Manufacturing Thermoformed Clear Aligners and Retainers on 3D Printed Models With the Form 2

Producing clear aligners and retainers is a valuable service that requires little initial investment from practices and labs alike. Treatment planning for these appliances is done using CAD software, then each substep of the treatment is fabricated by 3D printing a model, and thermoforming over these models. This application guide details the clear aligner and retainer workflow using a Form 2 3D printer, from start to finish.

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Essentials

Made by Formlabs

Form 2 3D Printer

Standard Grey or Dental Model Resin

PreForm Software (free)

Finish Kit or Form Wash

Form Cure (optional)

Made by 3rd Parties

Intraoral or desktop 3D scanner

Orthodontic CAD software

Plastic film for:

• Aligners: 0.030 inch or 3/4 mm thickness recommended

• Retainers: 0.040 inch or 1 mm thickness recommended

Thermoforming machine

Electric dental lab handpiece

Double-sided diamond cutting disc and carbide cutting bur

1. Scan

The orthodontic CAD software requires a digital impression file to create clear aligner models. Capture the digital impression either directly, using an intraoral scanner, or indirectly, using a desktop optical scanner to scan a polyvinyl siloxane (PVS) impression or stone model. Unless working inside a complete scan and CAD system, export the scan as an open STL format file.

2. Design

After capturing the digital impression, import the scan files into orthodontic CAD software and design teeth movement for the desired clinical outcome. Make sure to select a orthodontic CAD software that offers open STL file export to ensure compatibility with Formlabs PreForm software.

The exact procedures in treatment planning and design varies by software package, but generally follow the workflow described below. For detailed advice on treatment planning and design, contact the software manufacturer.

2.1 Import

Import the scan data into the software.

2.2 Build the model base

Depending on the quality of the data, the scans may need to be trimmed slightly below the gingival margin. Doing so can help minimize the model size and print time.
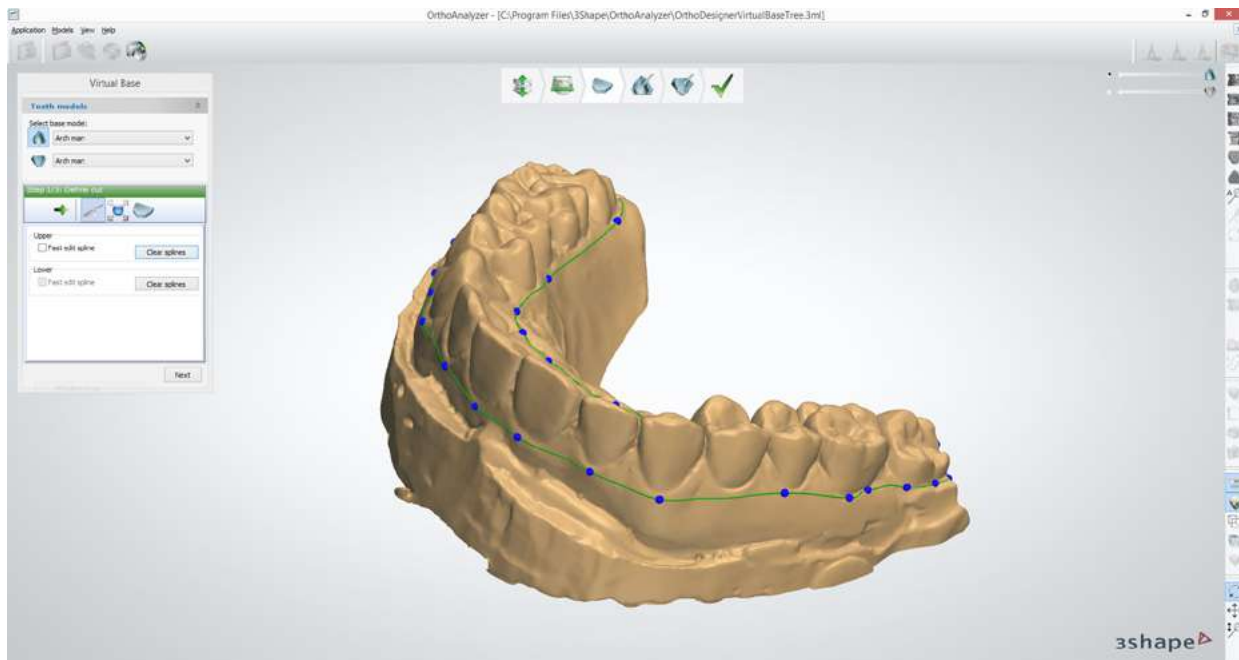
Next, build a horseshoe arch base for the model. As clear aligners are usually cut to the gingival margin of the patient's dentition, it is recommended to extend the base below the lowest point on the gingival margin by about 2 mm.

Keeping the height of the base close to minimum will help reduce print times and material use. Formlabs recommends keeping the base 2 mm below the lowest gingival margin.

If a taller base is preferred, avoid extending the base to more than 8-10 mm from the gingival margin, to keep the total model height below 19 mm. This will ensure that the larger model size does not stretch the thermoforming material to a point of being too thin.

2.3 Design Orthodontic Treatment

To design the orthodontic treatment, first section the teeth in the software, separating individual teeth from the complete model. Then, move each tooth to the final position. Subdivide the treatment plan into individual models with each stage moving the patient's teeth by slight amounts. The number of generated aligners depends on the complexity of the case.

Warning! Orthodontic treatment design should be done by licensed orthodontists only. Orthodontic CAD software can simulate tooth movements that are not realistic or feasible.
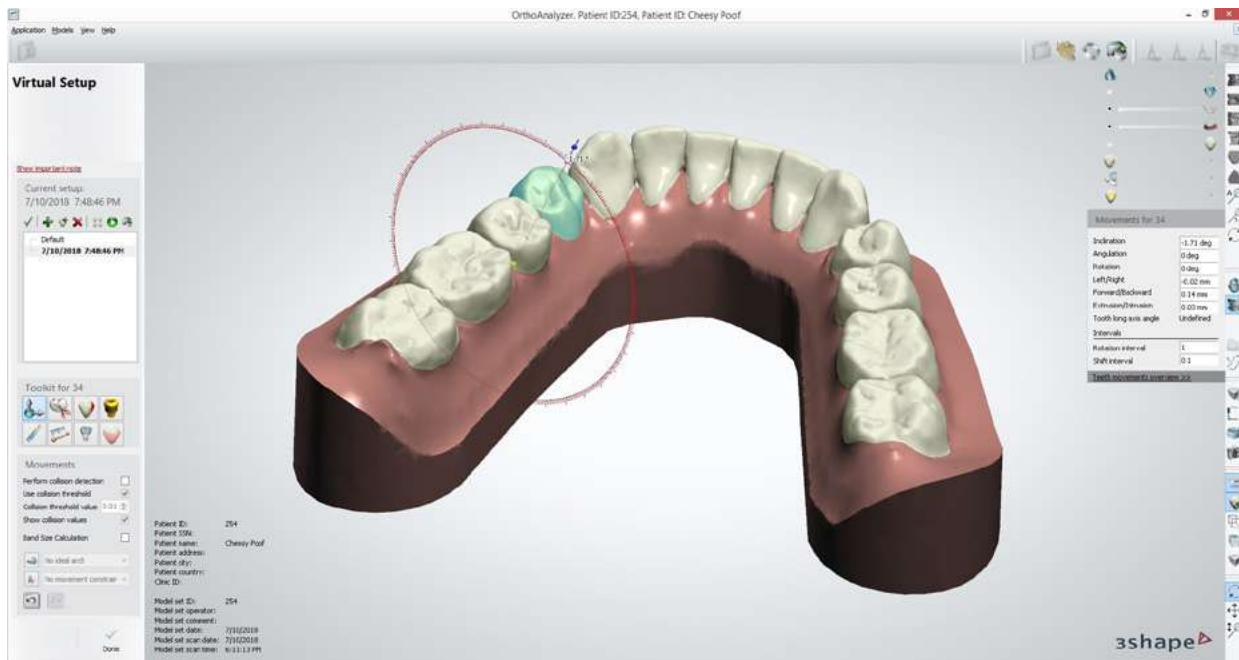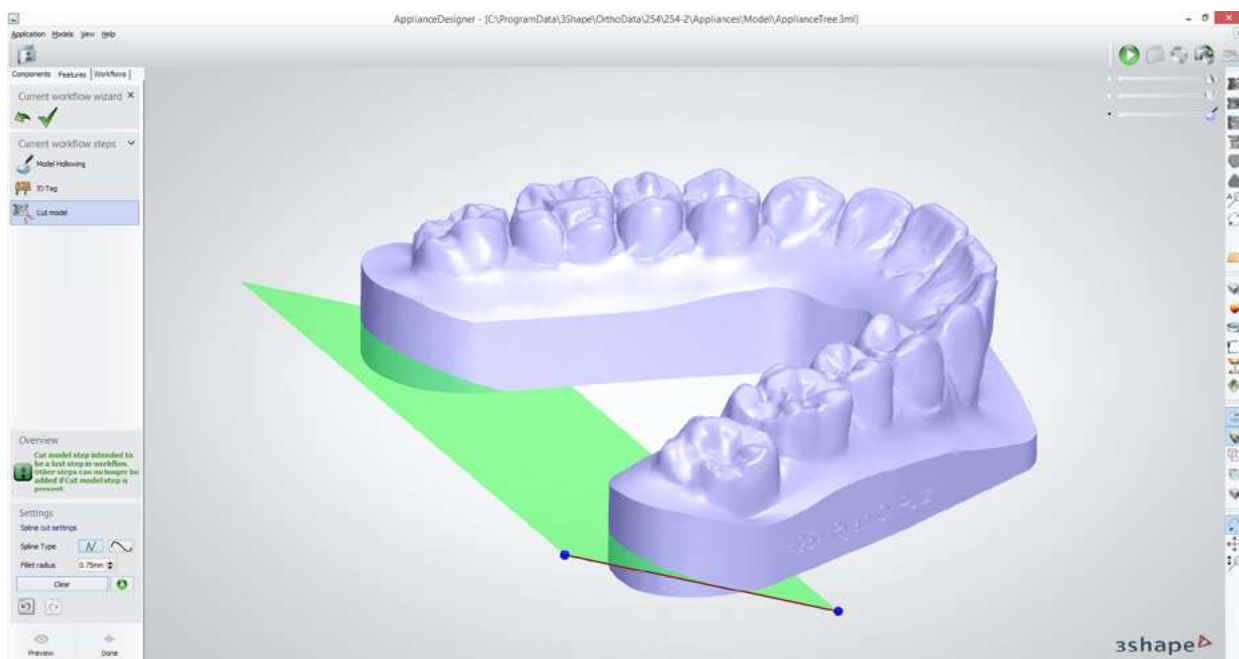
2.4 Model Sculpting (Optional)

For each model from the treatment plan, sculpting can:
- Improve printability
- Streamline part removal
- Add workflow-specific features, such as identification tags

These steps are optional and depend on the workflow and desired print orientation.

2.4.1 Chamfer the model base

Chamfering the model base makes removing parts significantly easier. This can be done easily at the rear of the model with a plane cut tool.

A chamfer angle of 30-45° is recommended, with a chamfer height of 2-3 mm to allow space for a part removal tool to be easily inserted.

2.4.2 Emboss identification tags on the model

Embossing identifying information on printed models can be very helpful for high-volume aligner production. A treatment stage number, ID number, and/or patient name can be embossed anywhere below the gingival margin except on the base of the model.

To ensure optimal printability, place the embossed information on the vertical wall of the extended base.

Hollow vs Solid Models
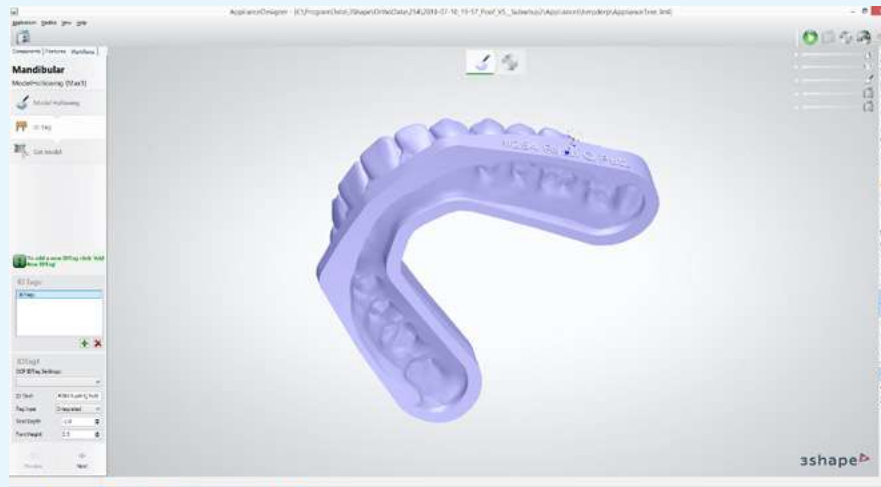
Hollowing the model can improve print time and reduce unit cost, although this feature is only available in certain orthodontic CAD softwares. If hollowing a part, ensure that wall thickness is at least 2-3 mm thick. Formlabs recommends printing solid models to reduce post-processing difficulty.

2.5 Export models

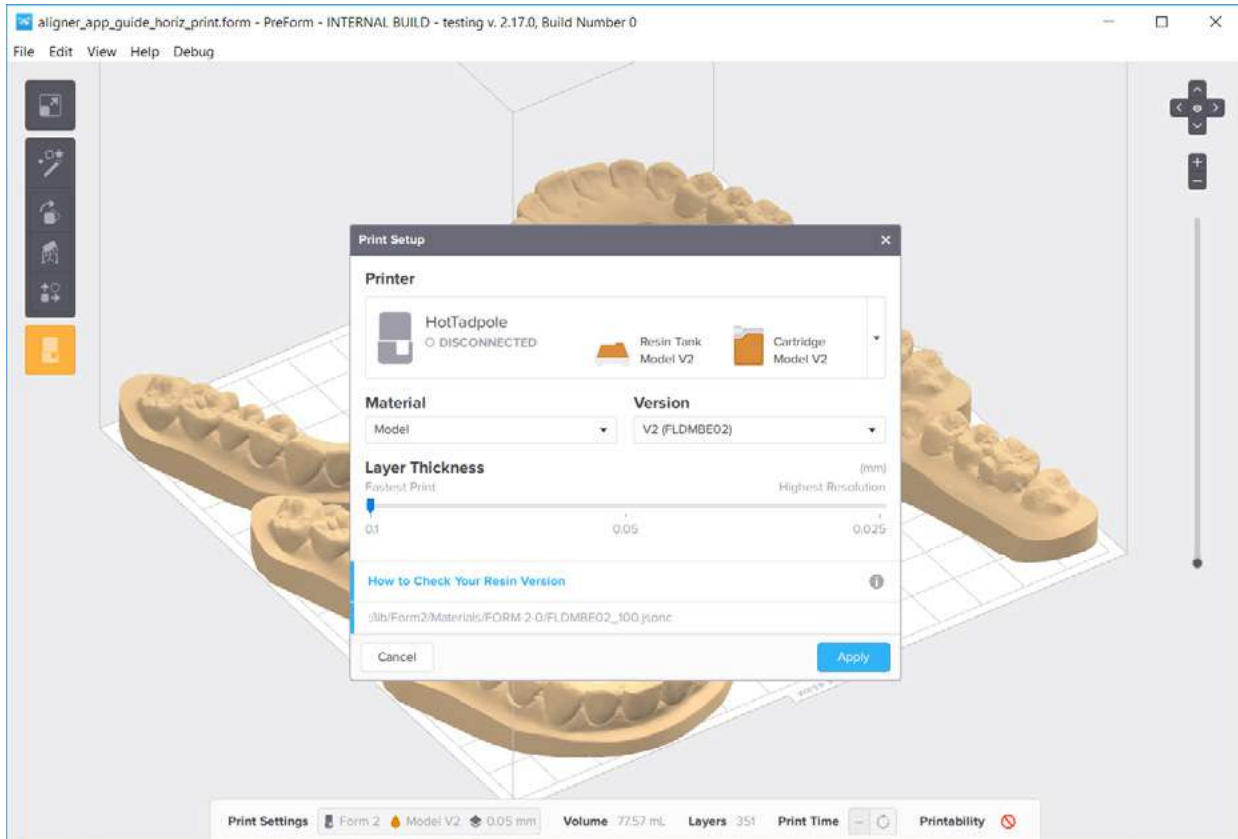Export models for each treatment step in STL or OBJ file format.

3. Print

3.1 Import model files into PreForm

Open PreForm and import the generated STL or OBJ file(s).

3.2 Configure print settings

In the 'Print Setup' menu in PreForm, choose the printer to be used based on its name, a unique combination of two words. Select "Model" or "Grey" from the Material menu, and 0.1 mm for the layer thickness.

Note: An analysis on accuracy in printed orthodontic models showed that 0.05 mm print layer thicknesses yielded only marginal differences in accuracy and precision, while doubling the print time. Printing orthodontic models at 0.1 mm thicknesses is strongly recommended, to reduce print times while still ensuring clinically acceptable accuracy.

3.3a Orient parts for printing without supports

| Horizontal	Vertical
- Faster print times - Fewer parts per build	- Slower print times - More parts per build

Note: Formlabs recommends printing horizontal models to maximize accuracy and precision, but many Formlabs users also have success vertically printing orthodontic models.

If printing parts directly on the build platform, the models must have a flat surface. The slicing tool on the right-hand side can be used to double check correct snapping of the part to the platform.

To orient the base of the part directly to the build platform, select the base of the model in Orientation > Select Face.
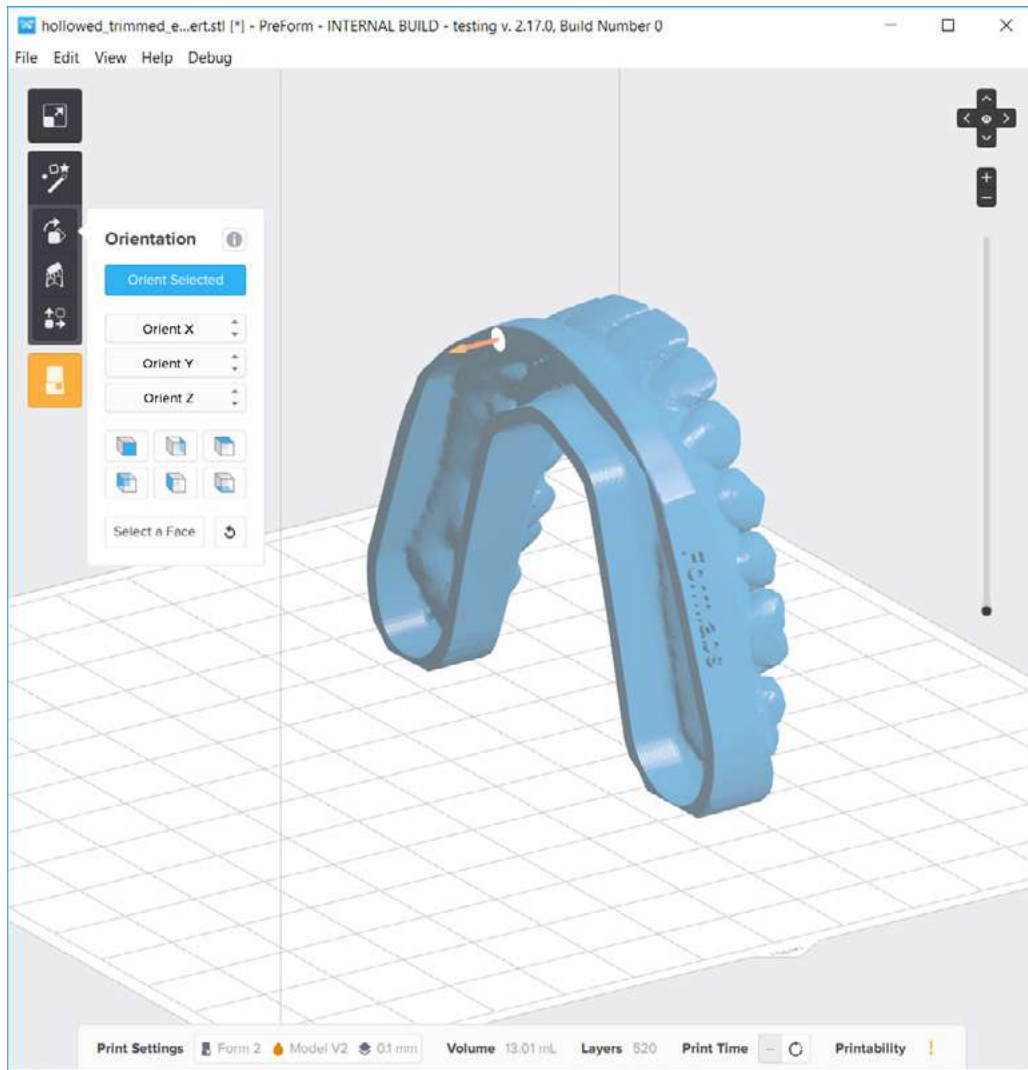
3.3b. Orient parts for printing with supports

Printing with supports makes part removal significantly easier and more consistent, but requires additional print time for the base and support pillars.

3.3b.1 Orient the models

Orient the model with the occlusion facing up and away from the build platform.

Orienting models at a 15° angle or greater is recommended. Lower angles improve print times. Higher angles allow for a higher density of models to be printed in the same build.

3.3b.2 Generate supports

Generate supports using PreForm's auto-generation feature, then inspect the model to ensure that there are no supports touching tooth surfaces or the gingiva. For improved print consistency, a point size of 0.7 mm for supports is recommended.

Remove any stray supports in Supports > Edit, or orient the model with a less steep angle.
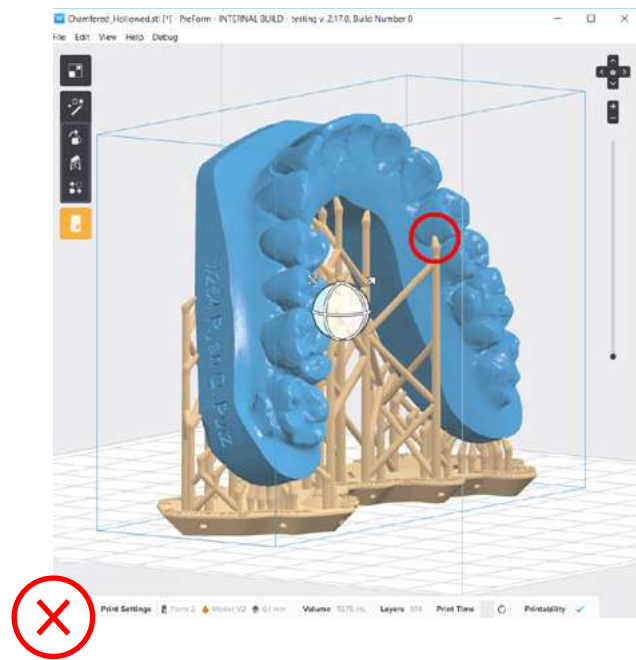
3.4 Prepare the printer and resin

Thoroughly agitate the resin cartridge by shaking and rotating it several times. Insert a resin tank, the Dental Model or Grey Resin cartridge, and a build platform into the printer.

Using Standard Resin Tanks vs. Resin Tank LT

For the highest accuracy and precision, Resin Tank LT is recommended for printing dental models. Testing of Grey and Dental Model on Resin Tank LT revealed no degradation of accuracy or precision over the lifetime of the tank.

If using the standard resin tanks, laser exposure forms white, clouded marks on the surface of the resin tank's silicone layer. This clouding eventually becomes extreme enough to affect accuracy. To avoid fit issues due to tank clouding, switch to a new standard resin tank after 50 consecutive prints, or with every second cartridge of resin, whichever comes earlier.

3.5 Print

Click the orange "Print" button in PreForm, then upload the job to the printer. Once the print is uploaded, press the button on the printer to start the print.

4. Prepare

4.1 Wash parts

Place the build platform, with the models still attached, in a Form Wash filled with isopropyl alcohol (IPA), 90% or higher. Alternately, remove the models from the build plate and place them in the included basket for washing. Set Form Wash for 10 minutes to clean the parts and remove excess resin from the models.

Warning! Hollow models printed directly on the build platform will trap liquid resin in the hollow regions underneath the model. Hollow models must be removed from the build platform prior to rinsing.

Using the Standard Finish Kit
Formlabs recommends using Form Wash for optimal resin removal and surface finish. If using the Finish Kit, remove parts first from the build platform with the part removal tool. Rinse the parts in two buckets of isopropyl alcohol (IPA), 96% or higher for an initial bath for 10 minutes, and a second bath for 5 minutes.

4.2 Remove parts

Next, remove parts from the build platform. For chamfered models, insert the included putty knife into the chamfer with a firm force, then twist the knife gently from side to side. Otherwise, grasp the base of a molar using the included pair of flush cutters, applying the same twisting motion.

4.3 Air or blow-dry

Use a compressed air hose to blow IPA away from surfaces. Inspect parts closely to ensure all uncured resin has been removed. Repeat wash if necessary.

If compressed air sources are not available, simply leave the parts to air dry before inspection.

4.4 Remove supports if needed

Use the flush cutters included in the Formlabs Finish Kit to carefully cut the supports at the points where they attach to the part. Use caution when cutting the supports, as the material may be brittle. Supports can also be removed using other specialized appliances, such as cutting disks or round cutting instruments like carbide burs.

4.5 Post-cure the models (optional)

Expose dental models to light and heat for optimal mechanical properties, accuracy, and precision. When using Form Cure, place the printed models inside Form Cure and post-cure for 30 minutes at 60 °C.

5. Thermoform

From this step, the workflow is identical to the traditional workflow for creating clear aligners and retainers.

Use a dental thermoformer machine on the printed model to form the clear aligner, using the recommended settings for the thermoformer and material being used.

> **Warning!** Depending on the aligner material being used, if the model base is too tall, the resultant aligner walls will be too thin. Ensure that the models generated are short enough for the recommendations provided by the manufacturer. Generally the recommendation is to keep model height below 19 mm..

6. Finish

6.1 Initial cut

Make an initial cut below the gingival margin using a rotary tool with a diamond disc attachment, then remove the aligner. To prevent fusion of the aligner and the model, avoid using a hot knife when removing the aligner from the model.

6.2 Deburr

Smooth edges and remove burrs by cutting closely along the margin using a rotary tool with a carbide bur attachment. Thicker attachments can help to efficiently cut closer to the gingival margin.

6.3 Polish

Use a polishing wheel to smooth all edges of the aligner.

Accuracy Study

An in-depth accuracy study showed that dentition of orthodontic models printed on the Form 2 were dimensionally accurate within ±100 microns over 85 percent of surfaces, providing a precise clinical fit. This was found to be similar across both Dental Model Resin and Grey Resin, both at 0.05 mm and 0.1 mm layer thicknesses.