



Assembly of e-NABLE's Raptor Reloaded Hand

by [andreasbastian](#) on January 15, 2015

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Intro: Assembly of e-NABLE's Raptor Reloaded Hand

The Raptor Reloaded is an updated release of the original that incorporates feedback from the **e-NABLE community** and has CAD design source files available in STEP, IGES, IPT, and F3D formats.

Updates in the 12-17-14 release include:

- Improved print-ability due to custom modeled supports
- Cyborg Beast compatible sizing
- Improved dovetail geometry
- New tensioner retention clip
- Easier to use tensioner pins
- Low profile elastics with two tie-off options
- More access to elastic and flexor routing channels
- Debossed versioning information on palm and gauntlet
- Slimmer, more anthropomorphic fingers
- Narrower knuckle block
- More intuitive assembly (new one-way proximals)
- Thorough documentation and modular design
- Source files in native Fusion 360 format, also STEP and IGES
- Additional velcro-mounting options as well as traditional velcro loop and leather options
- Re-oriented snap-pin head recesses to improve printability
- Knuckle pins are now removable, making the hand easy to repair and upgrade
- Strengthened tie-bars on finger tips

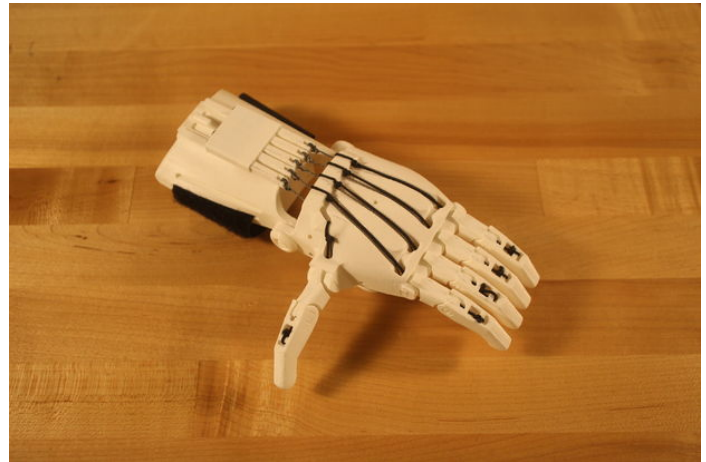
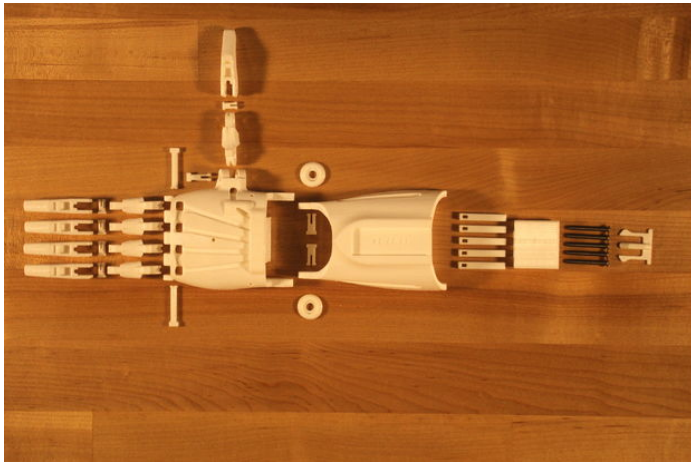


Image Notes

1. Palm (left)

Image Notes

1. Gauntlet

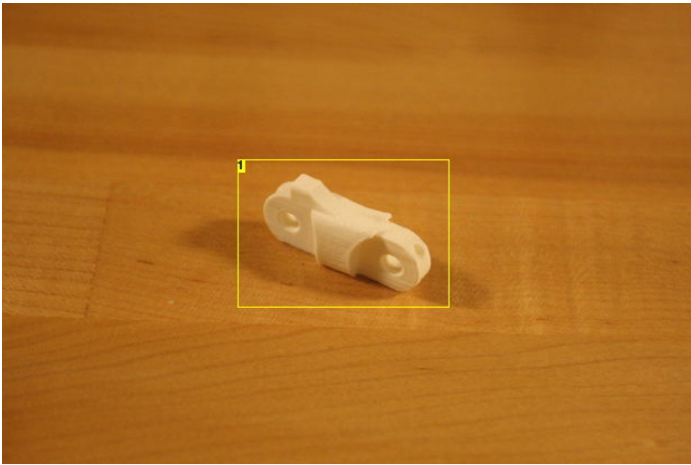


Image Notes
1. Proximal phalange

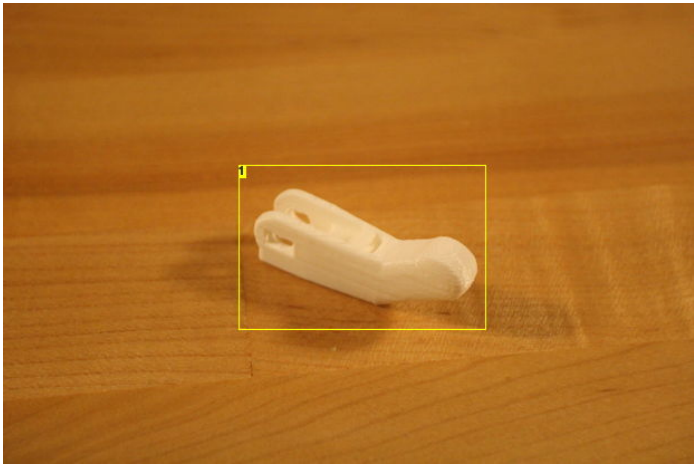


Image Notes
1. Fingertip

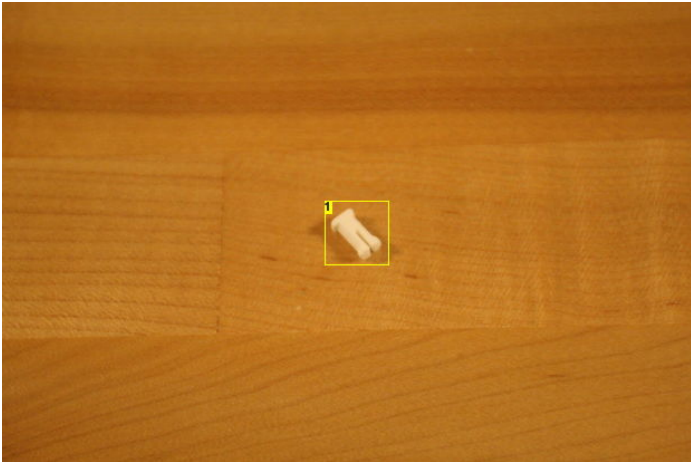


Image Notes
1. Finger snap pin

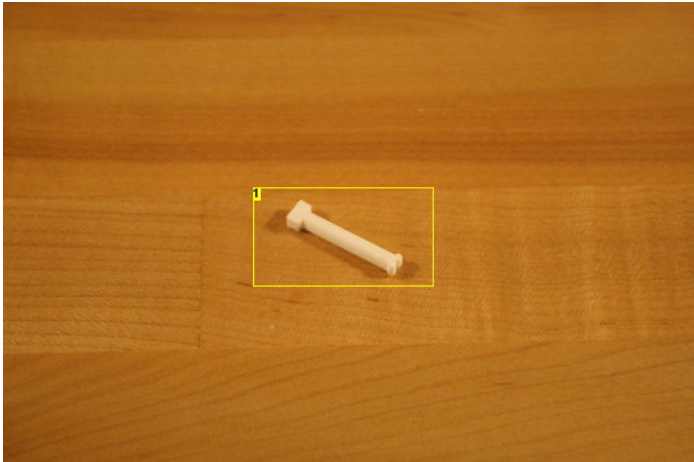


Image Notes
1. Knuckle snap pin

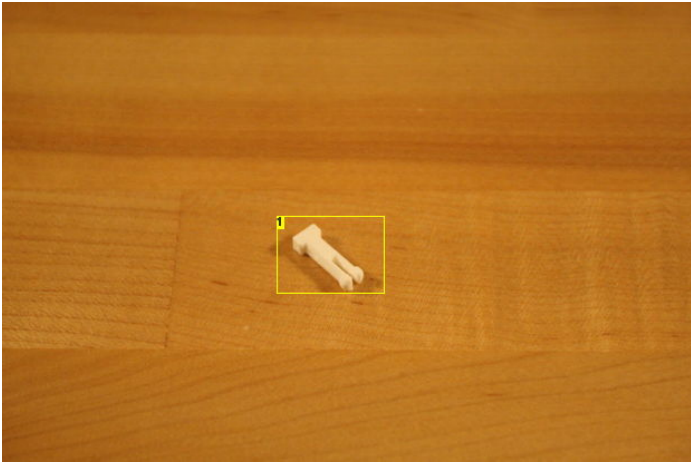


Image Notes
1. Thumb snap pin

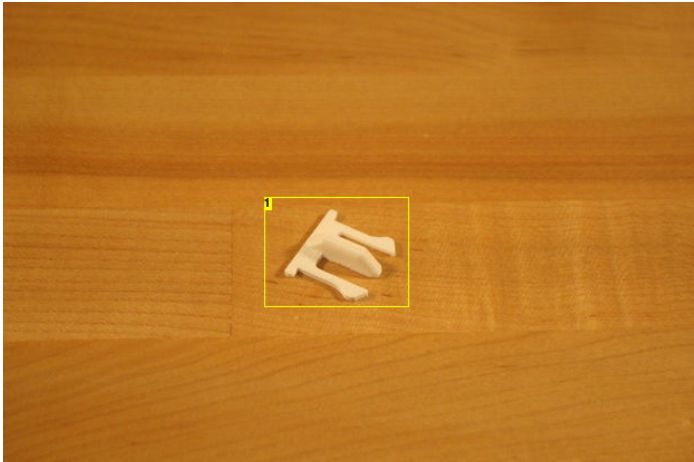


Image Notes
1. Tensioner retention clip

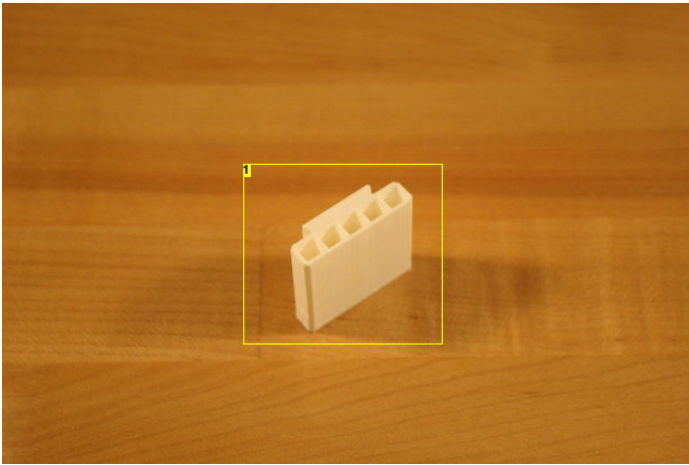


Image Notes
1. Tensioner block

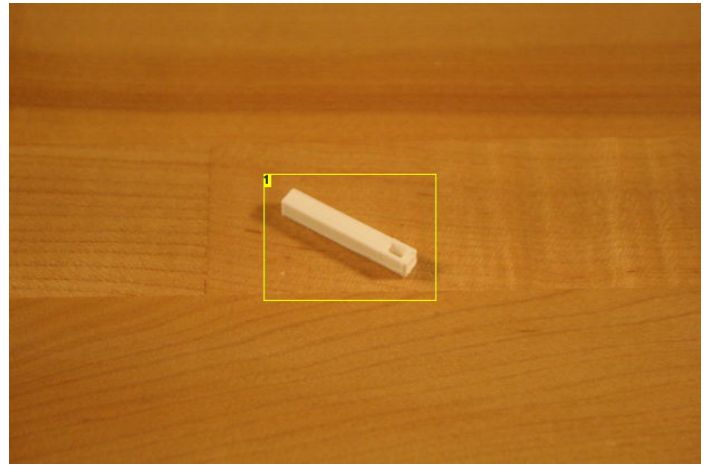


Image Notes
1. Tensioner pin

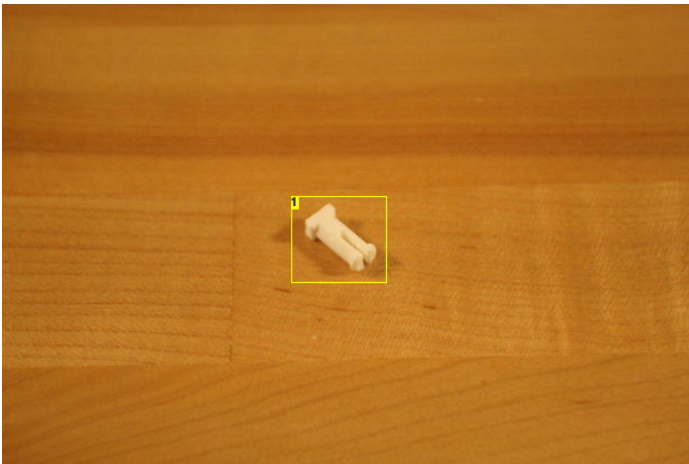


Image Notes
1. Wrist snap pin

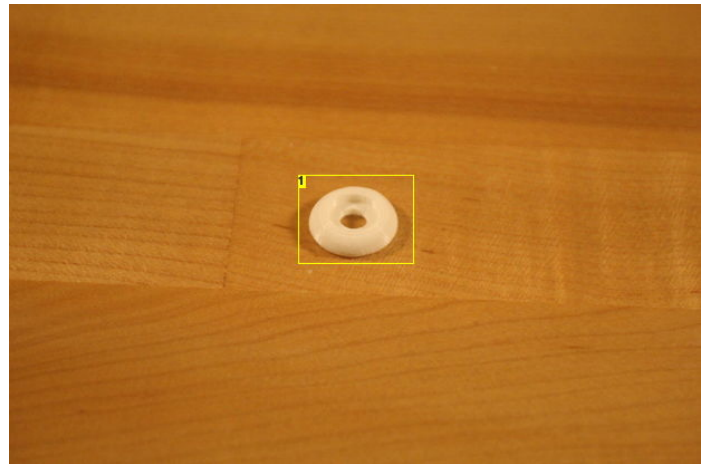


Image Notes
1. Wrist snap pin cap

Step 1: Size and Print the Parts, Secure Hardware

Download the latest **Raptor Reloaded** parts form [Thingiverse](#). The files are ready to print as is and do not require additional support material as custom removable support structures have already been modeled into the palm and gauntlet files. If you do wish to print without the included support, files without support are also available on the Thingiverse page.

There are two main options for sizing the Raptor Reloaded:

Linear Scaling (easy)

The main measurement used in sizing the Raptor Reloaded is the width of the recipient's complete hand at the knuckles. At 100% scale, the palm of the Raptor Reloaded measures 55mm at its widest point. To get the appropriate linear scaling factor for scaling the STLs, add 5mm (to account for the thickness of padding in the printed palm) to the width of the recipient's complete hand at its widest point. Divide this number by 55 to get the scaling factor for the STLs. For example, if the palm is 65mm wide, then $65 + 5 = 70$, and $70 / 55 = 1.27$, so the scaling multiplier would be 1.27 or 127%. Make sure to apply the scaling factor to all of the parts to ensure that they fit together. At higher scales, the clearances between the moving parts of the hand will grow, so glue or other modifications may be necessary to ensure that all the pieces stay secured to each other.

Parametric (more involved):

Because radial and lateral clearances for motion assemblies are absolute, linear scaling can cause problems at large scales. For those with some CAD experience, the native Fusion 360 source files as well as STEP and IGES files are available [here](#). Detailed technical drawings can be found on the [github](#). For an introduction to modeling in Fusion 360, see the [Getting Started in Fusion 360](#) page on [enablingthefuture.org](#).

Recommended Printing Settings:

- PLA (or ABS, PET, Nylon)
- 0.2mm layers
- 2 shells
- 35% infill
- Active cooling fan on

Additional Materials:

The Raptor Reloaded requires some additional hardware to assemble, most of which can be sourced from the [Hardware Sources](#) page on the e-NABLE website.

- 4ft Velcro, double-sided (2" wide)

<http://www.instructables.com/id/Assembly-of-e-NABLEs-Raptor-Reloaded-Hand/>

- 8ft Non-elastic nylon cord, 0.9mm-1.0mm
- 5ft Flexible elastic cord
- 5x Tensioner screws
- 4x Palm velcro attachment screws
- 12" (305mm) Firm Foam Padding (5 3/4" wide)
- 5x Lee Tippi Micro Gel Fingertip Grips (optional)

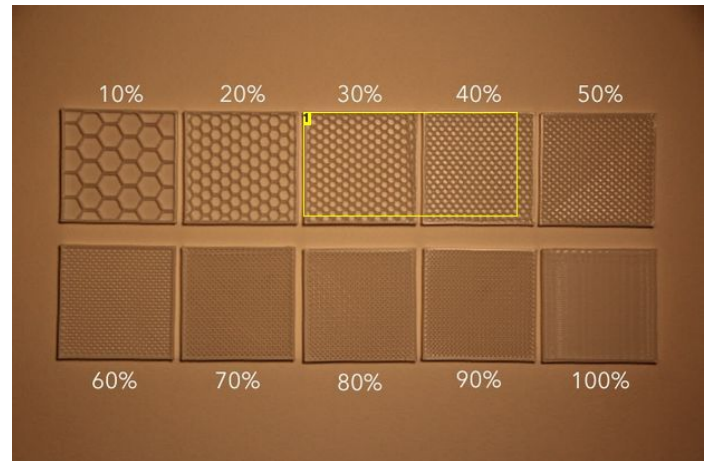
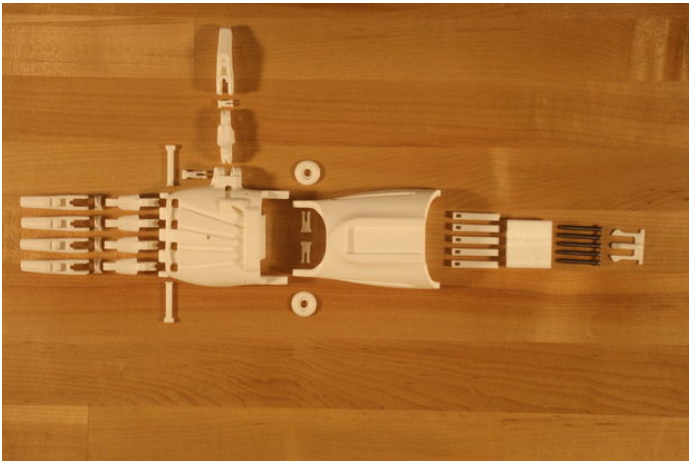


Image Notes

1. Recommended infill range

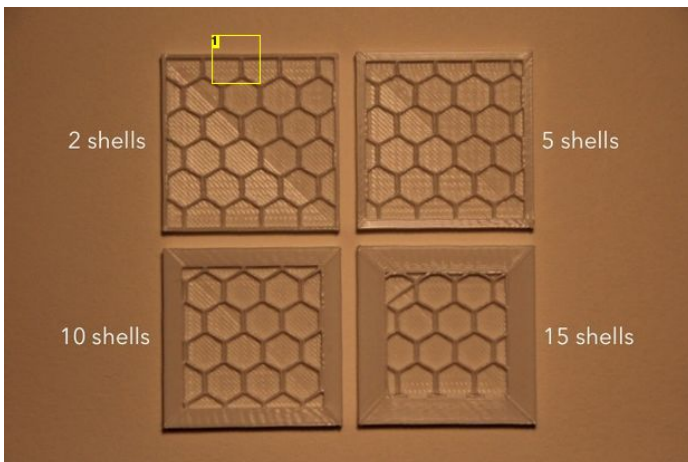


Image Notes

1. Two shells is typically adequate

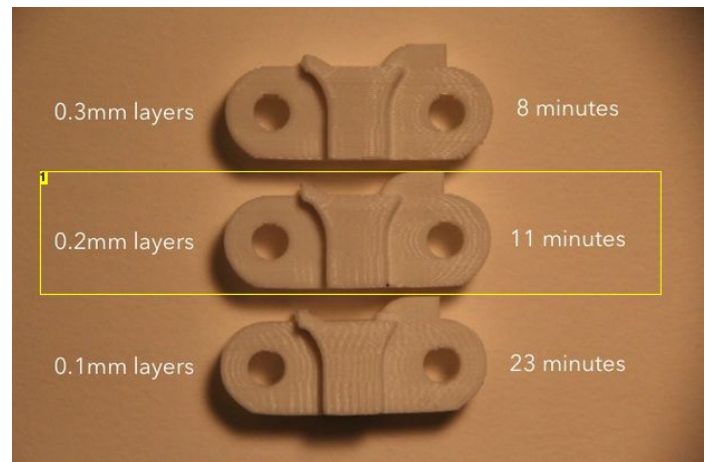


Image Notes

1. 0.2mm layers is a good compromise between speed and resolution

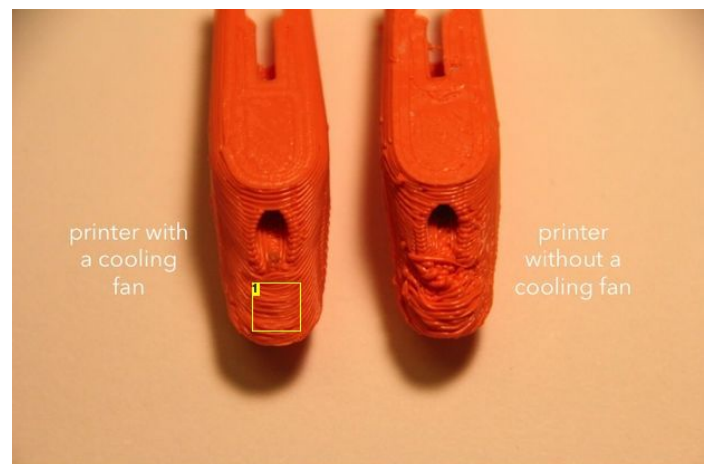
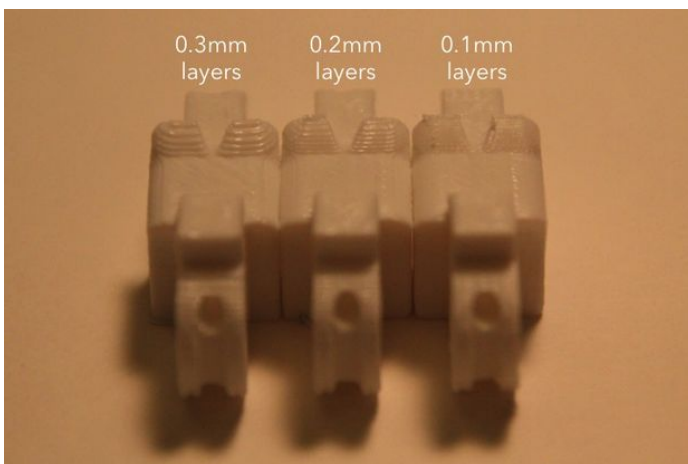
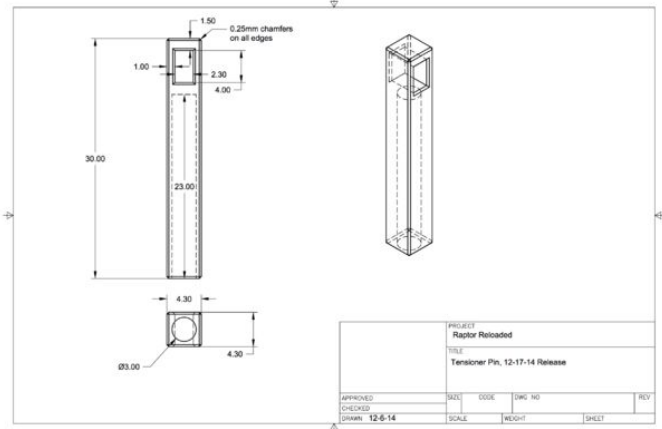
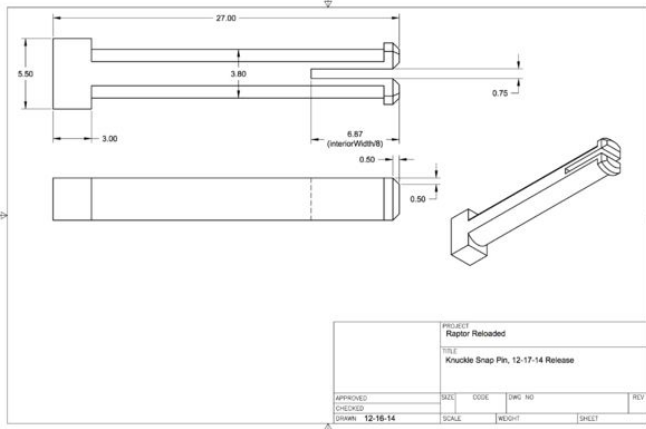
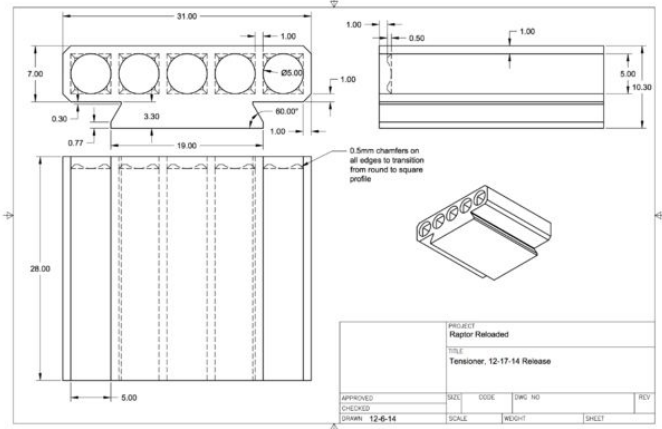
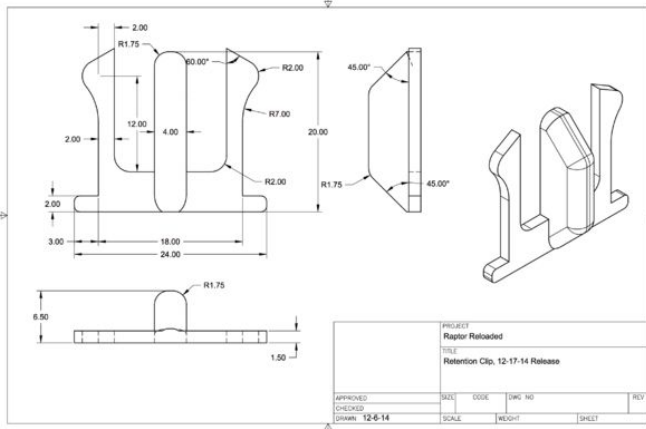
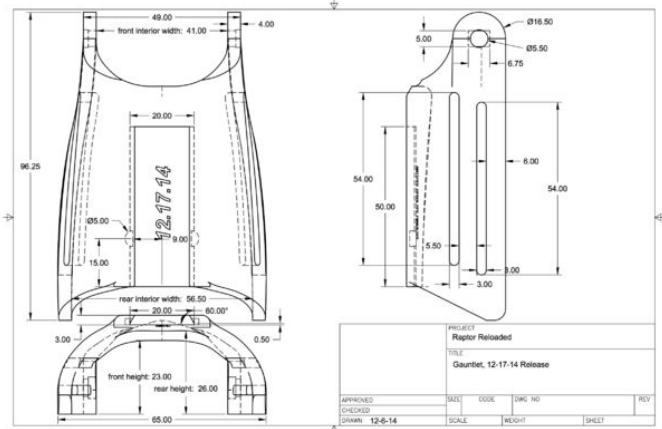
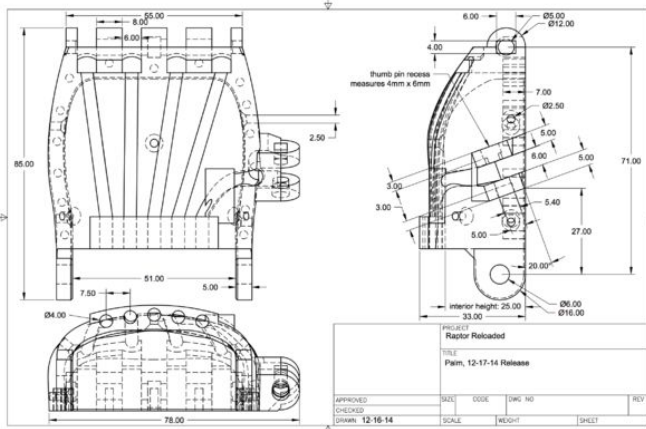
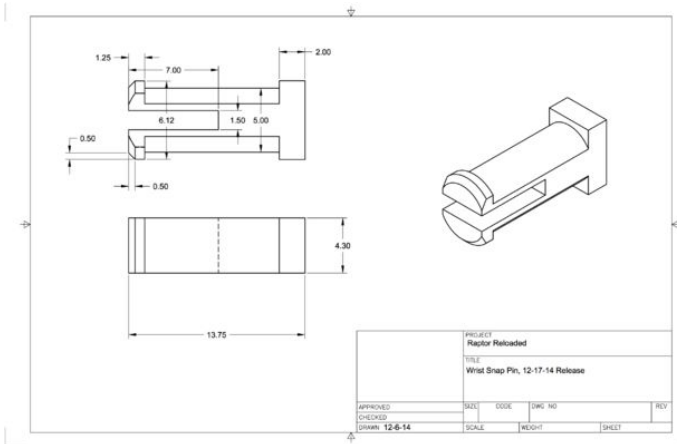
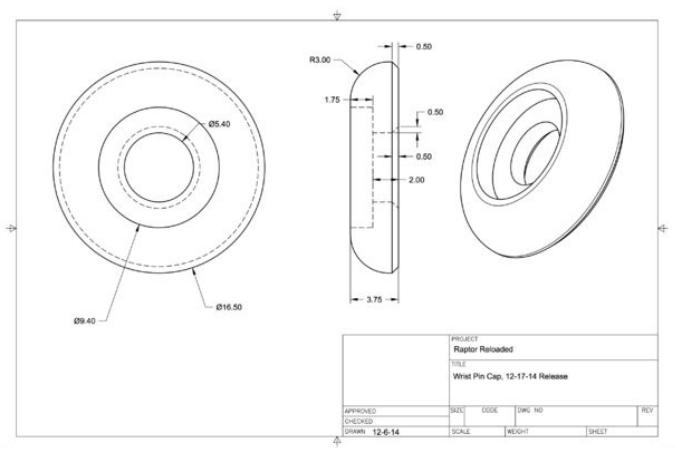
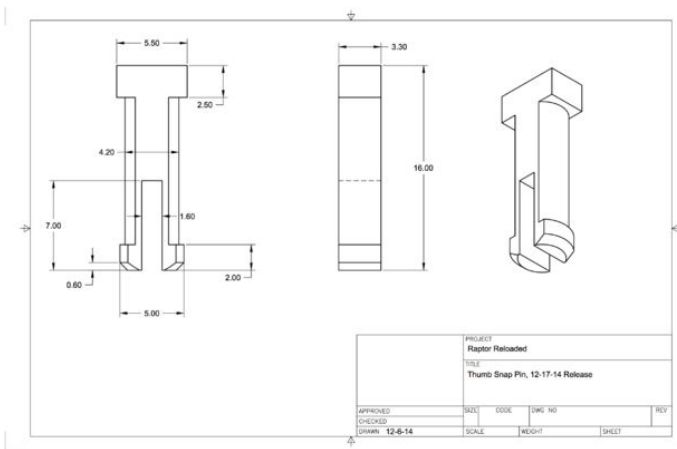


Image Notes

1. Active cooling helps resolve fingertips and other overhangs





Step 2: Assemble the Palm and Fingers

Start by removing the support structure, which can be done by inserting any edged tool in between the palm and the support structure and twisting. Next, check the fingertips for any defects. Small pieces of filament sometimes droop in the rectangular recess for the snap pin head-- be sure to remove these to ensure the snap pin seats well.

Assemble the fingers by inserting the proximal phalange into the matching recess in the fingertip, making sure the raised hard stop (the "square" region on top of one side of the proximal phalange) is facing away from the fingertip and the two small ridges on the top of the proximal meet the matching "wings" of the fingertip. Insert the snap pin and press until the rectangular head is seated in it's recess and the other end of the pin is flush with the sides of the fingertip. Repeat for the remaining four fingers. Attach the one finger to the thumb knuckle on the palm using the thumb pin and attach the other four fingers in the knuckles using the two knuckle pins. It is often helpful to get the knuckle pin started and then push its head using a table. If at a later point you need to remove or replace fingers, the knuckle pins can be backed out by pressing on their tips using the slot in between the bases of the middle and ring finger.



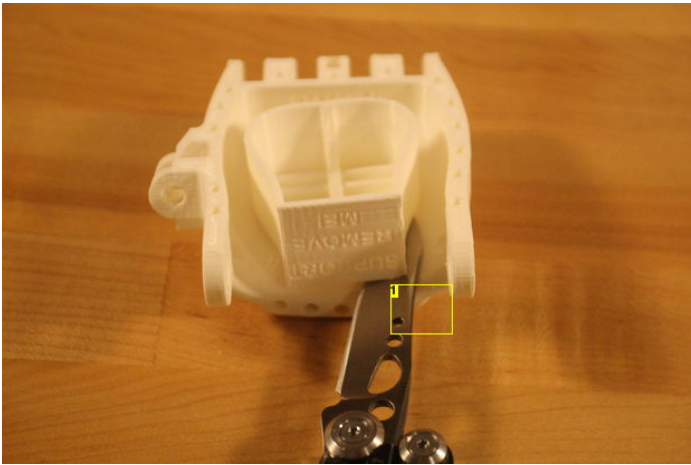


Image Notes
1. Any tool with an edge will work for removing the support structure.

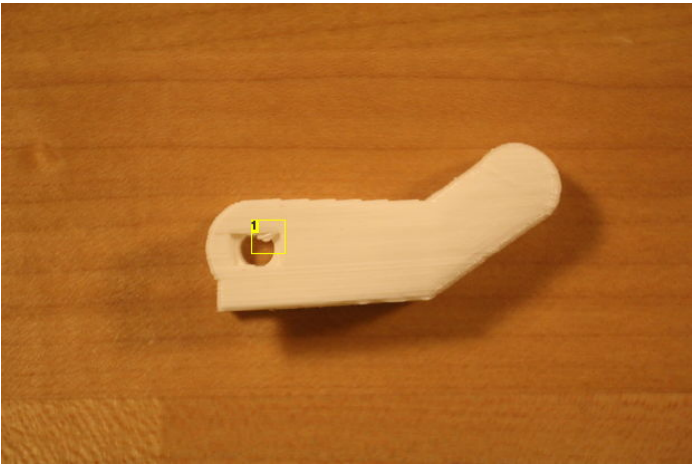


Image Notes
1. Sometimes the fingertips print with a small defect here.

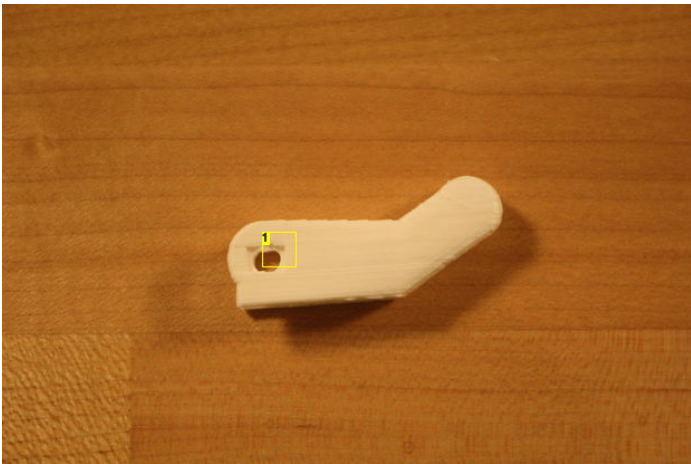


Image Notes
1. It can be removed with a blade or tweezers.

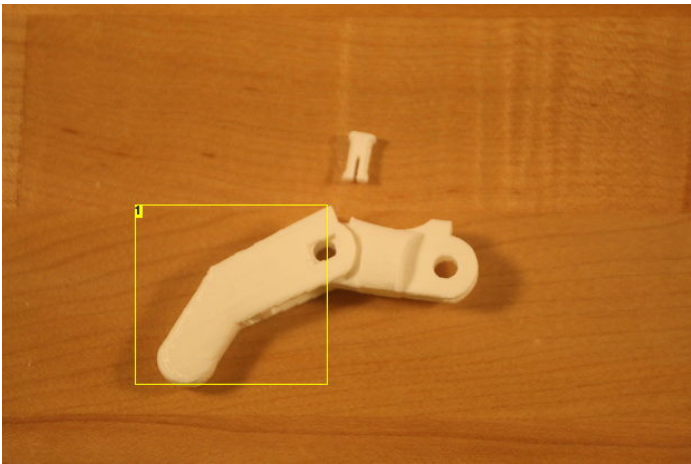
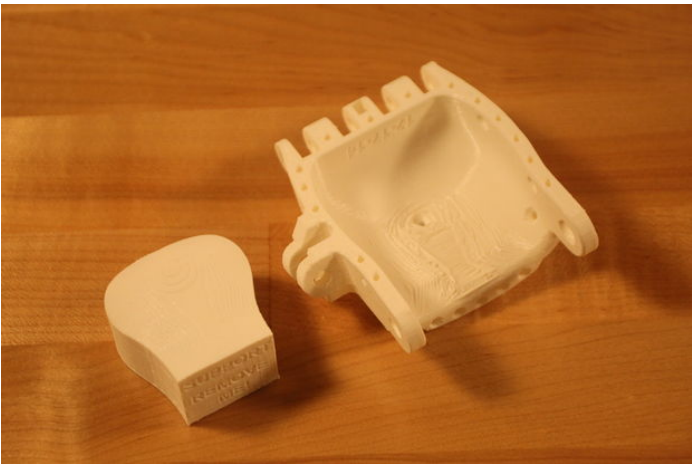


Image Notes
1. Fingertip



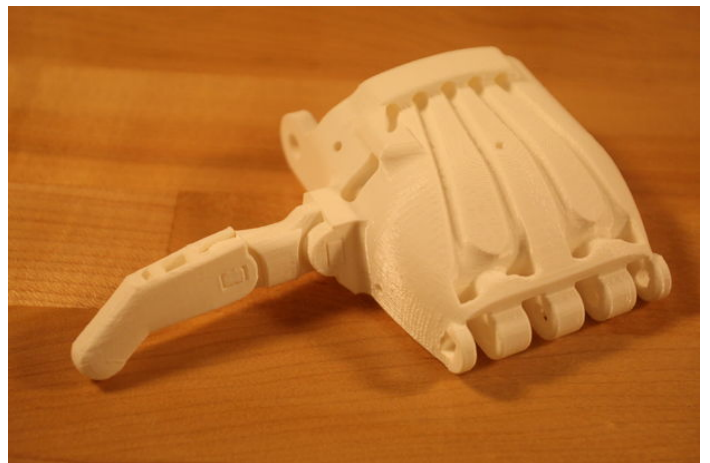
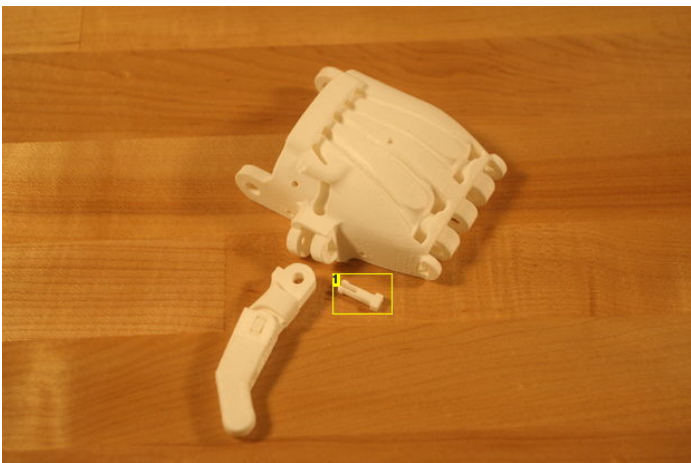


Image Notes

1. Thumb pin

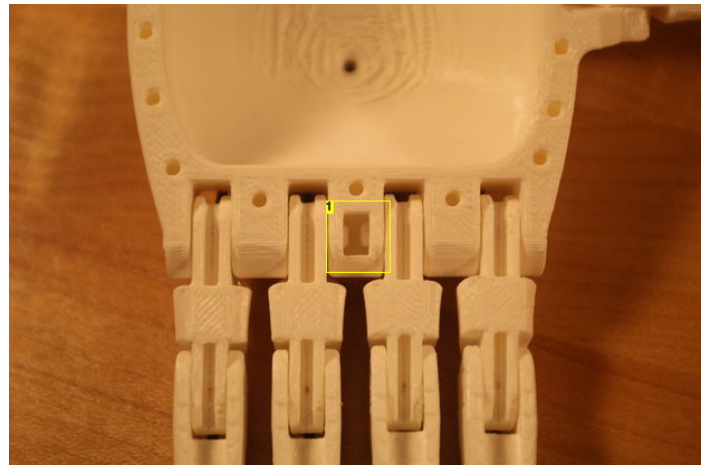
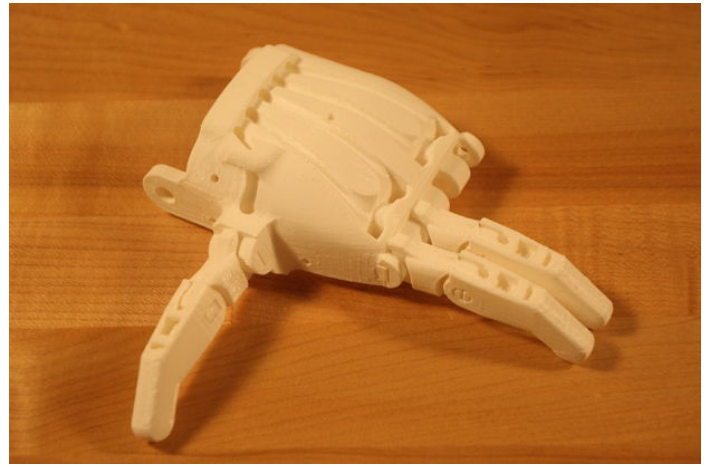
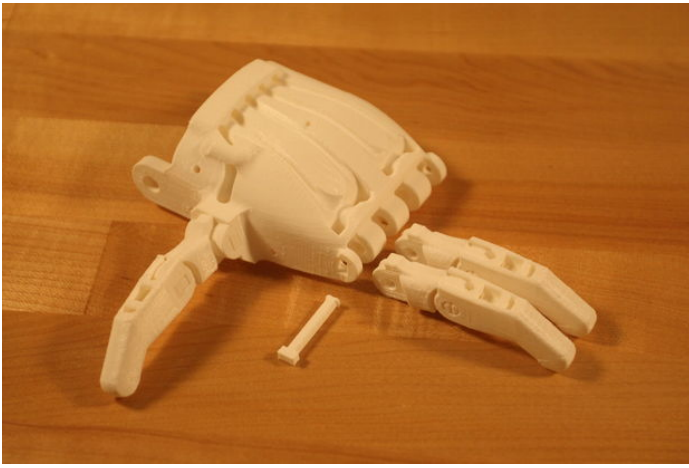


Image Notes

1. The knuckle snap pins can be removed by pushing on them from this slot.

Step 3: Install the Elastics in the Fingers

Check the [Hardware Sources](#) page on the e-NABLE website for vetted elastics options. I used 1.0mm black Beadlon elastic fabric cord from Amazon. Cut five lengths each a little longer than two finger lengths. I like to use tweezers to navigate the tight spaces where the elastics are tied. The goal of the elastics is to just counter to force of gravity on the fingers and to hold them gently open. This opening force is calibrated when tying the second end of the elastic cord to the back of the palm. The fingers should snap up after being pressed down, but should not require significant force to close.

Starting with the thumb, thread one end of a length of elastic cord under the bar on the back of the thumb tip until there is a little over an inch (30-35mm) of cord on the other side of the bar. Tie a clinch knot by twisting the free end around the longer side 2-4 times, then thread the free end through the loop at the base of the twist and through again the resulting loop:

After threading the elastic cord through the proximal and up through the cable guide, use the clinch (or two half hitch) knot to secure the end of the elastic cord to the cable guard as shown in the pictures. The goal is to use this knot to set the tension on the thumb, so tie it carefully after getting the appropriate tension.

For the remaining four fingers, I like to use the clinch knot on the finger tips and a two half hitch knot to secure the other end of each elastic to the rear cable guide on the palm. The two half hitch knot allows you to control the tension while tying the knot. See below:

Finally, I like to finish each elastic knot with super glue to ensure that it won't slip. Additional half hitches can be used as well.

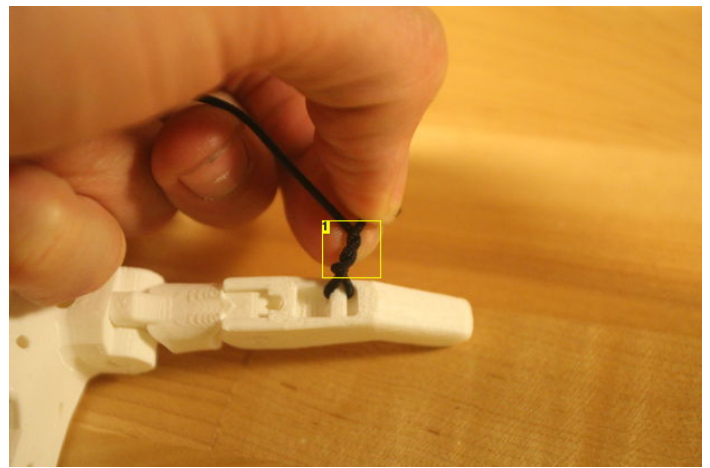
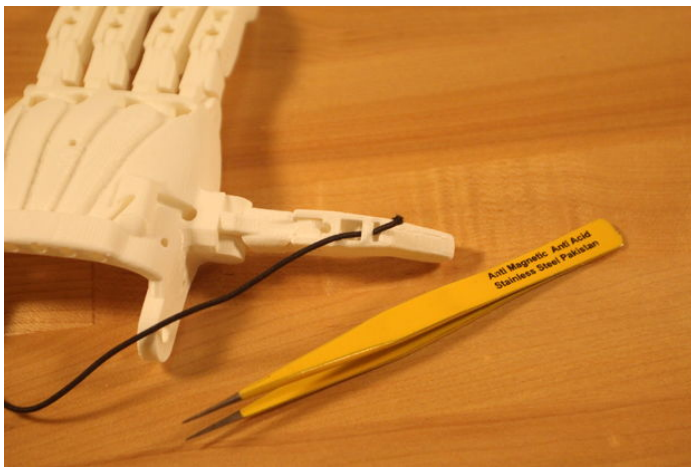


Image Notes

1. Twist 2-4 times around the long end of the cord.

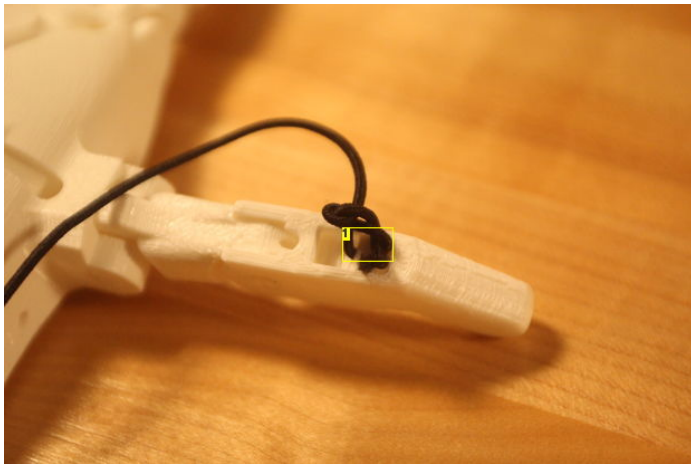


Image Notes

1. Thread through the loop at the base of the twist.

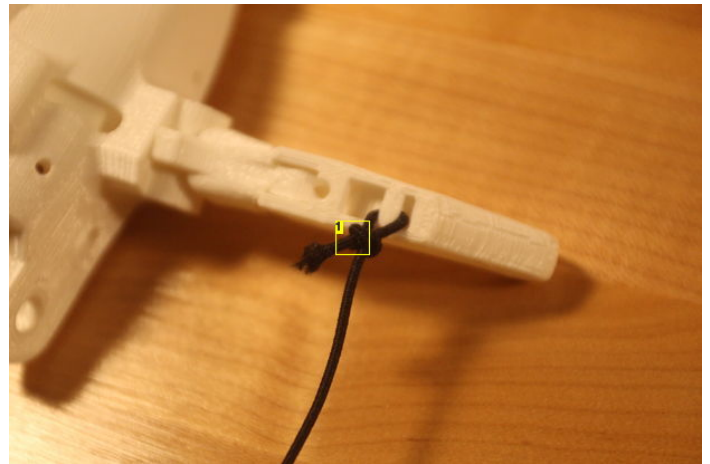
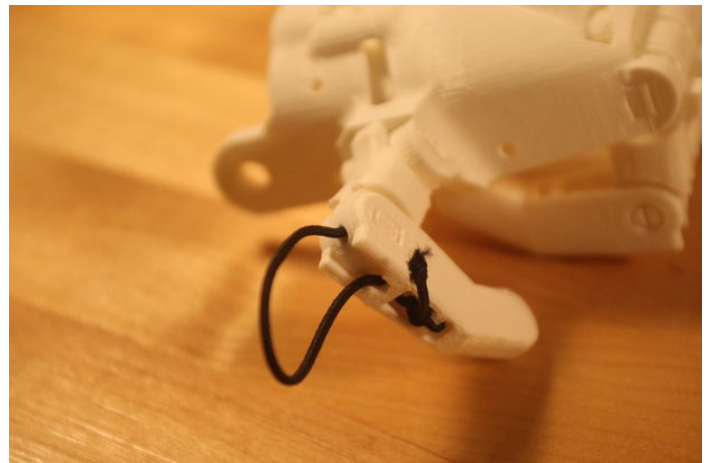
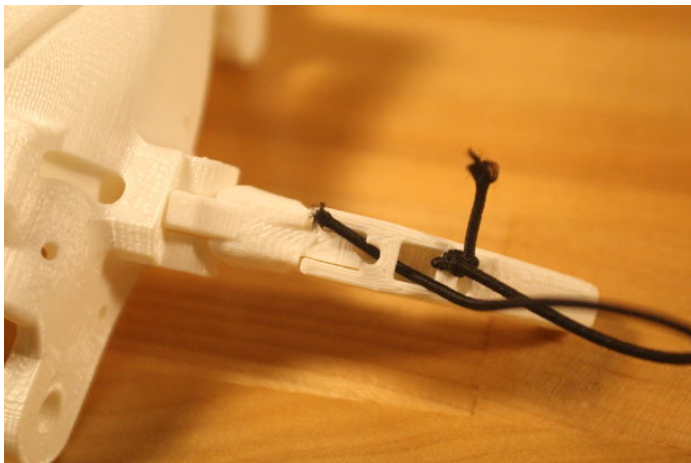


Image Notes

1. Then thread through the loop made by leading the short end through the loop at the base of the twist and tighten.



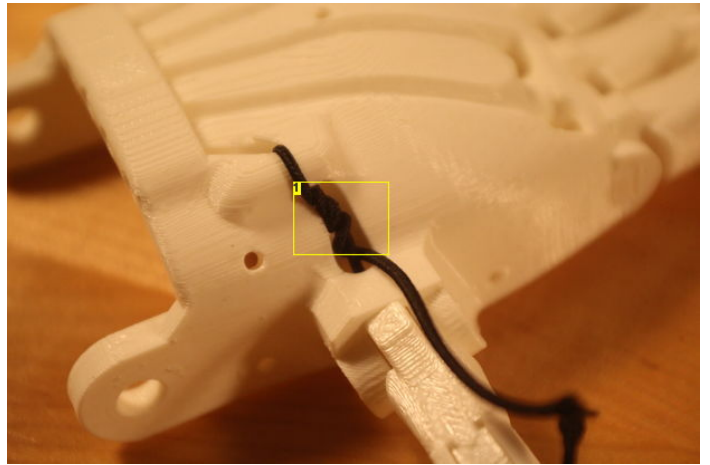
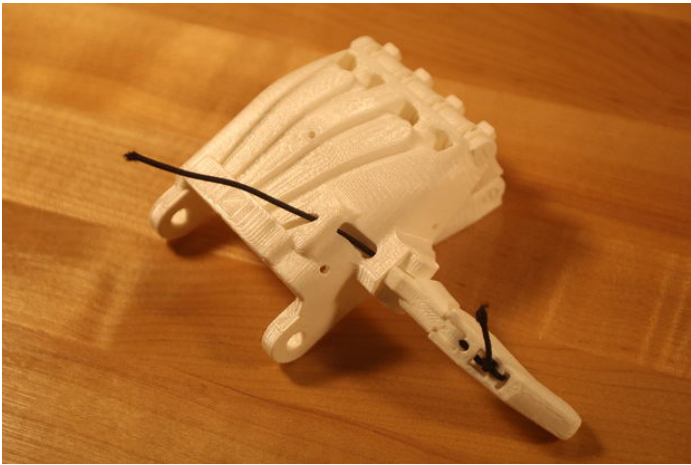


Image Notes

1. I used a clinch knot again, but a two half hitch would work just as well if not better.

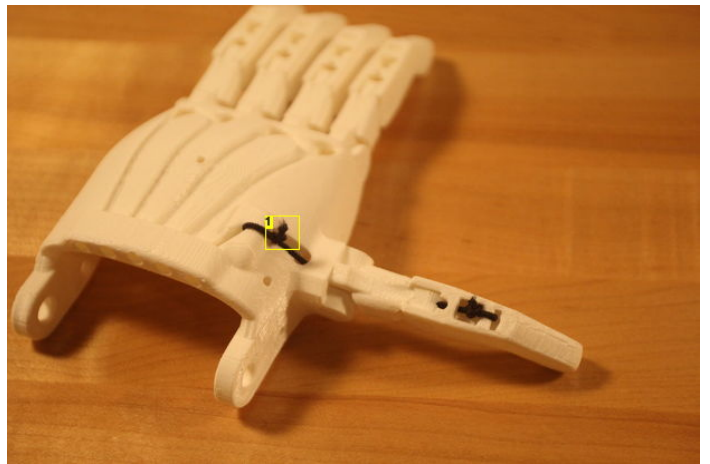
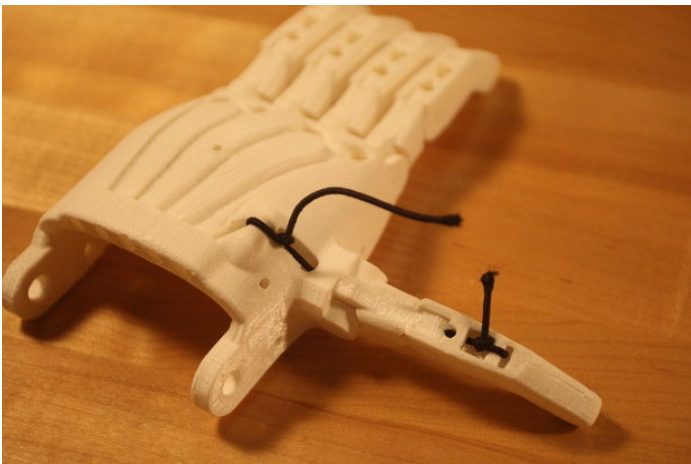
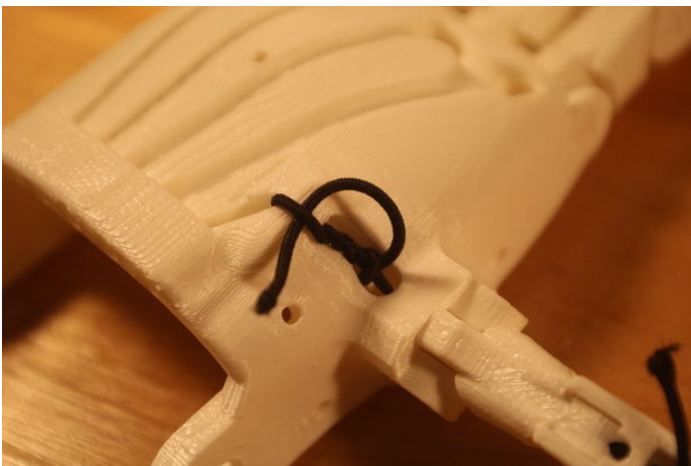


Image Notes

1. Trim the knot tails.



Image Notes

1. A drop of superglue helps secure each knot.

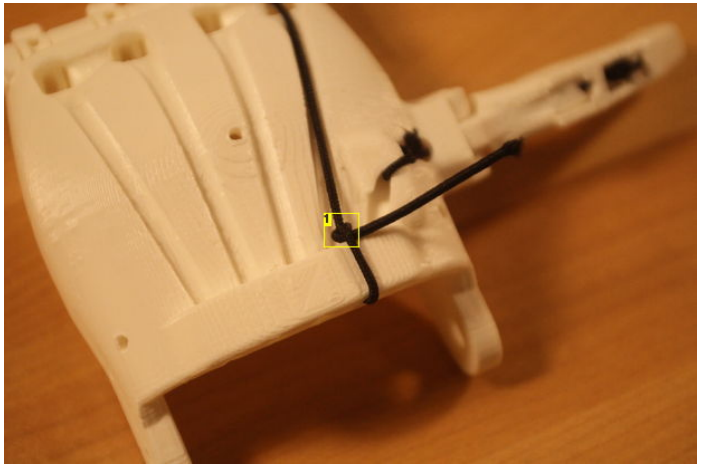


Image Notes

1. One half hitch.

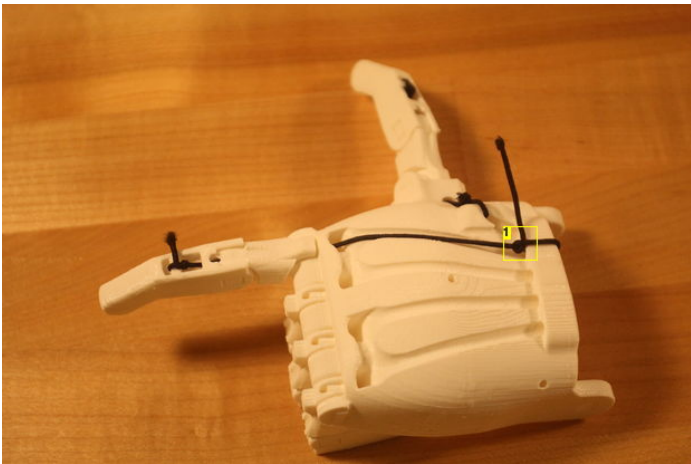


Image Notes

1. Adjust the tension using the single half hitch, then tie a second half hitch to lock it in.

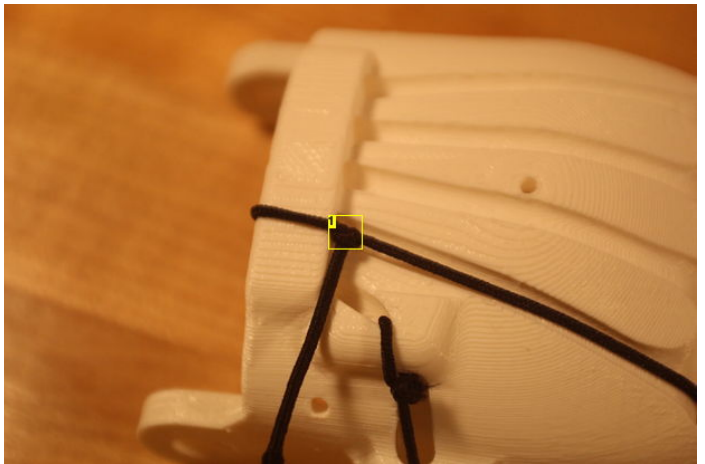


Image Notes

1. Two half hitch knot keeps the cord from slipping.

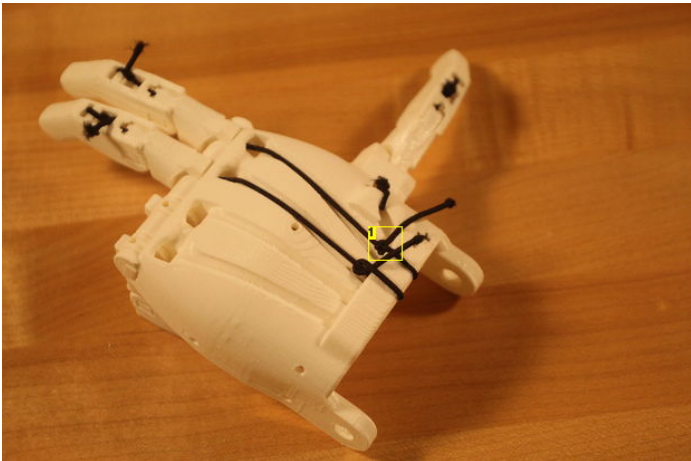


Image Notes

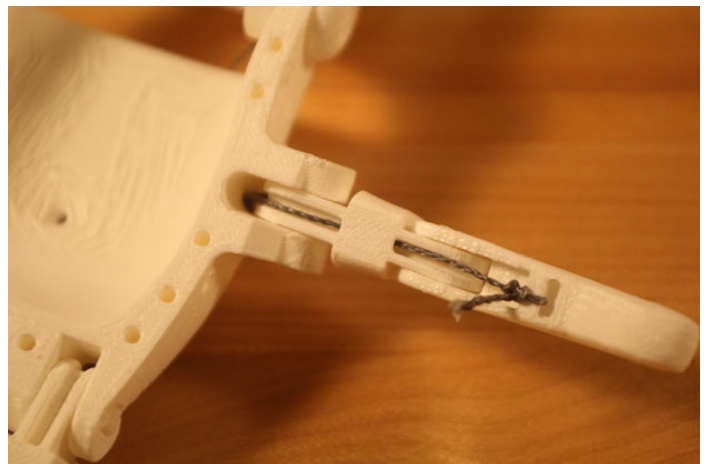
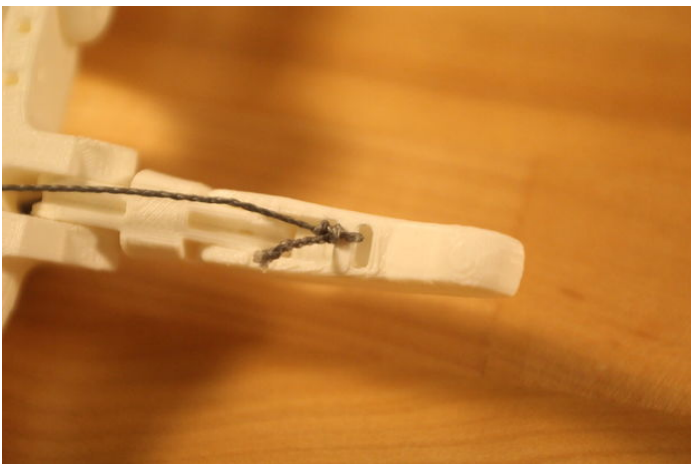
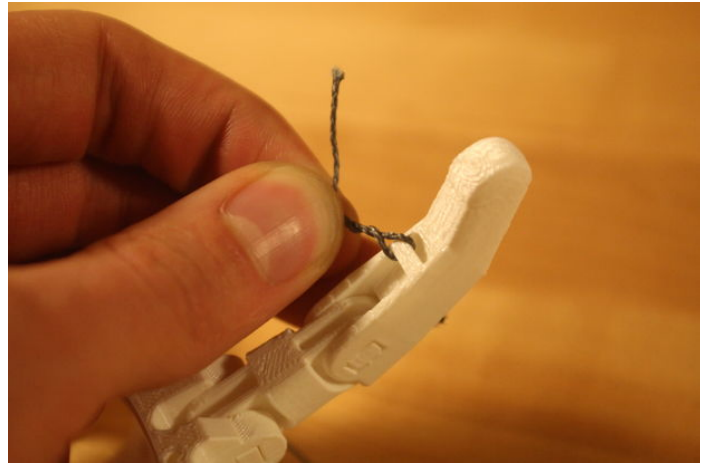
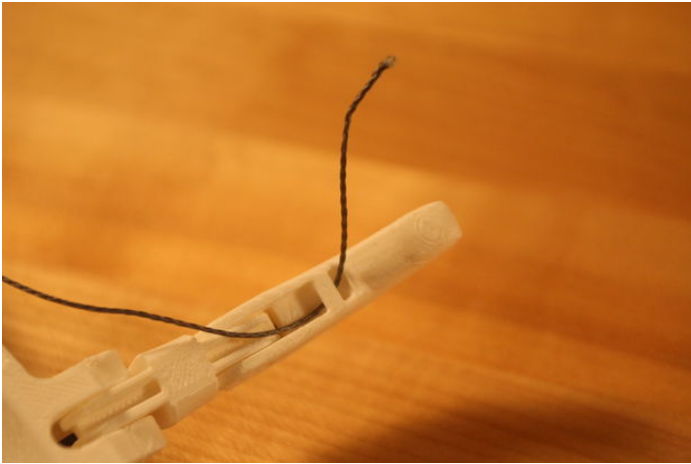
1. Two half hitches.

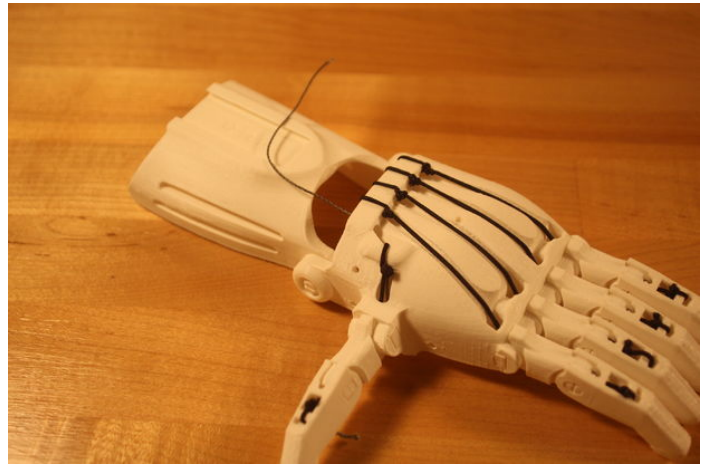
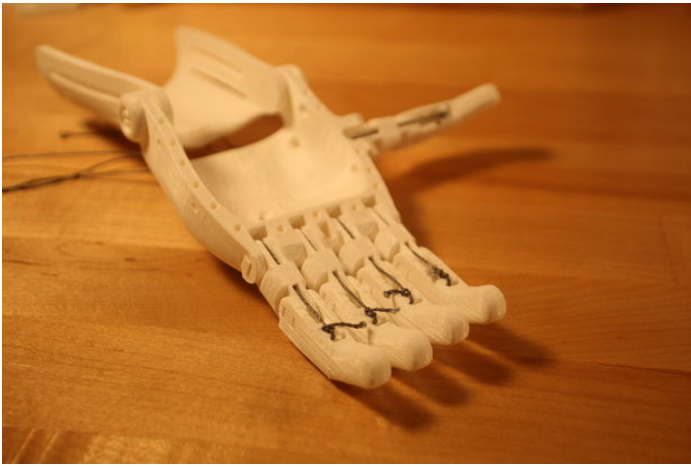


Step 4: Install the Flexors in the Fingers

Again, check the [Hardware Sources](#) page on the e-NABLE website for other vetted sources of flexor line. This braided nylon fishing line is the current recommended material for the flexors. As with the elastic lines, I like to use a clinch knot to secure the flexors to the finger tips.

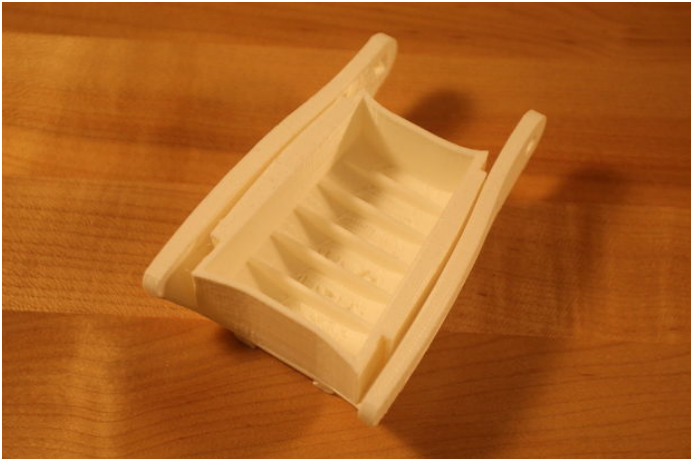
Cut five lengths of nylon line, each as long as the ultimate length of the assembled hand (fingers plus palm plus gauntlet). This is a good way to make sure that you have enough line when working with different scales. Starting with the thumb, use a clinch knot to tie on e end of the flexor line to the tie-bar. Then thread the line through the proximal and up through the proximal knuckle where the proximal phalange meets the palm. Be careful to ensure that the line doesn't get wrapped around the elastic cord for each finger. It should run parallel to it up over the top of the palm and out the back of the rear cable guide. Repeat this process for the other four fingers. After trimming the knot tails, I like to singe the tail to prevent fraying and then apply a drop of superglue to make sure the knot doesn't slip.

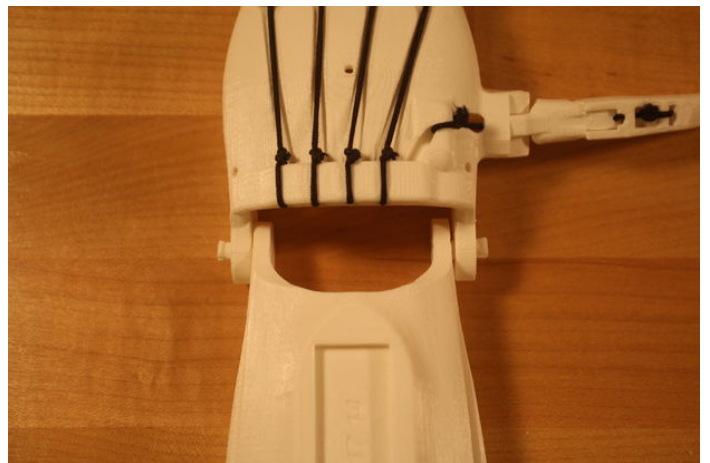
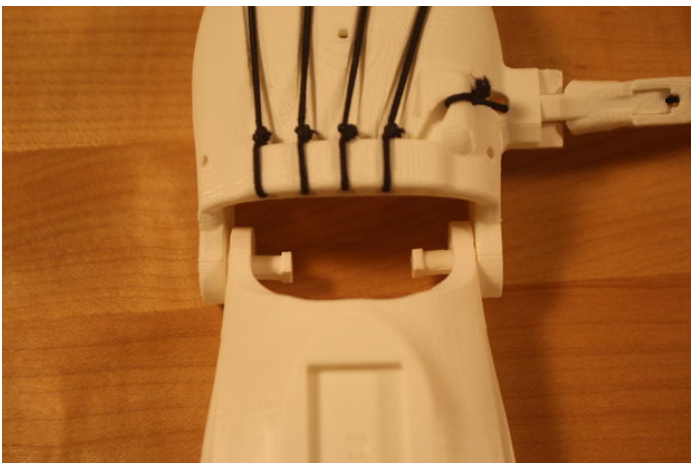
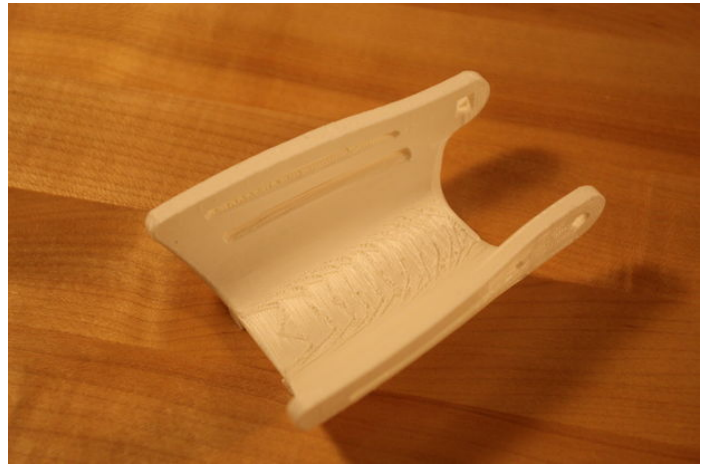


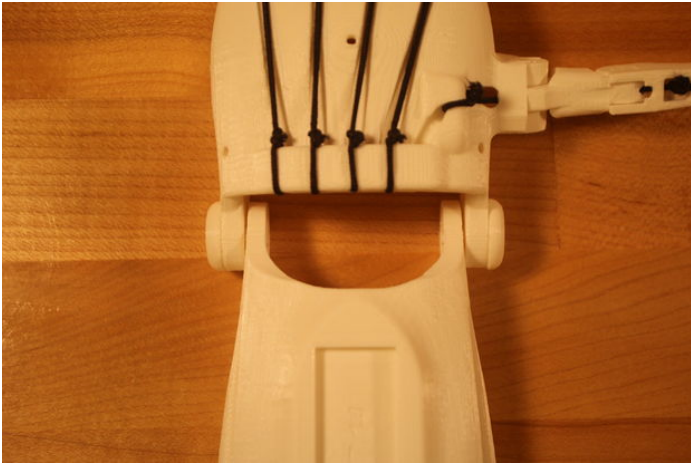
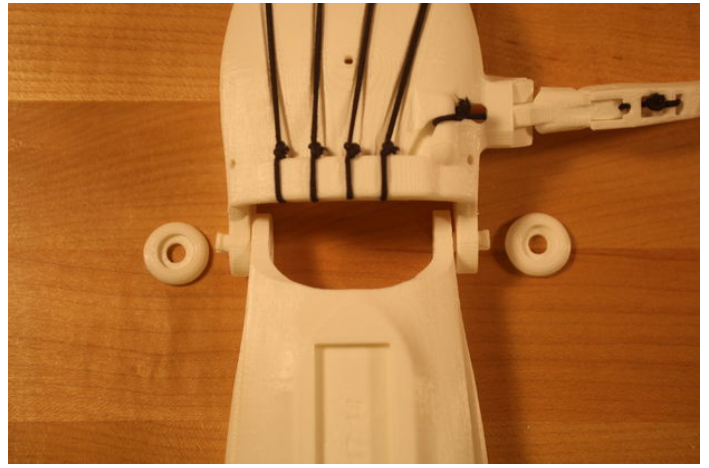
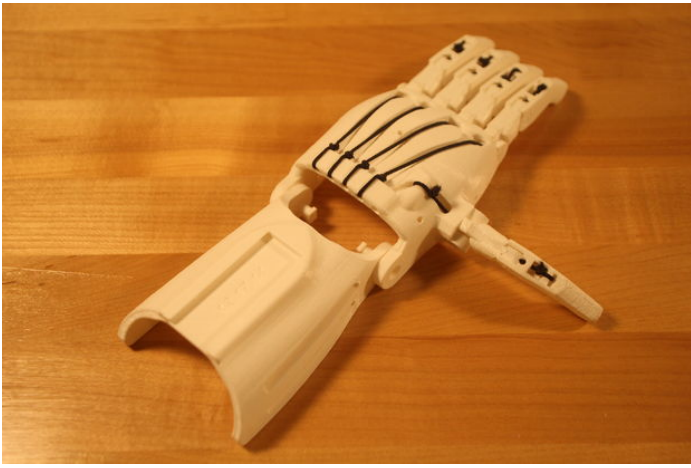


Step 5: Attach the Palm to the Gauntlet

Using an edged tool, remove the gauntlet support structure and set it aside for use in the next step. Press the two wrist snap pins through the holes in the gauntlet, making sure they are aligned with the head recesses on the inner faces of the gauntlet. Once they have snapped through, back the tips back and slide the palm into position so that the wrist axis is aligned. Press the wrist pins through the palm's wrist holes. If necessary, the wrist can be bent back and the corner of a table can be used to apply pressure to the pins. Once the pins are properly seated, snap the pin caps over each pin to complete the wrist.



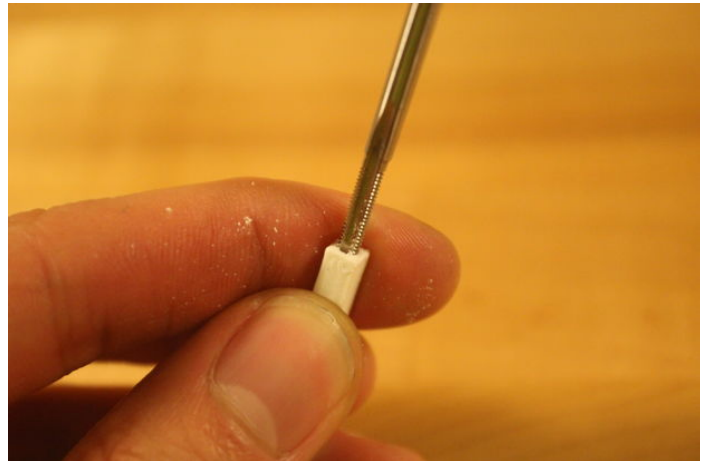




Step 6: Install the Tensioner

The tensioner is part of the design that suffers from linear scaling in that the holes in the tensioner pins change size as they are scaled for different recipients, so they will require different screws at different scalings. At 100% scale, the tensioner pins are sized to receive M3 screws. If you have access to a tap, it makes threading the tensioner pins easier, but it is optional.

Start by threading the tensioner pins, either with a tap or with the screw that will be paired with it. If using the screws to form the threads, first insert the tensioner pins into the tensioner block with the holes in the end of the pin facing "up". This will leave more room for knot tying later. Screw the screws about half-way in so that the tensioner pins can slide forward and backward in the tensioner body. Slot the body into the dovetail on the gauntlet and place the gauntlet support under the fingers of the hand to tilt the palm backwards slightly. Push all but the thumb tensioner pin back leaving just the thumb tensioner pin forward. Maintaining tension on the line, tie the thumb line to the pin using a cow hitch (see below) followed by a half hitch running through the cow hitch and a second half hitch around the flexor line (see pictures). Because the wrist is bent back and the tensioner pins are half-tightened, the tensioner screws can be backed out or tightened in to adjust the tension on the flexor lines. Repeat the process for the remaining fingers, trim the lines, singe the tails, and apply a drop of superglue.



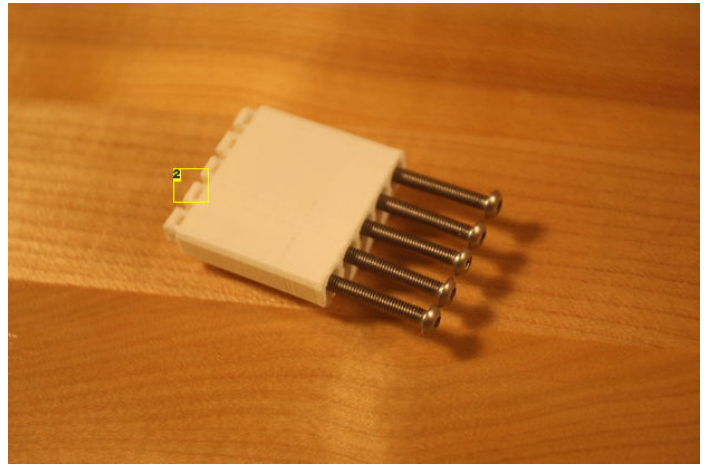
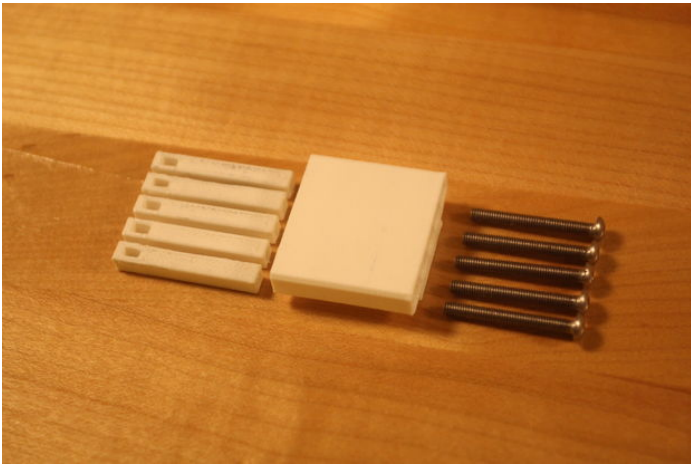


Image Notes

1. Be careful that the pins are aligned with the holes facing up.
2. Be careful to assemble with the holes facing up.

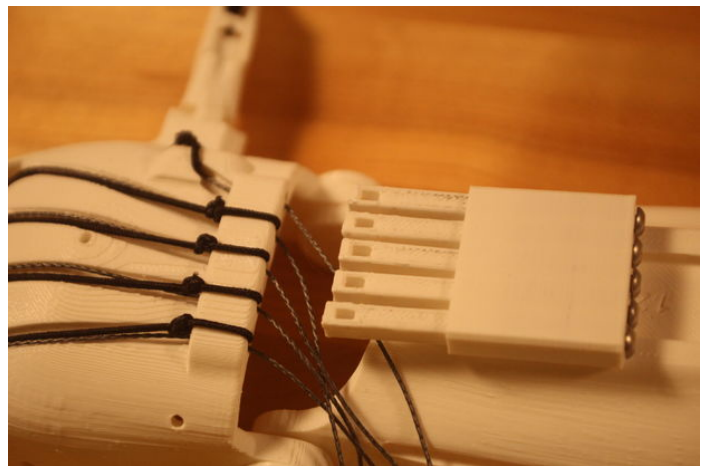
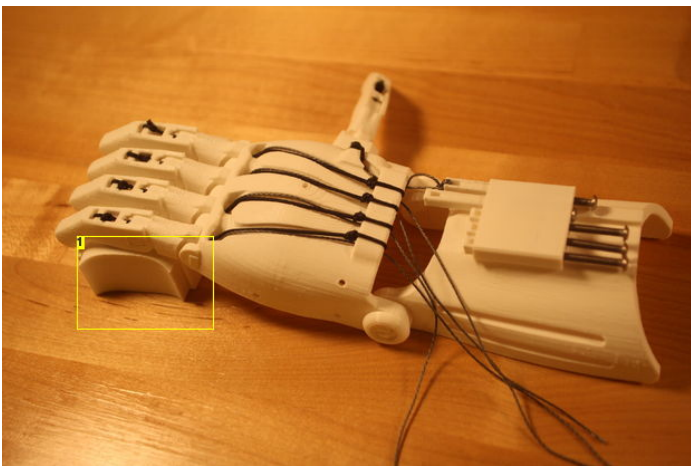


Image Notes

1. Gauntlet support structure

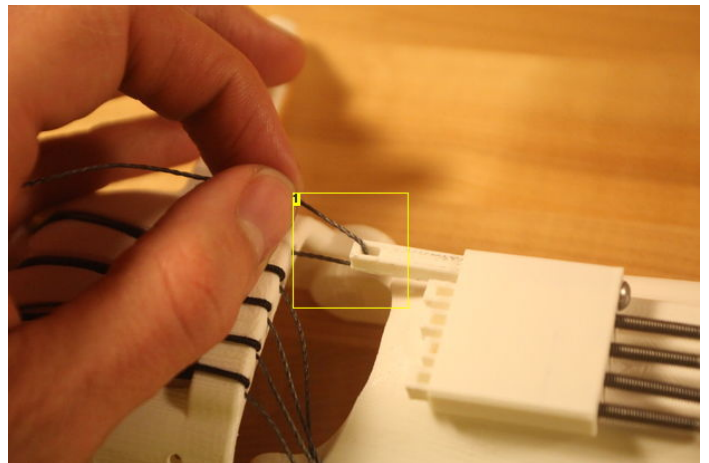
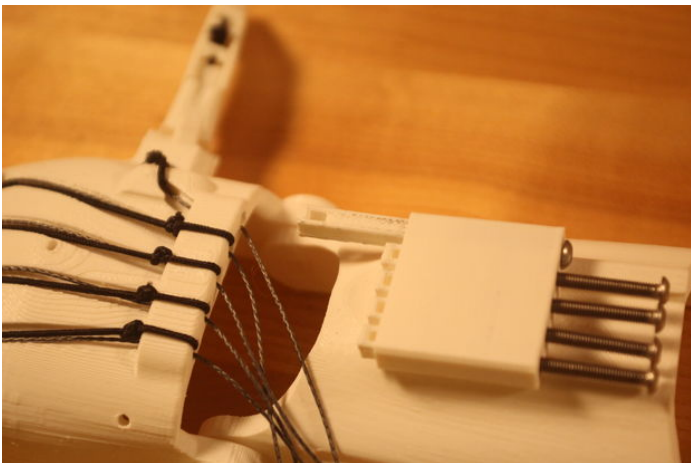
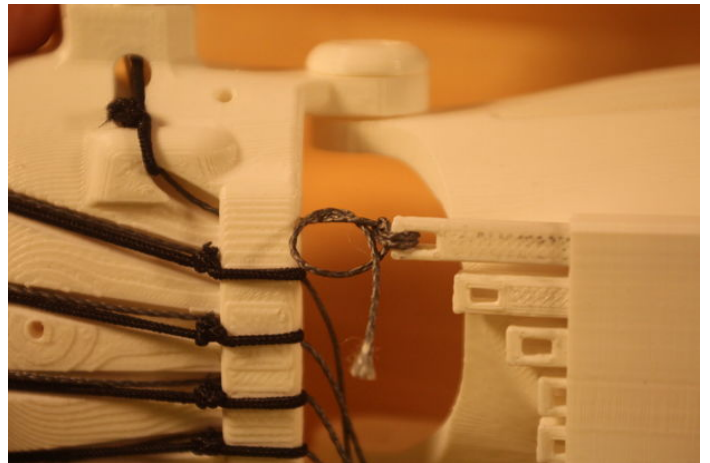
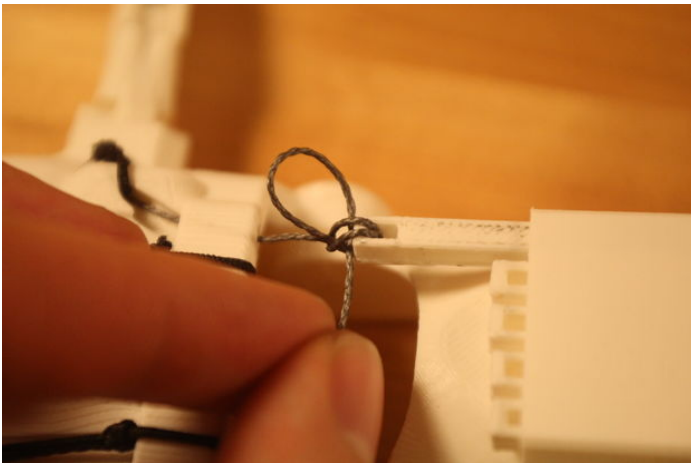
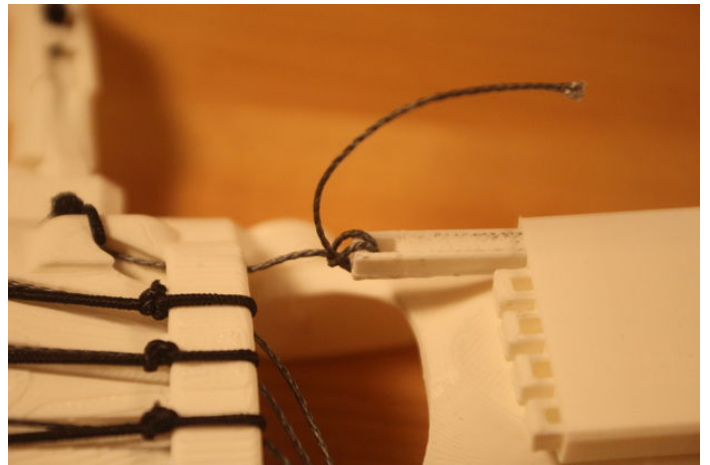
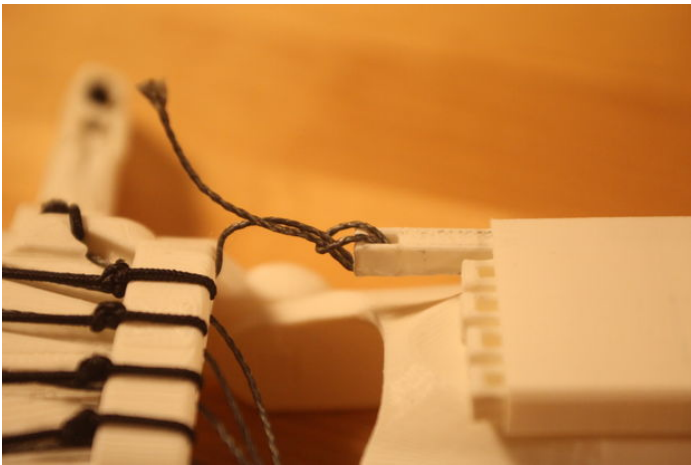
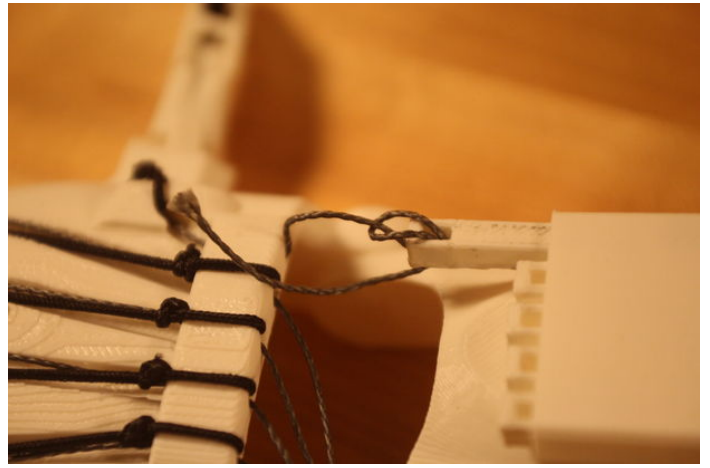
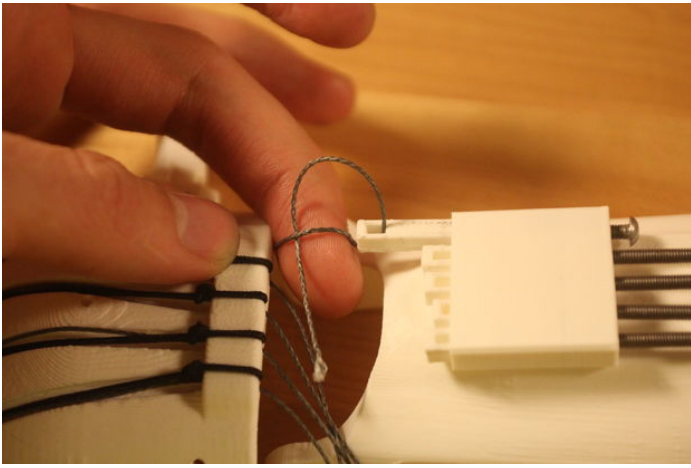
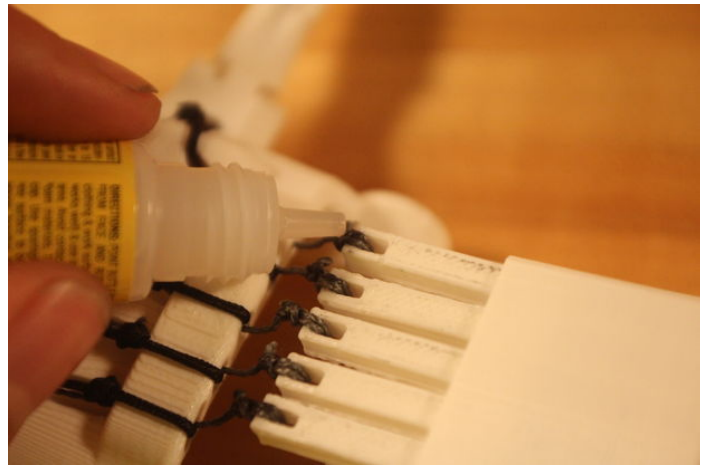
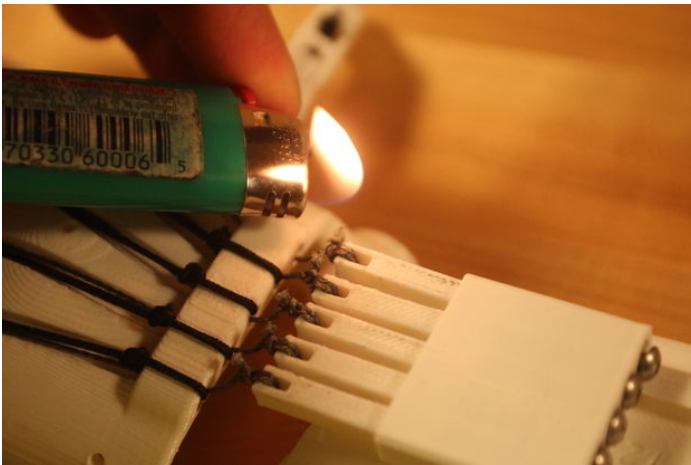
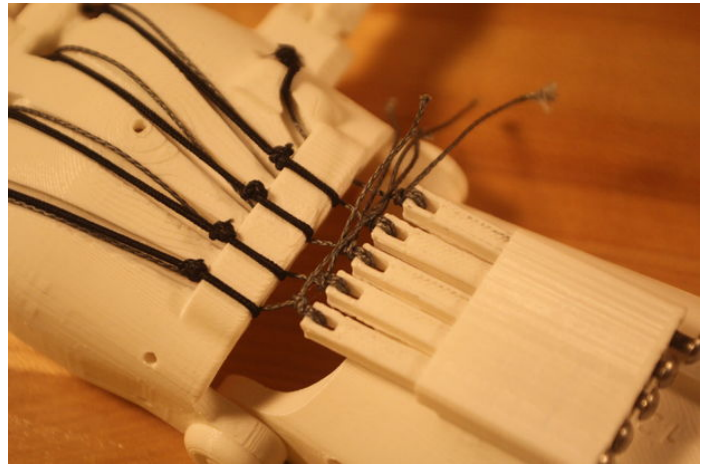
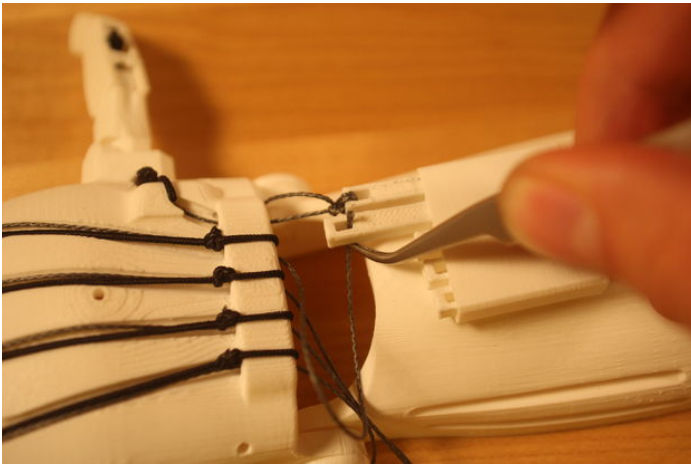


Image Notes

1. Draw the line up from below through the slot in the pin.





Step 7: Palm Options: Padding and Velcro, Leather, or Thermomesh

Now that the mechanics of the hand are complete, it's time to prepare it to use by a recipient by applying medical grade foam padding and velcro straps. I purchased my foam from Patterson Medical, one of the suppliers from the Hardware Sources page. Cover the interior surfaces of the palm with adhesive-back foam cut to size and save extra foam for fine-tuning the fit based on recipient feedback.

There are several options for enclosing the palm:

- Single velcro strap
- Double velcro strap
- Riveted leather
- Thermomesh (integrated or attached)

In this example hand, I used the single velcro strap as it has less give than the two strap option. Again, if you have a tap, it is nice to tap the four holes on the sides of the palm for securing the velcro, but it is not necessary. Cut a strip of soft-sided velcro to be 1/2" (~12mm) longer than the palm is wide on either side. Fold each side down and use the tips of tweezers or an awl through the mounting holes to mark the hole locations on the velcro. Use flat head stainless steel fasteners to secure the velcro to the inside of the palm. Repeat on the other side of the palm. It is helpful to have a ball-headed allen key to turn the screws closest to the knuckles.

Leather can also be cut to match the profile of the palm and screws can be driven into the holes around the perimeter to secure it.

Thermomesh palms, both integrated and bolt-on, have been successfully tested in the e-NABLE and will soon be available for more wide use.

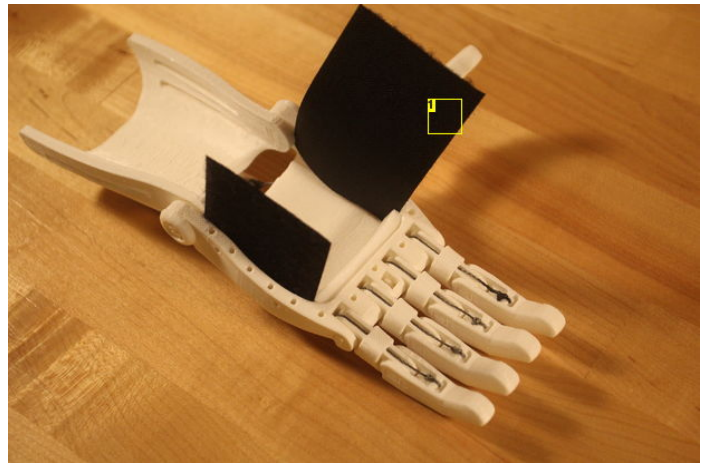
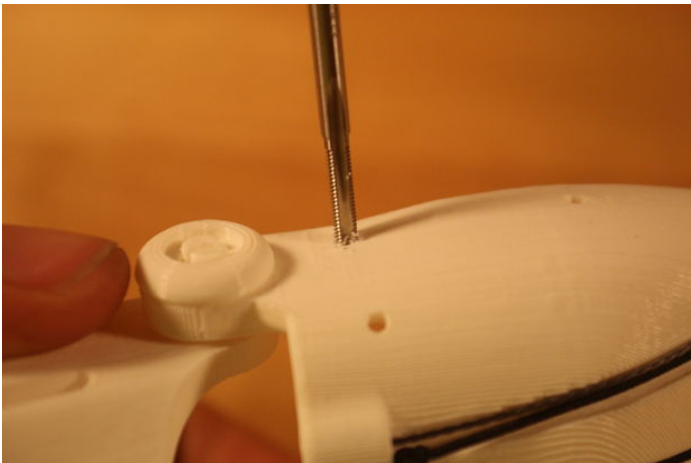
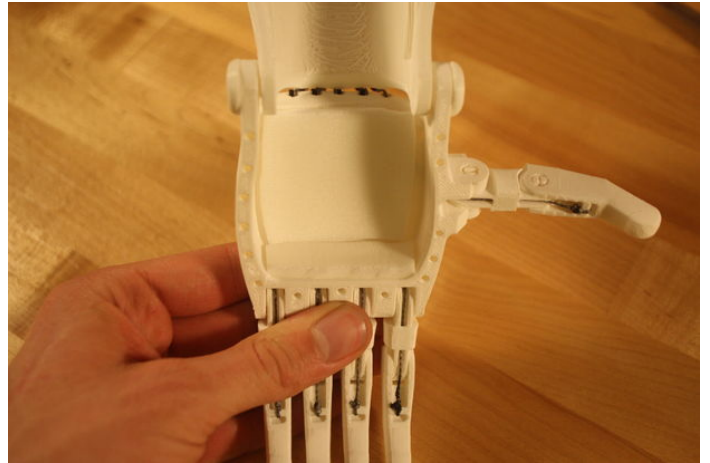
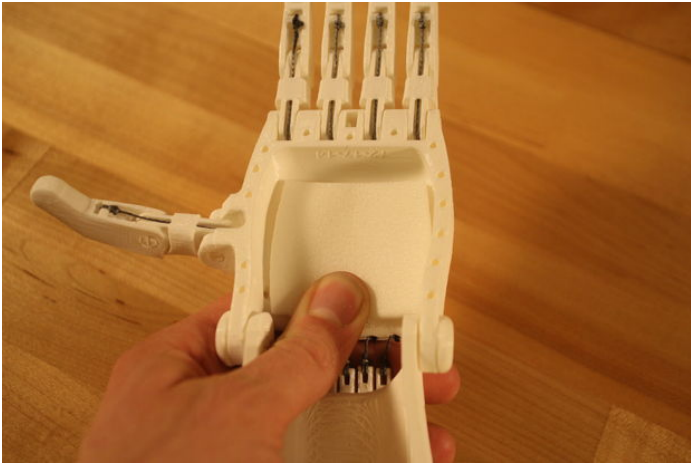
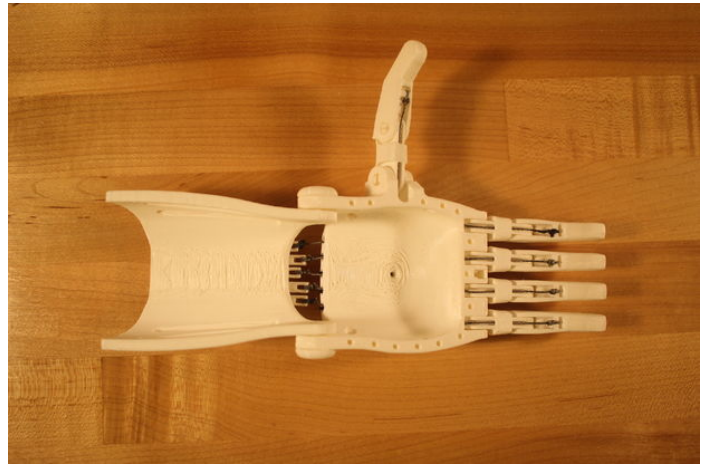
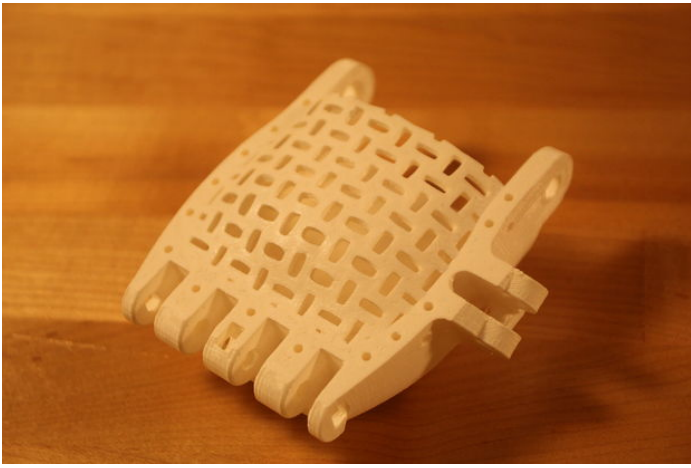


Image Notes
1. The two-strap method.

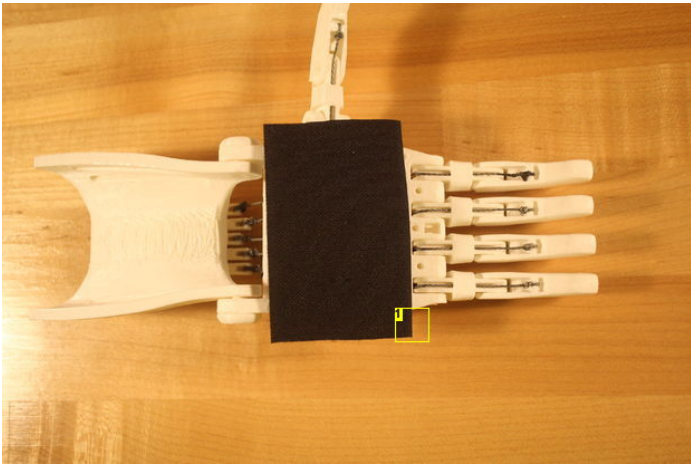


Image Notes

1. For the single strap method, use a 1/2" (12mm) overhand on each side

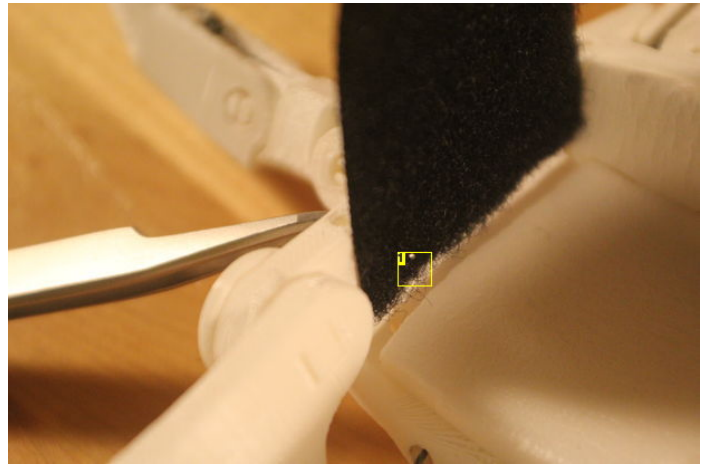


Image Notes

1. Punch through the velcro with something sharp (tweezers in this case).

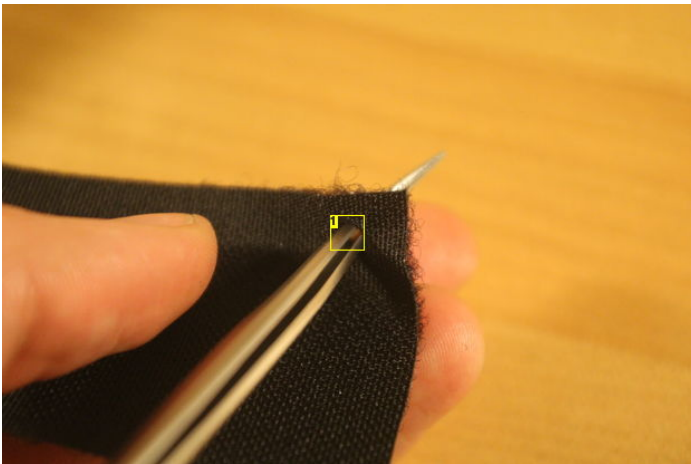


Image Notes

1. Widen the hole so that a screw can pass through.

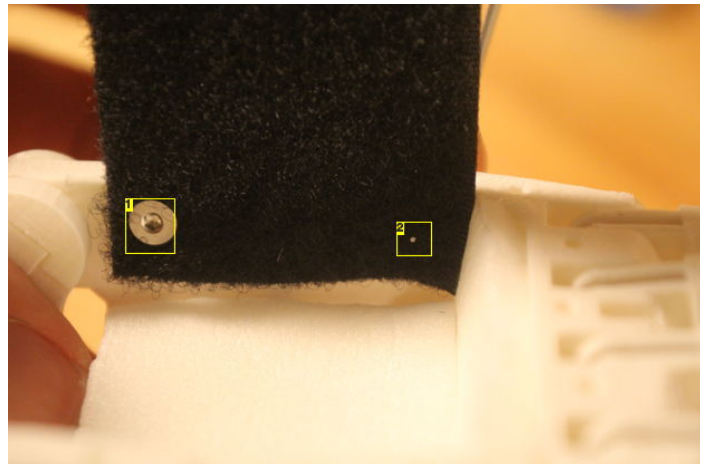
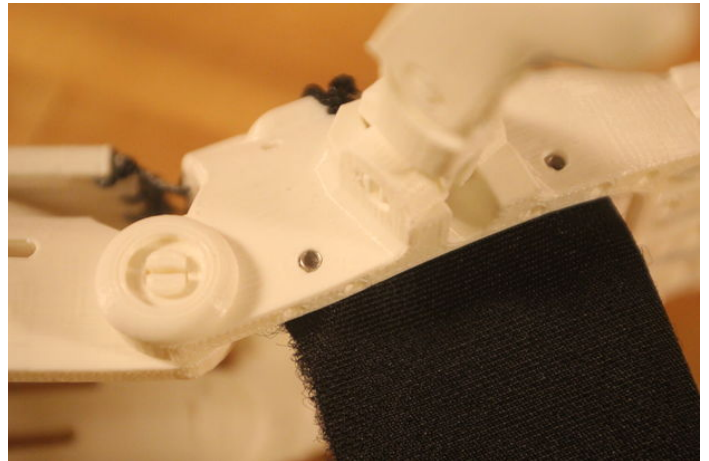
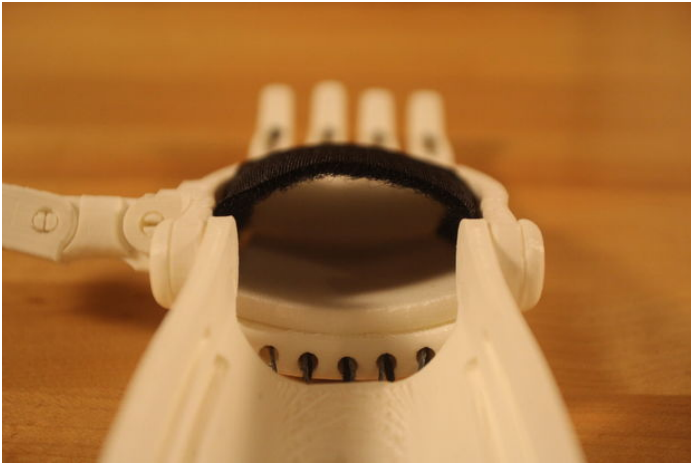
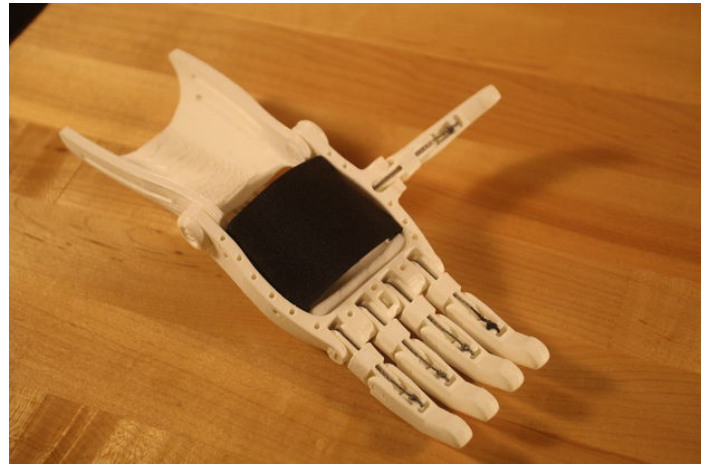
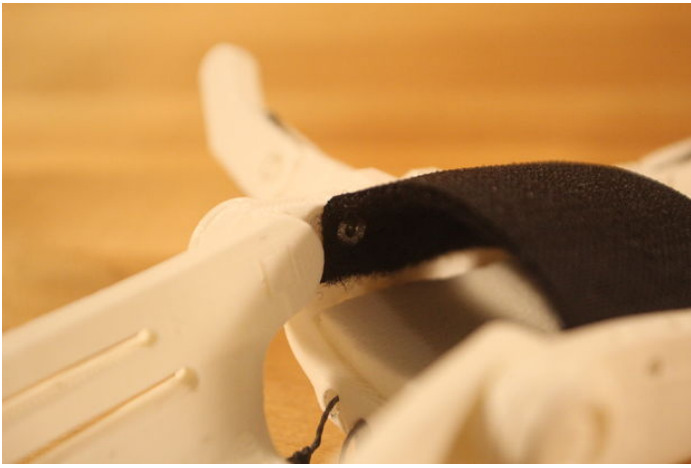


Image Notes

1. Flat head stainless steel fastener.
2. Punching the second hole.



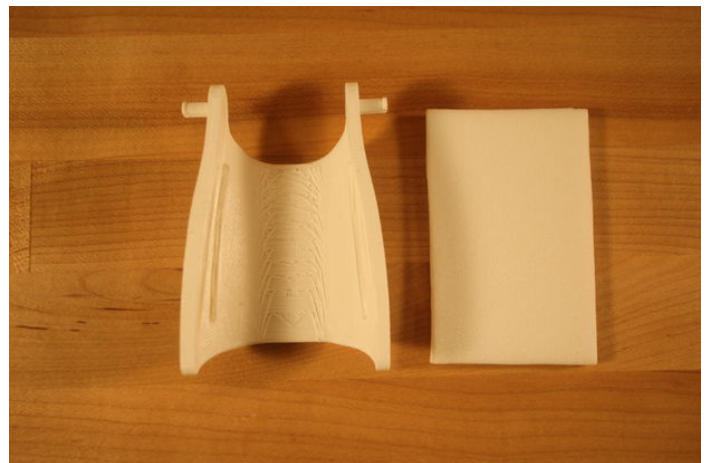
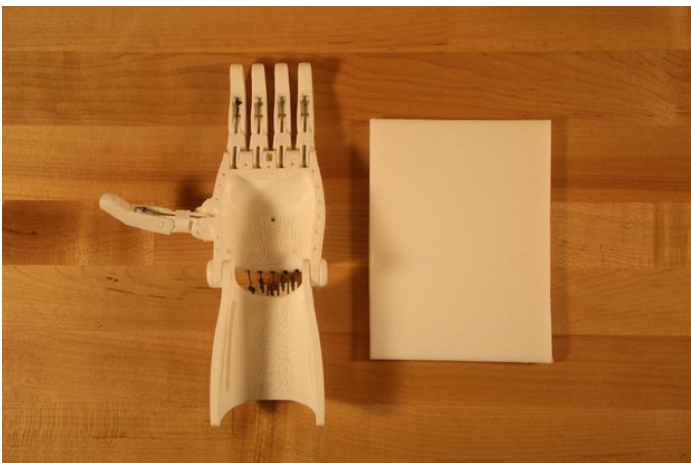


Step 8: Install Padding and Straps on the Gauntlet

Using the same foam as for the palm, cut a section to roughly match the inner surface of the gauntlet. I find it easiest to remove the gauntlet from the palm for this part or to do it before the tensioner. With better access to the gauntlet, a pen can be used to trace the edge of the gauntlet onto the foam for a clean fit.

After applying the foam, cut a strip of double sided or soft-sided velcro to be slightly longer than the assembled hand. Slide the strap through the "bottom" (closest to the build platform during printing) slots in the gauntlet with the soft side facing the foam. Position the long end of the strap on the same side as the thumb and tuck 1.5" (38mm) of the short end through the "top" slot and fold it back to meet the long side of the strap. Then either stitch or hotglue this short end back to the long strap. Fold the long end of the strap back in on itself (towards the gauntlet) so that when folded again, it can reach the far edge of the gauntlet where the short end of the strap is. Hot glue or stitch the folded end down to the long end of the strap. If using two-sided velcro, the long end should now have the soft loops on both sides and can be tightened down and secured on the hooks of strap portion between the wings of the gauntlet. If using separate loop and hook straps, cut and hot glue or stitch a section of hook strap to the area of the strap between the two wings so that the long end of the strap can be secured there. This strapping configuration is designed to be easy to use with the other more dextrous hand.

Finally, click the tensioner retention clip into the back of the dovetail to ensure that the tensioner doesn't have any opportunities to fall out.



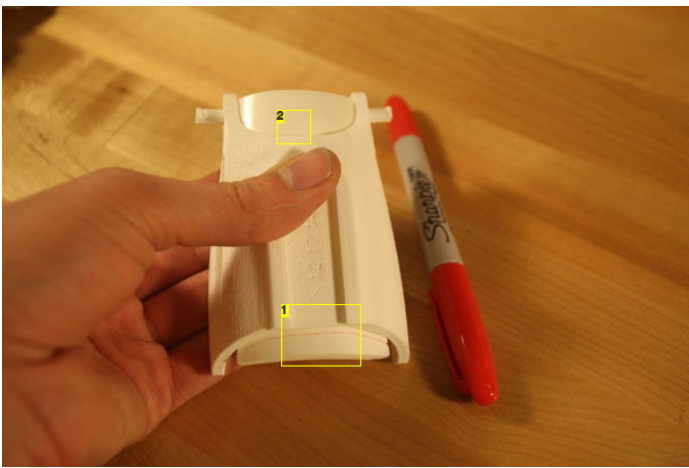


Image Notes

1. Mark the edge here.
2. Mark the edge here.

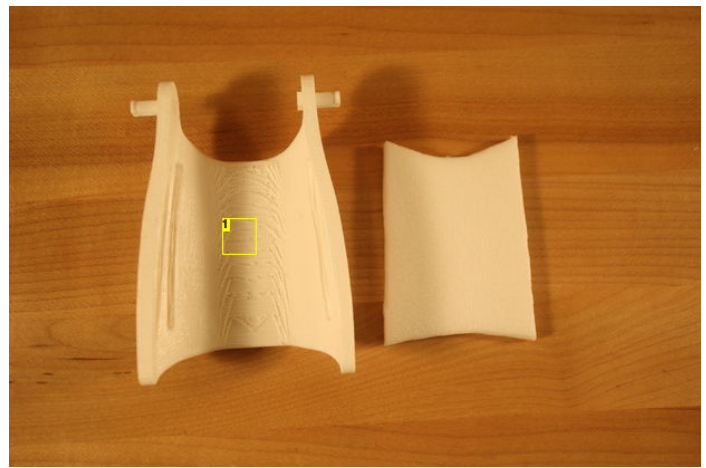


Image Notes

1. Once the foam is sized, attach here.

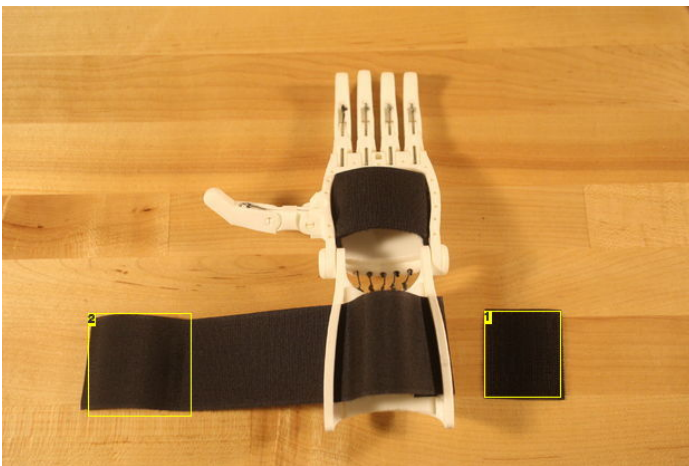


Image Notes

1. Attachment pad.
2. Fold over portion.

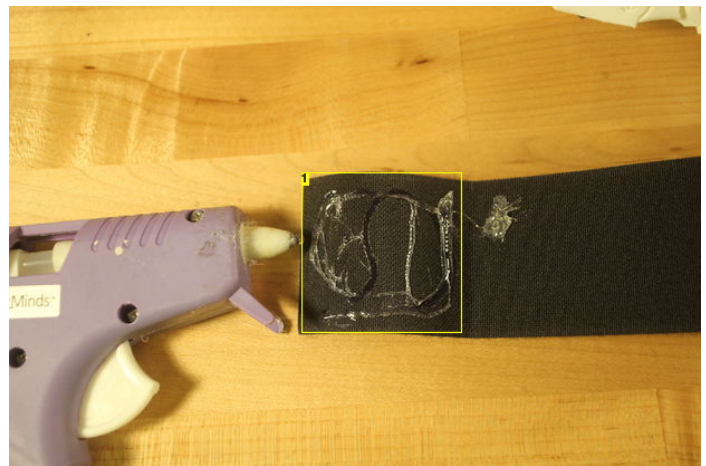


Image Notes

1. Hot glue or stitch.

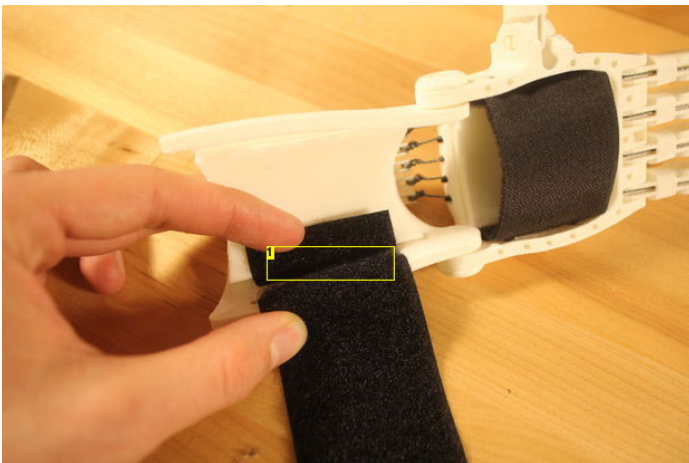


Image Notes

1. Apply hot glue or stitches here.



Image Notes

1. Hot glue.



Image Notes

1. If using hot glue, press down hard after applying to ensure a solid bond.

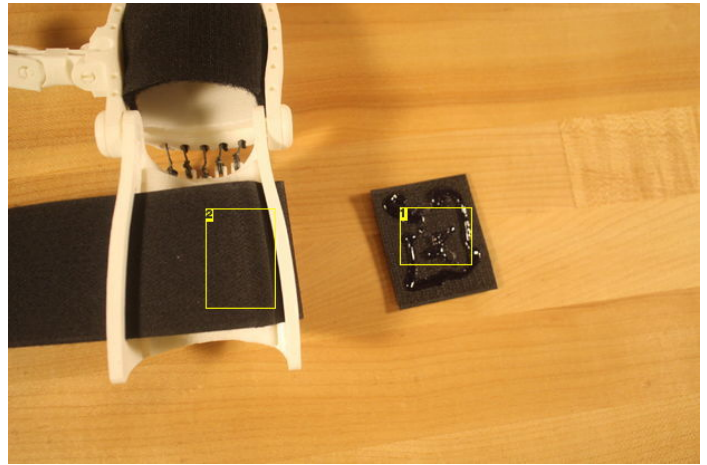


Image Notes

1. Apply hot glue to the attachment pad.
2. Hot glue or stitch the attachment pad here.

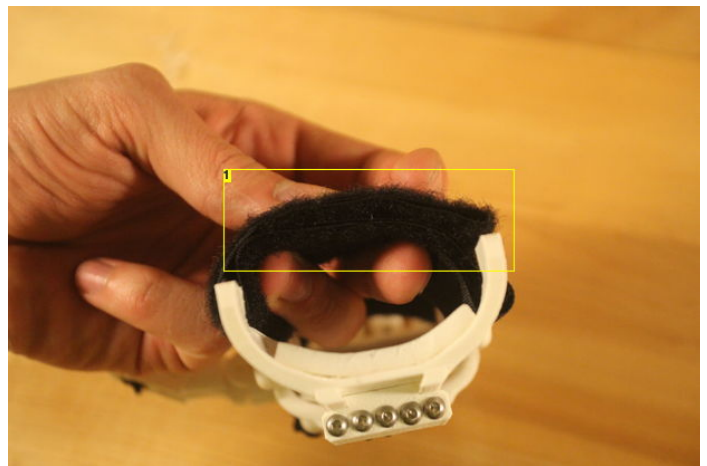
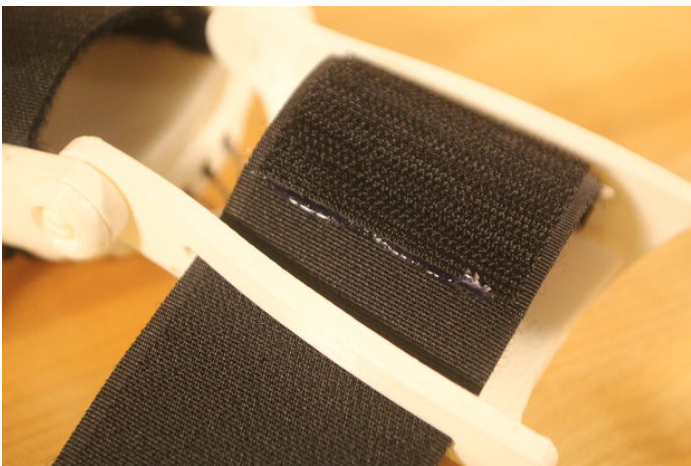


Image Notes

1. The strap can be folded over onto the attachment pad for easy one-handed tightening.

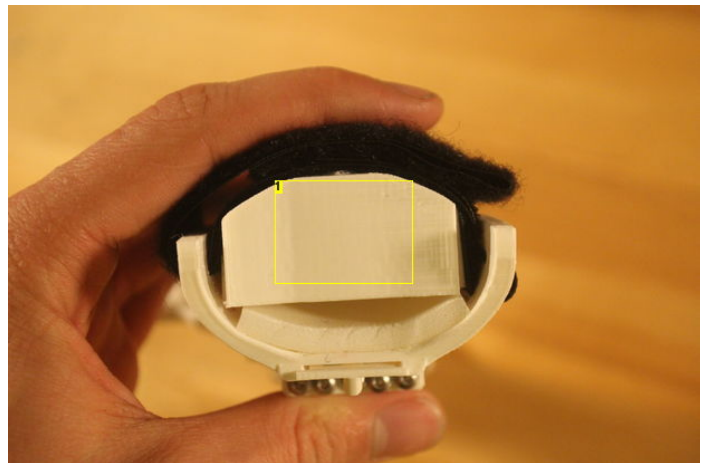


Image Notes

1. The gauntlet support structure can be used as a fit-check

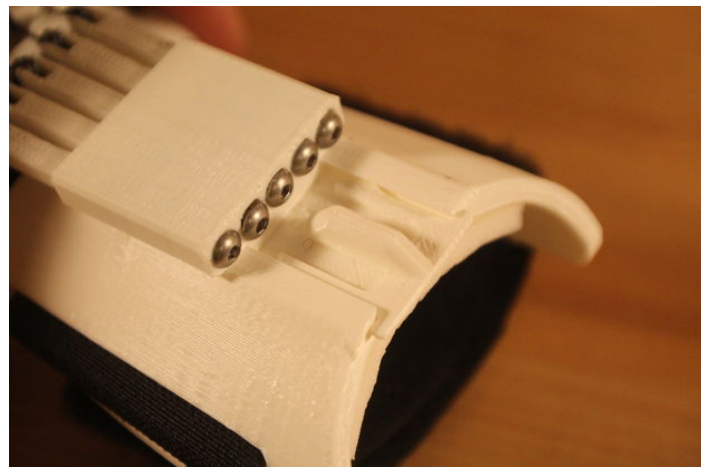
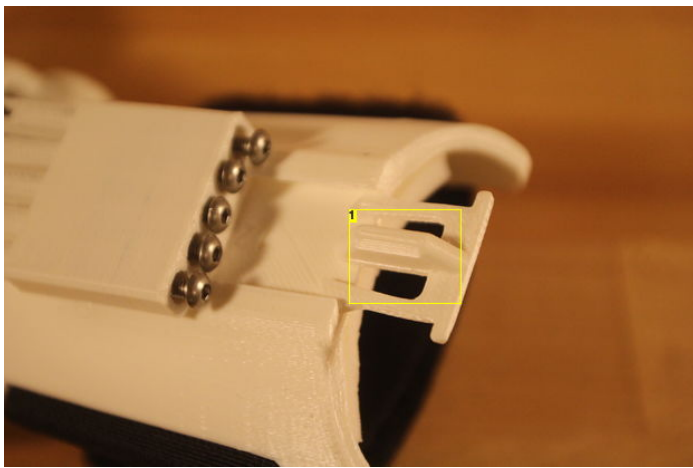


Image Notes

1. Insert the tensioner retention clip to finish the hand.

Step 9: Next Steps

Congratulations! You finished building the hand! Hopefully this is the first of many. Work with and listen to recipients' feedback about fit and comfort. We recommend using a prosthetic sock or similar sleeve when using these devices. Beeswax can be used to lubricate the joints and reduce squeaking. As the elastics break in, the flexors may need a little tightening to maintain performance.

Share feedback with the e-NABLE research and development community in the [Google Plus community](#) and together we can iterate upon and improve the design!



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Excellent Instructable for the new design!

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