APPLICATION GUIDE

3D Printing Rigid Insole Shells Using Fuse 1+ 30W and Nylon 11 Powder

Learn how to produce strong, ductile insole shells exceeding 4 million bend cycles with Formlabs' compact, affordable SLS ecosystem. Equipped with unmatched ease of use and the lowest CapEx in the industry, Fuse 1+ 30W empowers you to start 3D printing nylon 11 insole shells quickly and scalably. Whether you're taking your first step into digital production or are looking to streamline an existing workflow, this comprehensive guide will help you hit the ground running with insole shell production on the Fuse 1+ 30W.

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Introduction

An insole is an orthotic device that is used to help correct or support patients with abnormal foot posture. Here, we present a workflow for designing and producing a custom insole shell – a critical component of the finished insole – using a 3D scanner, a Fuse 1+ 30W SLS 3D printer equipped with an inert atmospheric control, and Nylon 11 Powder.

Important Note: Achieving the full range of benefits outlined in this application guide relies on the use of an inert atmospheric control (nitrogen atmosphere) to effectively eliminate air from the build chamber and prevent SLS powder oxidation. Please note that failure to incorporate these controls may lead to compromised performance of the printed parts.

Essentials

Required Hardware and Materials

Made by Formlabs

- Fuse 1+ 30W
- Fuse Sift
- Nylon 11 Powder
  - Material overview available here
- Powder Cartridge
- Build Chamber
- PreForm

Made by Third Parties

- Scanner
- CAD software
- Nitrogen source
  - Generator, compressor, bottle, dewar, or tank
- Vacuum
- Media blaster
- PPE

Workflow

1. Scan

The digital workflow begins with a scan of a foot. The increasing adoption of digital scanning in podiatry has led to the development of fast, accurate scanners that don't require extensive CAD knowledge to use.

Scans are most often taken directly of the patient, but in some instances, it may be desirable to take a traditional plaster or foam cast of the patient and scan that model instead. The chosen scanning method and device must both be compatible with the CAD software being used for design. Most scanners for this application come in one of these four formats; iPhone/LIDAR-based, handheld, pressure plate, or gait scanner. More information on choosing the best scanner for this application can be found here.

2. Design

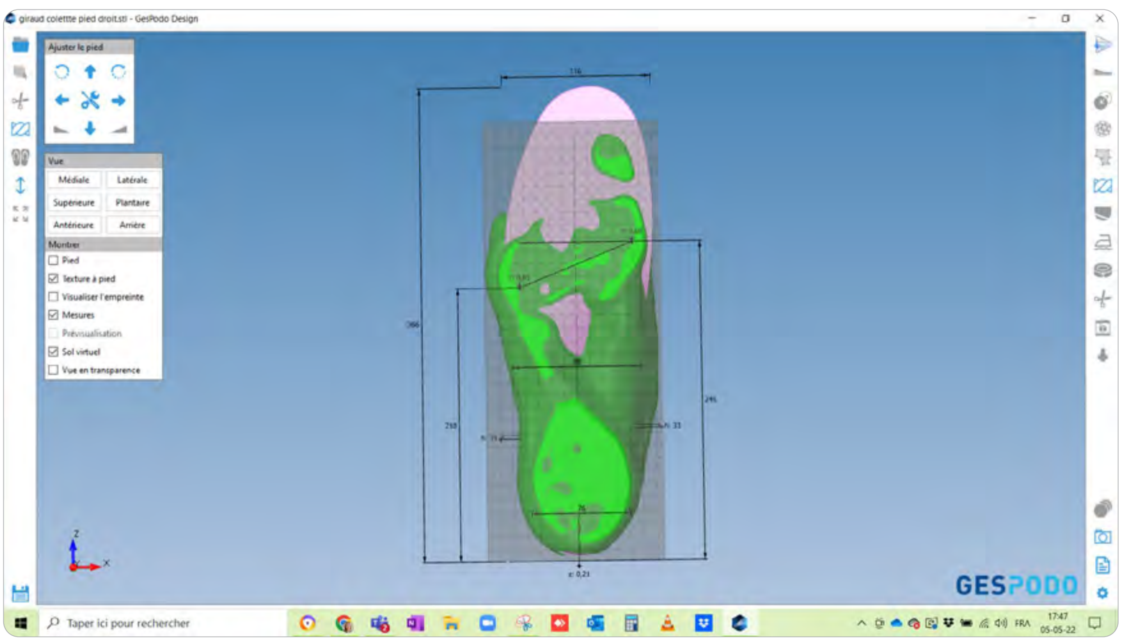
2.1 Choose a Software

Once a scan of the foot is obtained, specialized software is used to customize the insole to the patient's corrective or accommodative needs. When choosing a software, it is important to look for one that offers open .STL, .OBJ, or .3MF file export to ensure compatibility with PreForm, and confirm compatibility with the scanning method used. Software packages with proven compatibility to PreForm include, but are not limited to, FitFoot360, Gespodo FOOTCAD3D, and Amfit. The rest of this section will provide a generalized overview of a process that can be expected across many insole design software.

2.2 Upload the Patient Scan and Correct the Cast

Upload the patient scan into the design software. If the scan is not already in a neutral position, the software may be able to digitally manipulate it into the proper position. Software can also be used to clean the model and remove extraneous material that was picked up during the scan. A depth map can be used to display high and low points on the model, and the model can be edited by removing material, adding material, and smoothing the surface texture of the model.

Amfit's Correct and Confirm Editing Software displaying a depth map and 3D rendering from a patient scan.



Patient scan being measured in Gespodo FOOTCAD3D. A full demonstration of this software can be found here.

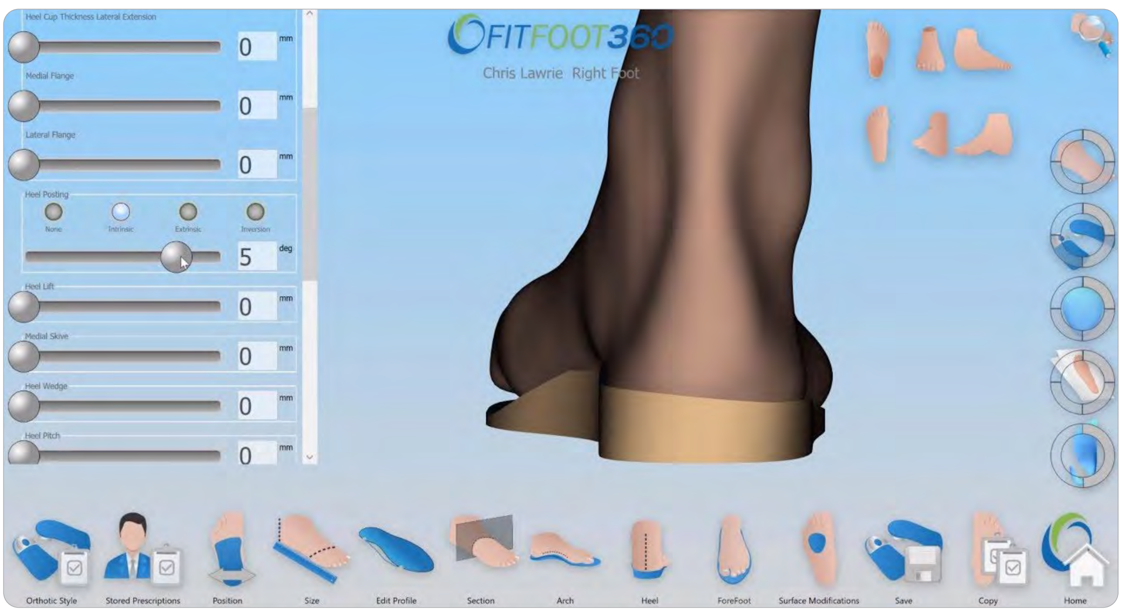
2.3 Select the Insole Type

Select the type of insole you're looking to create from a menu of different insole types. For this overview, we will focus on creating a rigid insole shell for comfort, but these software packages offer a variety of different insole types. The software will produce an adjustable .STL, .OBJ, or .3MF file for this insole type and display it against the plantar surface of the patient scan. The size and position of the whole insole shell, as well as individual features of the insole shell, can be adjusted in this step and as needed further along in the design process.

2.4 Customize the Insole Features

The insole design software will help you adjust features such as the arch depths, heel cup thickness, extensions, and flanges against your patient scan. Extrinsic and intrinsic postings can be added and adjusted for the forefoot. The same can be added for the heel, as well as heel lift, wedge, pitch, skives, and inversion postings.

The software will help with adding other patient specifications, including forefoot corrections, cut-outs, cuboid corrections, indentations, trimmed edges, met pads, relief, and met bars. Some users may opt to add a textured surface to the top or bottom of their insole shell to aid with slippage or adhesion to other layers.



Screenshot of FitFoot360's sliding scales being used to adjust the heel posting on a rigid insole shell. A full demonstration of this software can be found here.

2.5 Optimize for Printing

2.5.1 PLANTAR SURFACE

When printing in the preferred orientation, the device's minimum thickness on the plantar surface should not be less than 1.8 mm in order to maintain the rigidity required to support the user. Similarly, thickness should not exceed 3 mm, because increased thickness results in excess rigidity, which can lead to premature fracturing under stress.

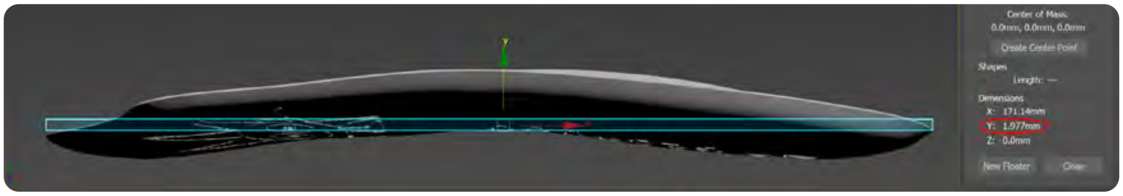


Diagram showing measurement of the device thickness on the plantar surface.

2.5.2 FOREFOOT AND EDGES

The forefoot and edges of the insole shell may be thinner than the plantar surface in order to create a smooth transition from the hard to soft material in the completed insole assembly. Optimal mechanical properties were observed on samples with edges approximately 2 mm thick. The printer is capable of unsupported geometry smaller than this if necessary. Care should be taken when using media blasting on very thin edges to avoid damage that could propagate into a fracture under extreme bending.

2.5.3 EMBOSSING AND ENGRAVING

You may want to emboss or engrave a company logo or patient identifier on the insole shell. The Fuse 1+ 30W is ideal for embossing, engraving, or other fine details included in the insole shell design. Some design guidelines for best results are listed below.

MINIMUM EMBOSSED FEATURES

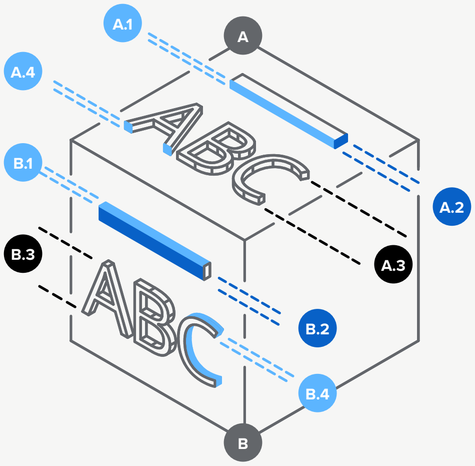
A. HORIZONTAL FACES:

- A.1 **Depth: 0.15 mm**
- A.2 **Width: 0.35 mm**
- A.3 **Text font height: 4.5 mm**
- A.4 **Text font depth: 0.3 mm**

B. VERTICAL FACES:

- B.1 **Depth: 0.35 mm**
- B.2 **Width: 0.4 mm**
- B.3 **Text font height: 4.5 mm**
- B.4 **Text font depth: 0.3 mm**

Embossed features are extruded from the surface of the model. Small embossed features may not be visible on the finished part. Use a bold font where possible for best results with embossed text.



MINIMUM ENGRAVED FEATURES

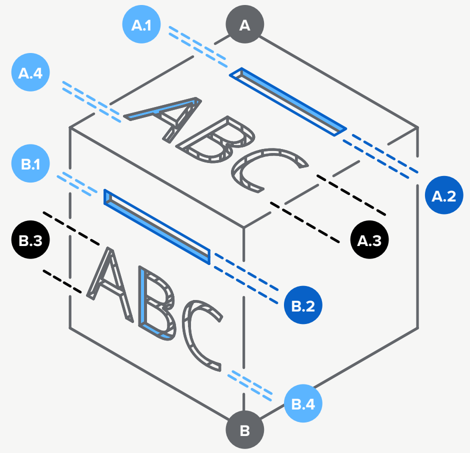
A. HORIZONTAL FACES:

- A.1 **Depth: 0.1 mm**
- A.2 **Width: 0.3 mm**
- A.3 **Text font height: 3 mm**
- A.4 **Text font depth: 0.3 mm**

B. VERTICAL FACES:

- B.1 **Depth: 0.15 mm**
- B.2 **Width: 0.35 mm**
- B.3 **Text font height: 3 mm**
- B.4 **Text font depth: 0.3 mm**

Engraved features are cut from the surface of the model. Small engraved features may not be visible on the finished part. Use a bold font where possible for best results with engraved text.



2.6 Export

Once the design is completed within the CAD software, the file should be exported in .STL, .OBJ, or .3MF format.

3. Print

3.1 Select Printer and Material

Ensure you have the latest version of PreForm and printer firmware installed. Open PreForm and select **Job Setup**. Choose the name of the printer that you intend to print on and select **Nylon 11 Powde**r from the material menu. The powder used can be a mix of fresh and used powder, but should contain a minimum of 30% fresh powder. When printing without an inert atmospheric control (nitrogen), use 100% fresh powder to maintain material performance.

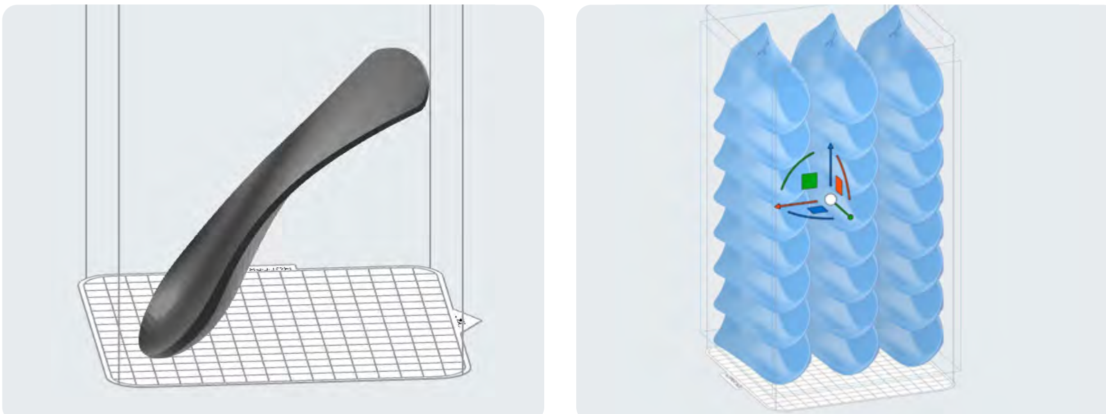
3.2 Import Model File Into PreForm

Click **File > Open** to import the .STL, .OBJ, or .3MF file that was exported from the design software into PreForm.

3.3 Orient Models

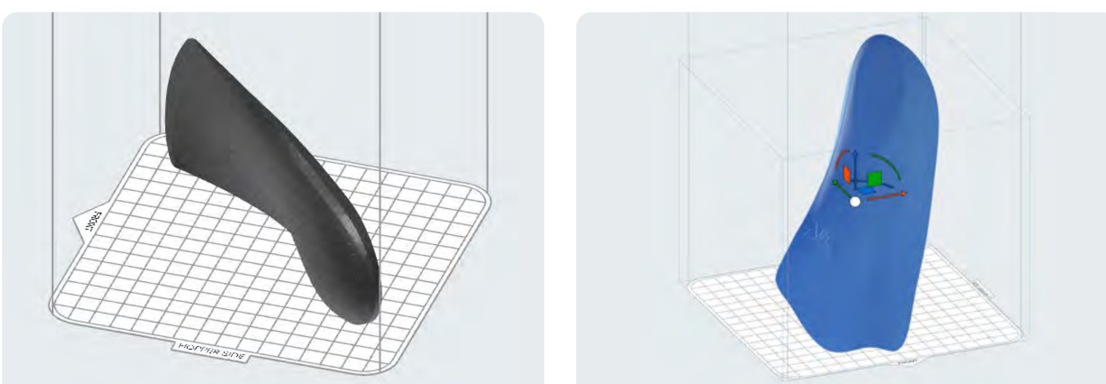
Printing flat is the best option for optimizing mechanical properties. To print flat, open the **Orientation** tab on the left side of the screen and click **Select Base**. Place the base so that it is normal to the plantar surface of the insole shell, and the part will sit flat.

Some scenarios may call for angled printing. Printing at an angle can be used to achieve longer insole lengths and improve packing. Internal testing conducted by Formlabs has shown that angling prints in the long axis (heel to toe) can increase the maximum insole shell length without a significant compromise in real-world performance. Parts can also be rotated on their long axis to improve packing. To angle the rigid insole shell, go to the **Orientation** tab on the left side of Preform. Using the **Orient X** or **Orient Y** input fields, enter the desired angle value so that the part tilts on its short axis. Printing insoles vertically, i.e., at an angle greater than 50° degrees from the build chamber floor, will lead to suboptimal mechanical performance and inefficient build chamber use, therefore resulting in a higher cost per part.



Rigid insole shell angled at 50° to the build chamber floor on the short axis (left) and a packed build volume, optimized by rotating shells 45° on their long axis (right)

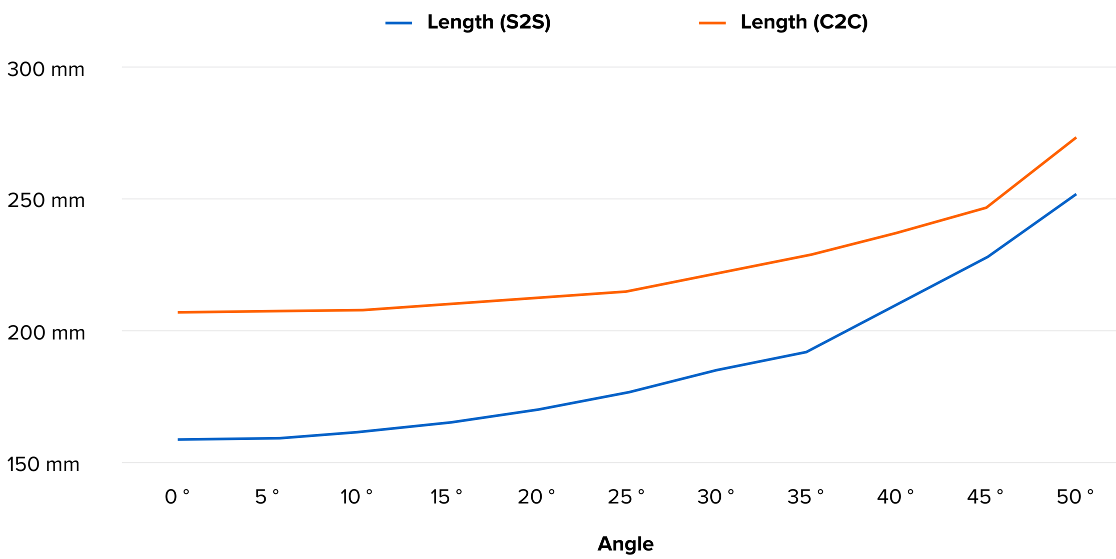
Very long insole shells can be printed diagonally across the build chamber floor, Corner to Corner (C2C) on their long edge. To print on the long edge, open the Orientation tab on the left side of the screen and click Select Base. Select the long edge of the part so that it appears to stand up on its side. Manually rotate the part in the Z direction so that it sits corner-to-corner in the build volume. If the insole is still too long diagonally, an additional angle of up to 50° can be added between the part and the build chamber floor. Additionally, a part being printed in this orientation can be rotated along its long axis to improve packing.



Rigid insole shell being printed corner to corner on its long edge (left) and a shell being printed on its long edge 50° from the floor of the build chamber and rotated 40° to improve length and packing (right).

Use the following chart as a guide for angling your prints to achieve prints up to 270 mm in length.

TOTAL PRINT LENGTH IN MILLIMETERS: Side to Side (S2S) vs Corner to Corner (C2C)



3.4 Arrange Models

Multiple copies of the same insole shell can be printed using the Array feature. To use the Array feature, go to the **Layout** tab on the left side of the screen, highlight your part, and select **Array Models**. Input the number of times that you would like to duplicate your design and set the desired spacing. Be aware that the spacing setting in the array feature measures the space between bounding boxes, not actual geometry, so to get curved parts like insoles to sit very close to one another, the spacing may need to be set as a negative value. Manual adjustments to spacing may be required to maximize the number of printed parts. If parts are spaced too closely together, a red outline will appear on the part to indicate that the spacing should be increased.

The **Layout** tab also allows you to create mirrored parts, which may be desirable for patients that require the same device design for both feet. To use the mirror feature, open the **Layout** tab and duplicate the part that needs to be mirrored. Highlight the newly duplicated part and select **Mirror Models**. Rearrange to fit in the build chamber as necessary.

The number of insole shells that can fit in the build chamber will vary depending on the design. More parts can be fit in the build volume by grouping right-foot and left-foot devices together, and aligning them at 180° to each other with the straighter edges along the outside of the build volume. Additionally, stacking insole shells so that the largest are on the bottom and the smallest are on the top, and batching prints by size (i.e., one chamber filled with devices sized men's US 8 / EU 41 and smaller, another chamber with devices size men's US 8.5 / EU 42 and larger) will help fit more in the build volume as well. Representative .FORM files of what an average build volume may look like can be downloaded here and here.

The build chamber volume can be maximized by limiting the build to all right-foot models, or all left-foot models, at one time. For this reason, high-throughput users may want to consider utilizing two printers: one exclusively for right-foot shells, and one exclusively for left-foot shells. This will allow the capacity of the build chamber to be maximized while producing right and left shells simultaneously.

3.5 Prepare the Printer

Add Nylon 11 Powder to the printer using a Fuse Series Powder Cartridge and insert a clean optical cassette. Insert a build chamber and follow any other preprint checks prompted by the machine. To preserve material performance, make sure you use at least 30% new powder mixed with, at most, 70% recycled powder that's only been used in nitrogen atmospheres. Formlabs recommends a refresh rate of 30% new powder with 70% recycled powder to minimize waste and production costs.

3.6 Prepare the Nitrogen Supply

Nitrogen is essential to producing optimal mechanical properties for insole shells when using recycled power. Once installed, the nitrogen system is relatively passive, requiring very little attention during normal operation. Nitrogen can be provided from any source that meets the following specs: concentration of 99.5% or greater, flow of 0.5 SCFM, pressure range within 36-120 psi, and a gas temperature at the machine inlet of 18°C (64.4°F) or more. This calculator by Airgas can be used to figure out your Fuse 1+ 30W's nitrogen demand, and your recommended supply mode.

The Fuse 1+ 30W will notify the user if the system is performing outside of parameters, however manually checking that the printer is receiving nitrogen is possible by accessing the printer status screen, toggling **Nitrogen System** to **ON**, and checking that the touch screen says **N2 Mode**.

3.7 Upload the Print

In PreForm, click the orange print button on the right side of the screen to upload your print to your selected printer.

4. Post-Process

4.1 Cool the Print

The cooling process starts within the print enclosure. Once printing is complete, the build chamber remains in the printer for 75 minutes. After the initial 75 minutes of cooling inside the printer, the build chamber can be removed from the printer and placed either in Fuse Sift or on the floor so that another print can be started. The build chamber will then continue to cool outside of the printer for the amount of time suggested by PreForm next to **Chamber Cooling**. If the build chamber is cooling in the Sift, the Sift will stop displaying the "hot build chamber" warning screen when cooling is complete.

4.2 Extract Parts Using Fuse Sift

Use the touchscreen to turn on the Fuse Sift's light, and then the sifter. Raise the print bed, either a little at a time or all at once, to eject the cake. Use the wire brushes and picks provided to scrub unsintered powder from the fused parts. Clean up excess powder into the sifter so that it may be recycled. Do not share the same Fuse Sift for parts that were printed with nitrogen and without nitrogen. This will lead powder cartridges to become filled with a mix of oxidized and non-oxidized powder, which can result in mechanical property variability across the build volume for your next print.

4.3 Media Blast

Use a media blaster with glass media to do a final clean and smooth of the finished parts. Some lower-cost media blasters that are suitable for Nylon 11 Powder include Fastenal, Grainger, and McMaster-Carr. Additional recommended media blasters can be found sorted by region on this page.

5. Complete the Insole Assembly

Once the insole shell has been 3D printed and post-processed, additional layers of softer material can be added to create the whole insole. The exact materials added depend on the patient's need and the designer's preference. Oftentimes, a leather, silicone, neoprene, or foam layer is added above and below the rigid shell for cushioning, slippage prevention, and moisture control. Ensure that any adhesives used to add additional layers to the Nylon 11 Powder Shell are compatible with the material according to the technical data sheet, and biocompatible.

The insole is ready for delivery to the healthcare professional or patient.

6. Modify

After observing the patient and collecting feedback, the healthcare provider may choose to make additional modifications to the insole shell. The Nylon 11 Powder insole shell may be modified with the addition of padding and extensions that may be off-the-shelf or printed with Formlabs TPU 90A Powder material on a dedicated machine. (Note: do not use the same Fuse 1+ 30W printer for both Nylon 11 Powder and TPU 90A Powder).

If necessary, hand tools that the provider already has in-office can be used to remove material or add texture to increase adhesion to other layers or minimize slippage. The material can also be thermoformed by hand using a heat gun. For increased rigidity and glossy appearance, insole shells can be vapor smoothed. Note that this may result in decreased flexibility.

Biocompatibility

Nylon 11 Powder has been evaluated in accordance with ISO 10993-1. It is certified for skin contact (ISO 10993-10), non cytotoxic (ISO 10993-5), and a non-irritant or sensitizer (ISO 10993-10). More information on the compatibility of Nylon 11 Powder can be found on the technical data sheet.

Limitations

1. Material

The only suitable material for this application currently offered by Formlabs is Nylon 11 Powder.

2. Orientation

Printing orientations other than those highlighted above can lead to suboptimal mechanical properties if the insole is not reinforced with additional material.

3. Build Volume

The build volume of the Fuse 1+ 30W build chamber is 165 x 165 x 300 mm.