure unit. The VAT is cleaned and dried with soft paper towels.

The funnel and the varnish filter can be removed from the bottle, which is immediately closed. The filter is disposed of as hazardous waste and the funnel is cleaned in isopropanol.

3.3 Removing the component from the building plate

The removal of the component can be done at different times after the initial placement of the building plate in the cleaning solution. This depends on the nature of the building plate, the cleaning station and personal preference.

Smaller SLA printers can be equipped with a magnetic building plate, which allows the components to adhere to a very narrow metal foil. This foil can be bent so that the component can easily be removed. For larger SLA printers (190x150 mm and larger), these magnetic plates are less recommended. With large and heavy components, the magnetic effect is not high enough and the metal foil can detach from the construction plate at the corners. This leads to a poor printing result.

In any case, the component should be rinsed well in the cleaning solution before it is removed. It is important to avoid scratching the surface of the building plate as this would have a negative effect on the adhesion and the surface of the component. The component can be lifted at the corners with a soft plastic or silicone spatula and detached from the building plate. With large components, several tries may be necessary, as in some cases only small areas will come loose at first. In such cases, the building plate should be dipped into the solvent again. The solvent then flows between the component and the building plate at the loosened areas and loses its adhesion.

Particularly with tall and narrow components, do not attempt to remove the component from the building plate by means of force. Since the components have not yet been hardened, they could easily break during the attempt.

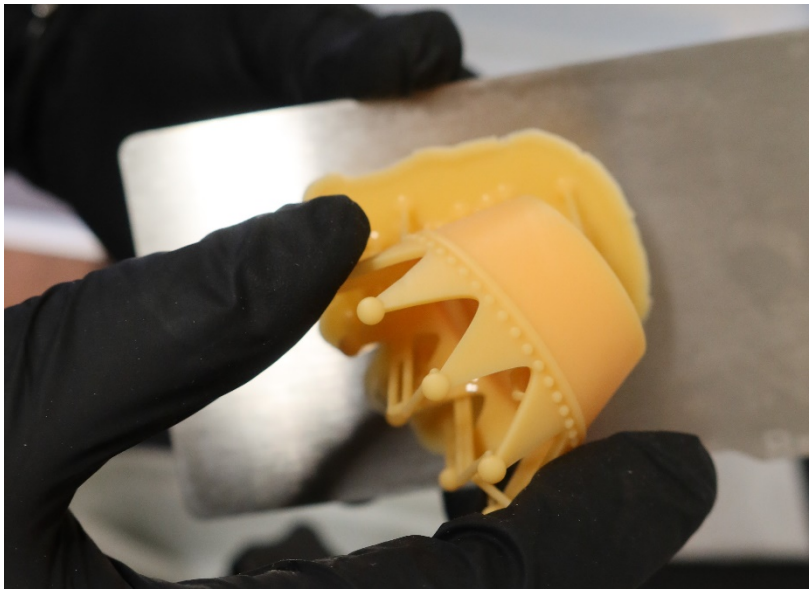

Figure 7 Removing the component from a flexible build plate

3.4 Cleaning the building plate

After removing the components, the building plate must be cleaned with clean isopropanol. Resin residues must be removed without leaving any residue. The surface of the construction panel must be kept free of grease.

Constant cleaning of the construction panel with alcohol causes the guide of the construction panel, the spring elements in the holder and the guide for fastening to become sluggish. These can be made slippery again with Teflon spray.

After cleaning, the building plate can be reattached. It must be hand-tightened with the adjusting knob.

4 Cleaning and post-processing

Compared to FDM printing, the post-processing of SLA printing is very room-, time- and material-consuming. Even when used carefully, a supply of isopropanol, paper towels and UV protective varnish is needed. Again, be sure to wear protective gloves, respiratory protection and a work coat.

First of all, one should physically separate the area of the printer and the cleaning station for safety reasons.

The entire finishing process for SLA printing includes:

1. Preliminary cleaning/rinsing
2. Final cleaning
3. Drying
4. Post-curing of the component with UV (curing)
5. Removal of the support material
6. Application of UV protective paint and drying

As the list shows, the post-processing can take several days, depending on the size and detail of the component. Attempts to shorten or omit individual steps are therefore understandable, but lead to poorer results.

An essential step in the finishing process is cleaning and curing. Today, many manufacturers offer suitable "wash and cure" systems in which these steps can be executed one after the other. These devices are designed for the size of their printers and offer a compact and material-saving solution.

4.1 Preliminary and final cleaning

Intensive cleaning is crucial for a good quality component. If resin residues remain on the component, they cannot dry and harden sufficiently. Even after painting, resin residues are visible due to colour differences.

To ensure intensive cleaning, a multi-bath technique should be used. This means that the component is cleaned in at least two, preferably three, baths. The three-bath strategy is described below.

The building plate is taken directly from the printer and put into bath one in order to rinse off the coarse resin residues. This bath has the highest degree of contamination of the cleaning baths used. Here, the component and the building plate can be roughly cleaned either with a magnetic stirrer or simply by swivelling. Then, after about 10 minutes, the building plate and component are placed in the second bath. Here, the isopropanol is much cleaner than in the previous container. Harder residues are removed at this stage. Particularly in the case of thin components or tightly positioned support material, drops of resin can adhere. These can also be removed mechanically with a fine toothbrush or cotton swab. Afterwards, the building plate and component

are put into the final bath. Here, at the latest, a stirring mechanism should be used to move the cleaning agent. For large, filigree components that are rich in support material, the last bath should not be less than 10 minutes.

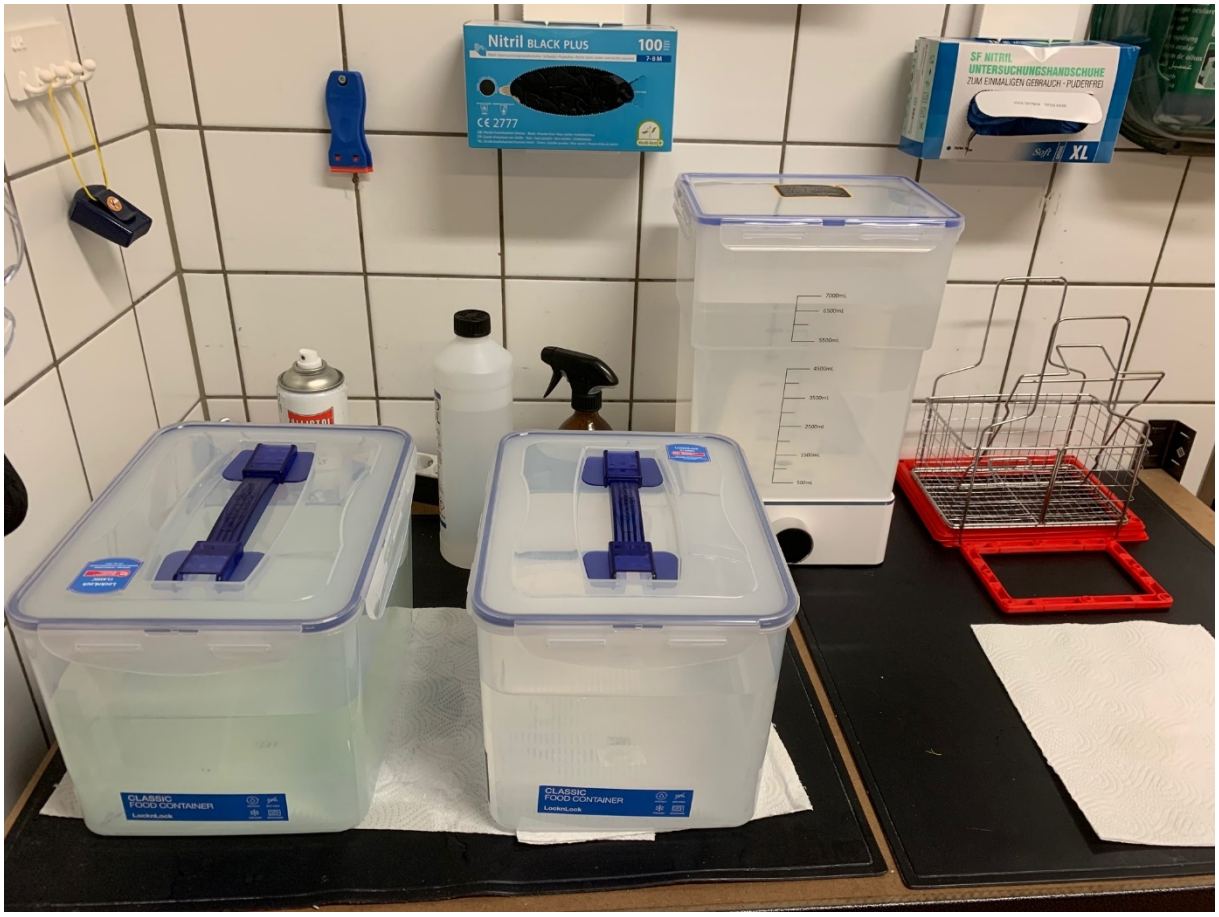

Figure 8 Three-bath washing station – centre background bath with magnetic stirrer

The advantage of this method is the overall more economical use of the cleaning agent. If only one bath was used, the isopropanol would have to be changed more frequently to maintain the cleaning effect. In case of heavy soiling, only the isopropanol in bath one is disposed of and replaced with the filling from bath two. Bath two receives the cleaning agent from bath three, which is in turn refilled with fresh cleaning agent. Thus, in our example in Figure 8, 21 litres of isopropanol are needed. However, it can be used for a much longer time. Containers must be closable to avoid evaporation or spillage.

In any case, the country-specific safety regulations for handling isopropanol must be respected.

Contaminated isopropanol is best collected in chemical canisters and disposed of as hazardous waste at a recycling company.

4.2 Drying and curing

The drying of cleaned parts is best done in a well-ventilated room on a draining sieve or paper towel. The drying process can be supported with light compressed air for angled and hollow components. Isopropanol evaporates very quickly, so drying is very fast for simple components. For drying hollow components, the component must be placed on a paper towel with the drainage holes facing downwards so that residual resin can drain off.

After drying, the component must be cured with UV light. In the hobby sector, open UV lamps are often used for this purpose, the light intensity of which cannot be adjusted. Since UV light can be harmful to the eyes, CE-certified curing stations from SLA manufacturers must be used for reasons of occupational safety. These have protective devices that switch off the UV light when the unit is opened or the light protection cover is removed. In addition, the UV intensity and curing time can be adjusted to achieve an optimal result.

Figure 9 Curing chamber (example XYZ Printing) with mirror unit

A common mistake is to select too high a UV-intensity or too long a post-curing time. Models made with a transparent or white resin can be "overexposed". This is shown by the fact that the models show a yellowish colouration. The tolerances are different

for each manufacturer. The corresponding values can be found in the data sheets for the resins used.
If necessary, this should be tested with test prints for the respective resin and the curing station used.

Generally, it is recommended to choose a lower intensity, but to extend the curing time a little. The model can also be turned upside down so that the underside is also hardened. With transparent resin, this should be done at half the curing time in order to cure all sides sufficiently.

4.3 Removal of the support material and post processing

Especially with dense support material, one is tempted to remove it before curing, as it can often be removed simply by pulling. However, the surface material of the component may also be removed by mistake, which creates small dimples on the surface that can only be removed by sanding with sandpaper.
It is better to remove the support material after curing with a scalpel or fine side cutter with a flat blade. Any remains of the support material can be removed with wet sandpaper with a 5000 grit, in order to achieve a smooth surface.

If SLA components are to be used in well-lit rooms with daylight or outdoors, UV protection must be applied by means of a varnish. Basically, all acrylic varnishes used in model making are suitable. For outdoor use, suitable weatherproof varnishes must be chosen. They can be applied with a brush, airbrush or paint spray. If the component is painted with acrylic paints, make sure that the paint itself is UV-resistant.

For clearcoats, there are acrylic clearcoat sprays with matt or gloss finishes. Although the resin surface appears smooth, it absorbs lacquer very well. Therefore, the lacquer must be applied in several **thin** layers to avoid paint runs. Apart from that, follow the paint manufacturer's safety and processing instructions.

5 Troubleshooting

5.1 Component adheres to the VAT floor instead of the building plate

The most common problem with SLA printing will be the lack of adhesion of the component to the building plate. As a result, the cured resin sticks to the bottom of the VAT.
There are four main reasons for this failure:

1. Adjustment of the building plate is not correct
2. The plate is not free of grease
3. The exposure time was chosen incorrectly
4. The lifting speed of the Z-axis is incorrect

If the adjustment is incorrect, the distance between the building plate and the transparent VAT bottom side may be too large. This means that the hardened resin cannot adhere sufficiently to the building plate, as the adhesive effect of the VAT bottom side is higher. The adjustment must therefore be checked and the distance reduced if necessary.

Manufacturers usually design the bottom side of the building plate to be coarse in order to achieve better adhesion. If the building plate was not cleaned correctly or with dirty isopropanol, its adhesion may be reduced. In this case, the building plate should be cleaned again with isopropanol or ethyl alcohol.

Another reason for a lack of adhesion is the setting of the wrong exposure time. The exposure time can usually be taken from the printer manufacturer's data sheets. If the exposure time is too short, the curing is not sufficient to adhere to the building plate. The adhesion to the bottom side of the VAT is higher because the exposed part is slightly harder at this point.
If no manufacturer's curing tables are available, a test print in the form of a 2cm³ cube should be made.

The exposure time of the first layers should be increased step by step by 5 seconds each, the exposure of the following layers by 1 second each.

All manufacturers of SLA printers try to increase the printing speed. This is achieved amongst others by reducing the motion times of the Z-axis. A critical factor in this regard is the lifting of the building plate after exposure. If it is too fast, it can be compared to a quick suction cup from a glass plate. If the movement is too fast, the suction cup is not released from the glass plate, but pulls it up with it. If the problem persists, you can try a "bottom lift". "Lifting" or "Lift-off Speed" can be slowed down. The speed is usually given in millimetres per minute. The speed should be gradually slowed down by 10 millimetres per minute.

5.2 Incomplete print due to insufficient support material

Another common error is the effect that areas of the component are printed incompletely or break off and fall off during the printing process.

This can be caused by the reasons below:

1. No support material was provided for that area.
2. The intended support material was too thin or created with too large distance.

Figure 10 Insufficient support structure

As can be seen in Figure 10, the two legs of the horse in the foreground are not printed. On the hind leg the support material is completely missing, on the front leg only two (too thin) columns were added.

Basically, the thickness and density of the support material must be adapted to the component. Exposed and heavy components are of course subject to gravity and the support material is not completely capable of bearing loads, as it has not been hardened. Therefore, as a precautionary measure, the support material should be thicker and closer together for exposed and heavy components. It should be noted that the support structures are not only added to the underside of the component (in the example above, the hooves), but over the entire area.

5.3 Deformation due to incorrect positioning or insufficient support material at the edges

A common error that occurs is deformation on the bottom of the component. This can be caused by incorrect positioning of the component on the building plate and/or insufficient support material at the edges of the component.

Figure 11 Deformation due to incorrect positioning and insufficient support material at the edges

In the example in Figure 11, the model of the "Notre Dame" was positioned with the bottom part parallel to the building plate. In this example, two mistakes were made at the same time.

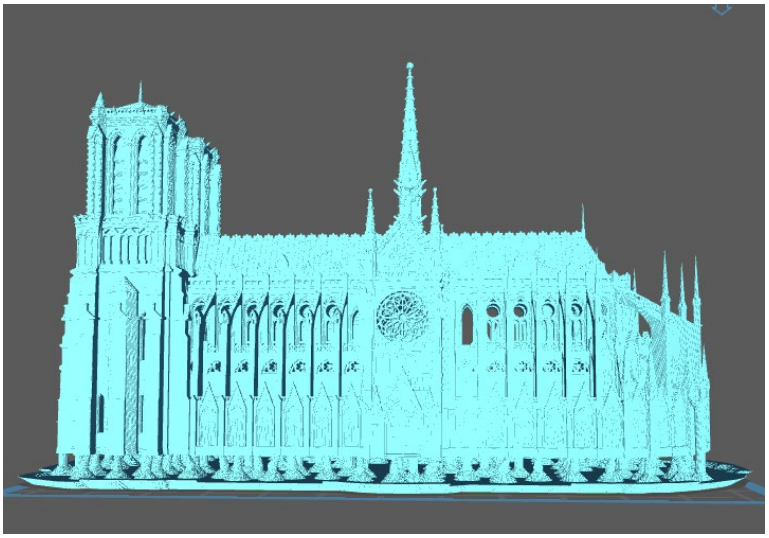

Figure 12 Positioning and support material of the example

On the one hand, the arrangement of the component causes warping of the component due to the suction effect when the construction panel is lifted. This effect has already been explained in Tutorial 6. On the other hand, Figure 12 clearly shows that only one row of support structures has been added to the edges. Even if the component is arranged correctly at an angle (see Figure 13), considerably more and densely placed support structures would have needed to be added here.

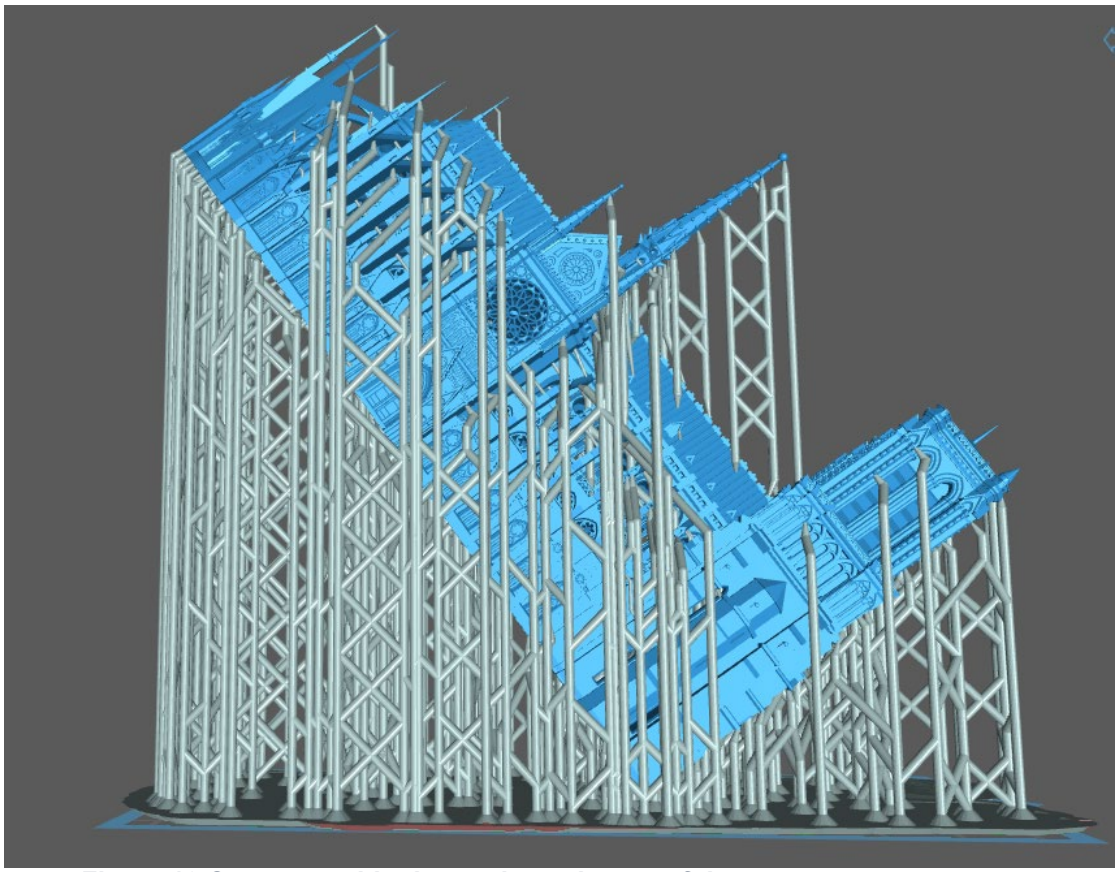

Figure 13 Correct positioning and attachment of the support structure

6 List of Figures