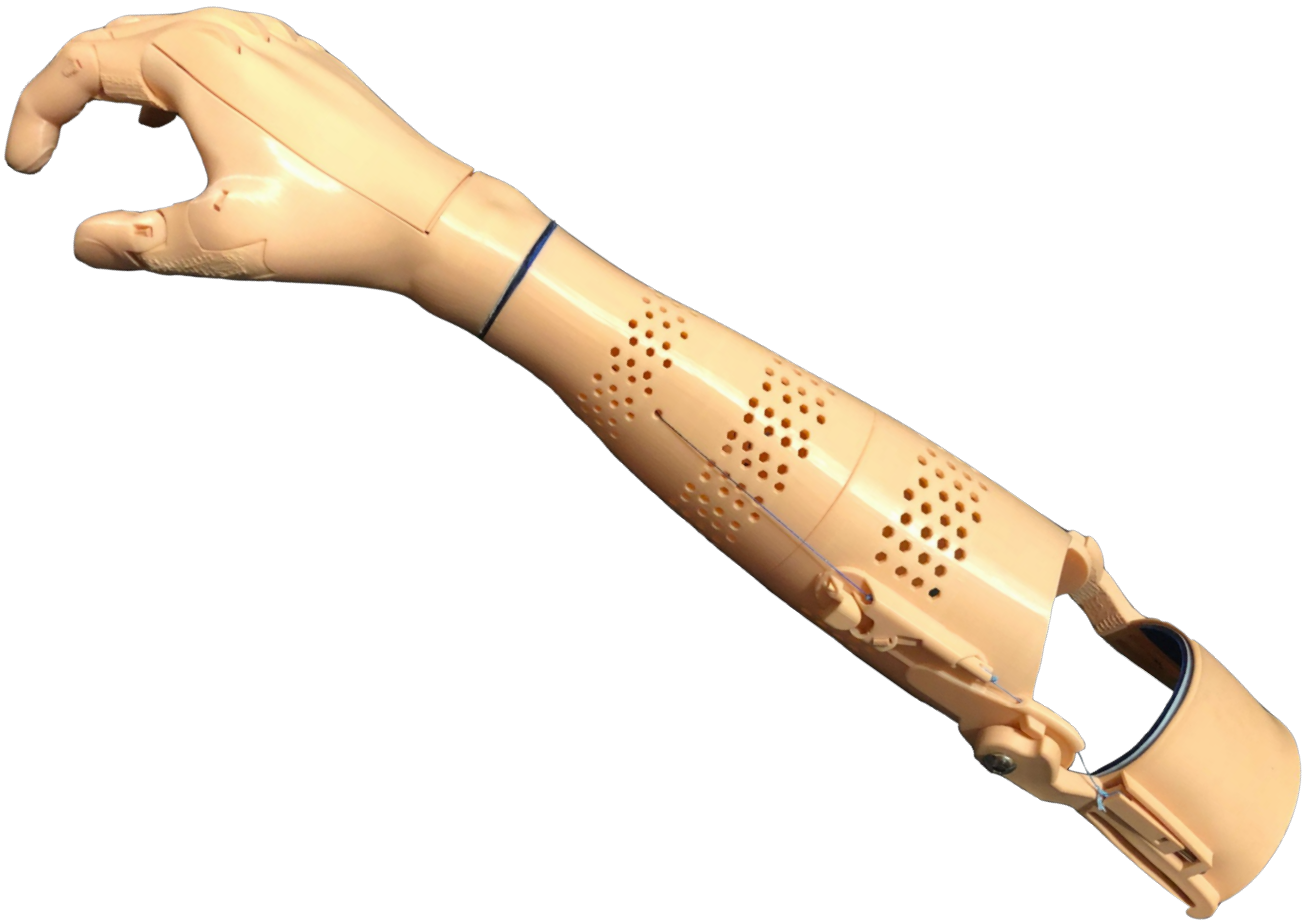
Kwawu Arm 2.0

Socket Version

Instruction Guide



Jacquin Buchanan

January 2018
Revised July 2020

Welcome!

This instruction guide is made up of two main documents:

1. ***Using OpenSCAD to render Kwawu Arm 2.0 - Socket Version***

    - ***Outlines how to measure the recipient and explains how to use the program OpenSCAD to prepare correctly sized STL files for printing.***

2. ***Printing and Assembly Guide: Kwawu Arm 2.0 - Socket Version***

    - ***Includes printing suggestions, assembly instructions divided into specific phases and fitting recommendations***

The updated printing and assembly manual was created as a part of TJ Posillico's Eagle Scout Project, Troop 52, East Northport, NY. Special thanks to all those who 3-D printed, assembled the test arm, revised the manual, and otherwise assisted with the project.

Important Links:

- Thingiverse STL files to download (use OpenSCAD to modify and scale the STL files) https://www.thingiverse.com/thing:2841281
- This video is a great demonstration of the function of the arm: Kwawu Arm 2.0 Demonstration (https://www.youtube.com/watch?v=o5p5qpXizaQ)

Using OpenSCAD to Render Kwawu Arm 2.0

Socket Version

Jacquin Buchanan January 2018

This document will walk you though using OpenSCAD to size and make printable STL files for the Kwawu Arm 2.0.

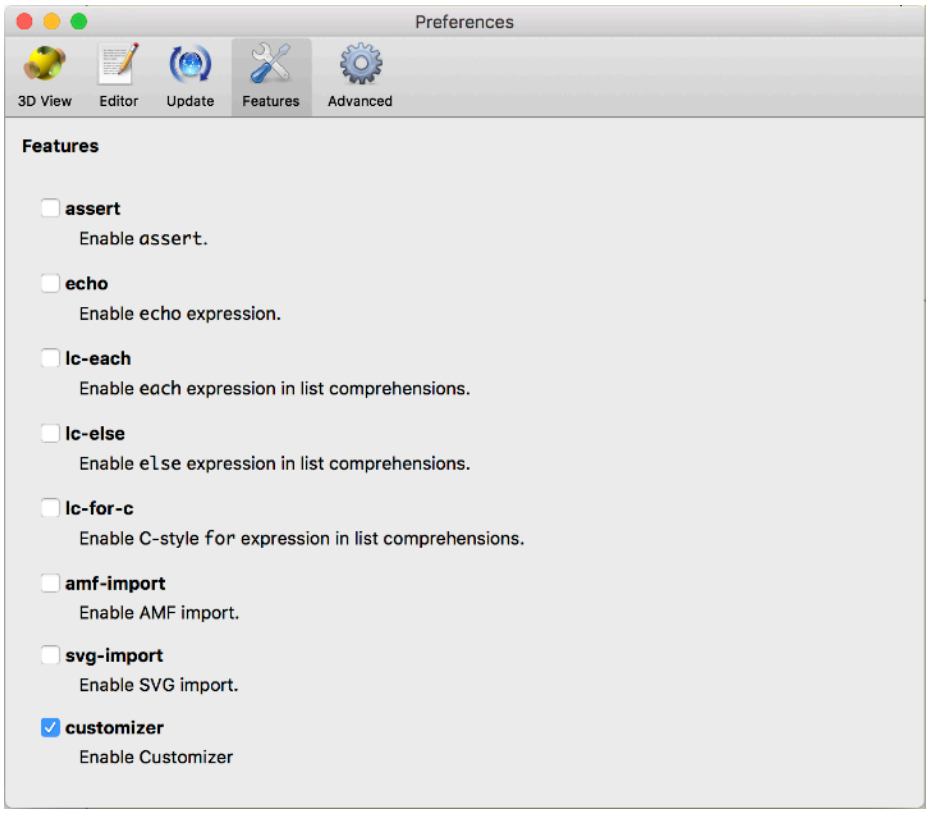
Downloading and Installing OpenSCAD

1 Download and install OpenSCAD. You need the latest development snapshot to be able to use the customizer feature. Unlike the old stable version which has a yellow program icon, the development snapshot has a blue icon. You can find it here:

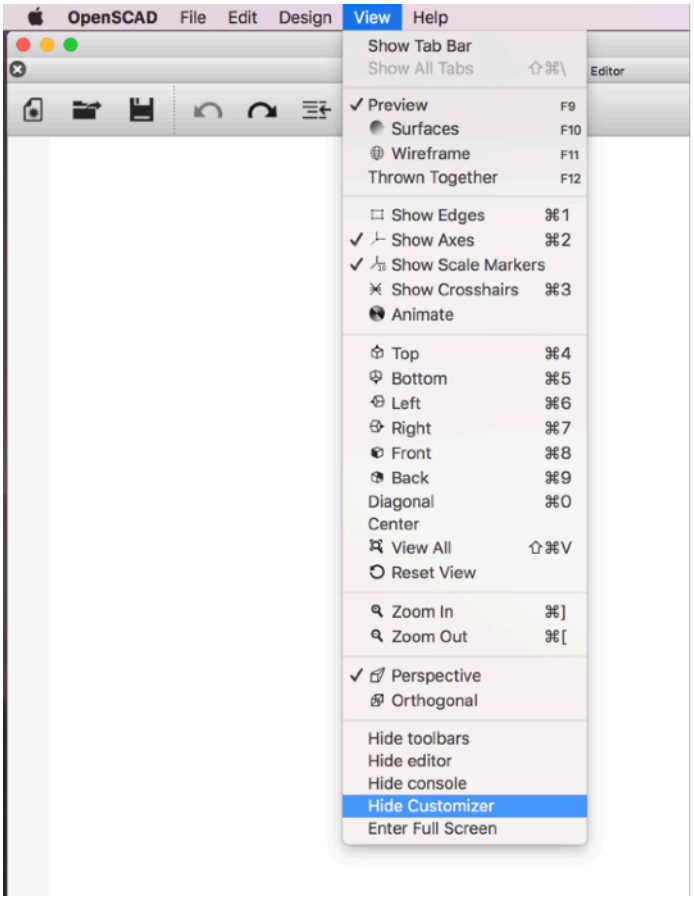
http://www.openscad.org/downloads.html#snapshots

2 Once you have installed OpenSCAD, open the file "Kwawu 2.0 Prosthetic Arm- Socket Version.scad"

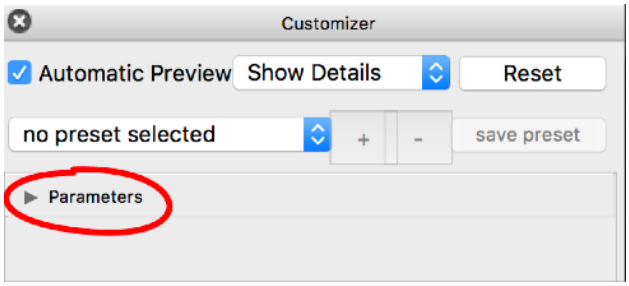
3 Go to the Preferences menu, and in the **'Features'** section, ensure Customizer is enabled (you only need to do this once).



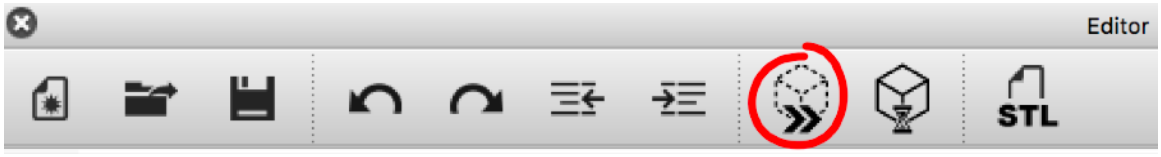
4 Uncheck 'Hide Customizer' in the View menu to show the Customizer UI at the right.



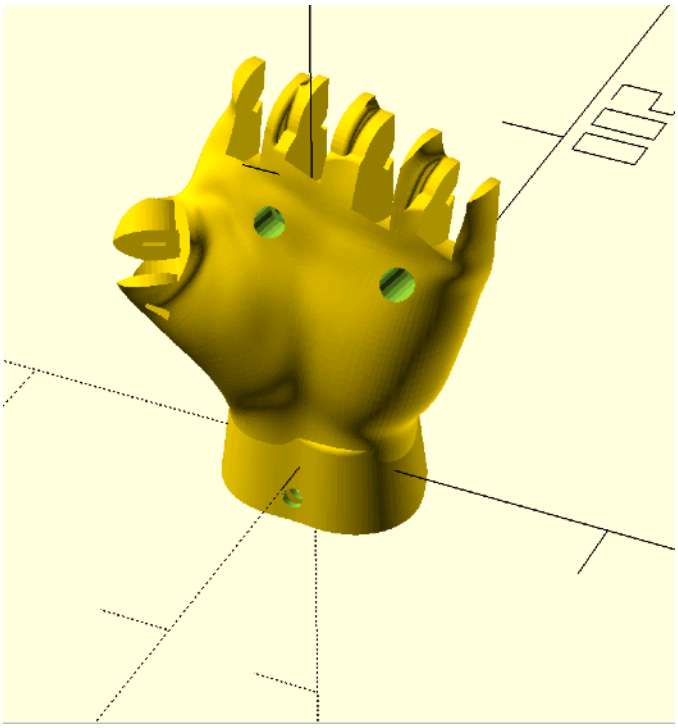
5 In the Customizer menu on the Right Hand side, click the little black arrow to display the parameters. Make sure “Automatic Preview” and “Show Details” are both checked.



6 Hit the Preview button (F5) to get a quick preview (should not be necessary if ‘Automatic preview’ is enabled).



You should see a preview of the palm in the main window it looks something like this.

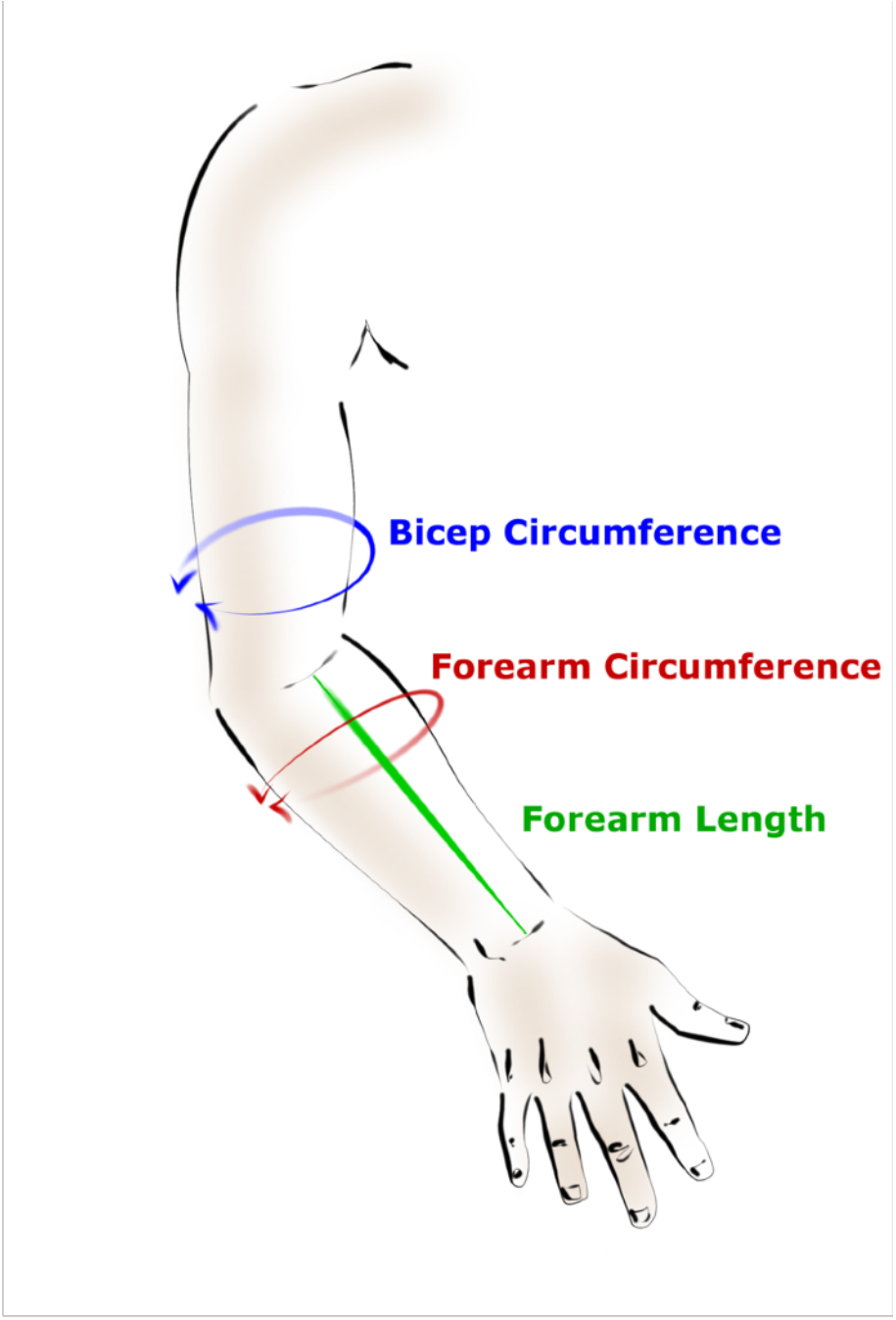


If the object is too large or small press the “View all” button

Now you are ready to set all the sizing parameters. Once you have set all the parameters you will need to render each part and save to an STL file.

Measuring Your Recipient

There are several measurements you will need from the recipient. The circumference measurements you will want to make on the residual arm. The Forearm Length and Hand Width you will make on the intact arm. All measurements are in millimeters.



Bicep Circumference: Measured around the upper arm at is thickest point. Measured on the residual arm being fitted with the prosthesis.

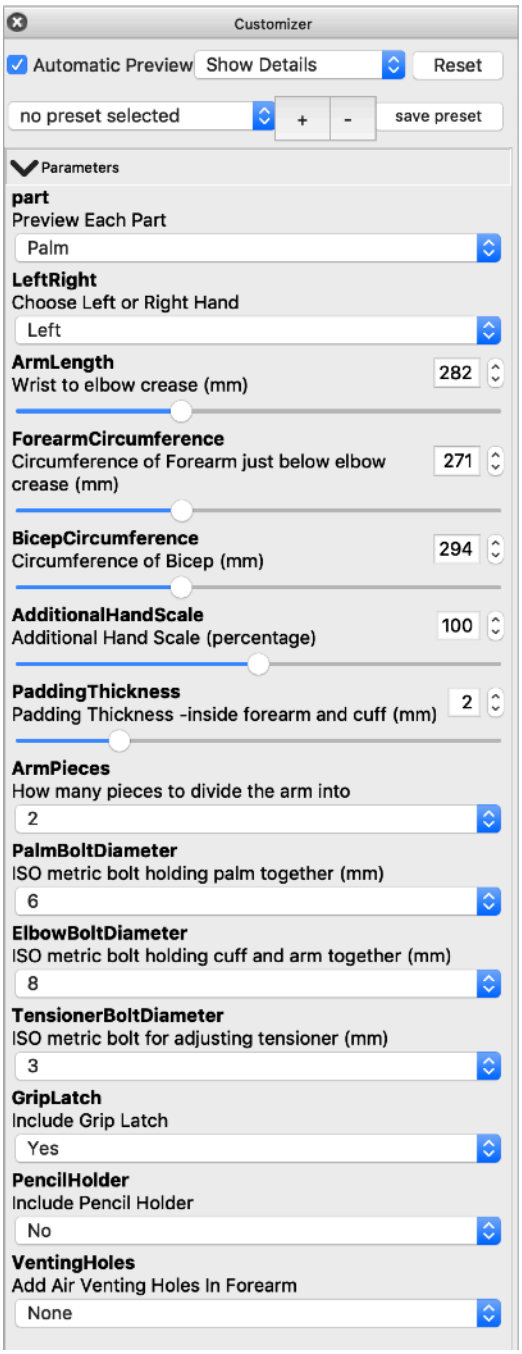
Forearm Circumference: Measured around the forearm at its thickest point. Measured on the residual arm being fitted with the prosthesis.

Forearm Length : Measured from the elbow crease the the wrist crease. Measured on the intact arm. I recommend you use a measurement **5% to 10% shorter than the intact arm**. The smaller

size gives better mechanical advantage and does not generally appear to be shorter than the intact arm.

Sizing Parameters

Once you have measurements from the recipient you will enter various parameters into the Customizer Parameters side bar.



Part : Only one part can be previewed, and/or render at a time.

Left Right: Choose which arm you will be making left or right.

Arm Length, Forearm Circumference, and BicepCircumference: All are from the direct measurements take in the previous section. While these can be any numbers allow by the sliders, you will want all four sliders to be roughly aligned vertically. If the sliders do not roughly line up vertically together then the arm will likely have an unnatural look to it. Meaning you will have a child's hand on an adult's arm or vice versa.

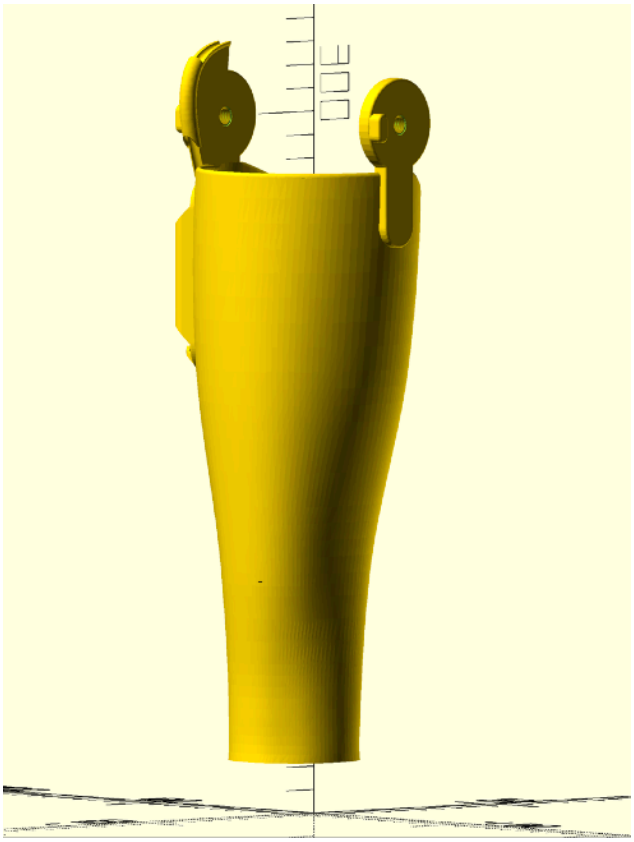
Additional Hand Scale: This parameter allows scaling of the hand above or below the basic scale of the arm. This is sometimes necessary if the recipient has a particularly "stocky" arm, or the opposite a thin arm with large hands. Left at 100% the arm will always make a smooth transition to the hand. If this scale is less than 100% there will be an edge at the wrist, because the wrist is larger than the hand. If this is above 100% there will be an edge because the hand is larger than the arm.

Padding Thickness: Choose the thickness of the padding that will be used to line the cuff and forearm. This thickness will contribute to the overall circumference of the forearm and the cuff.

Arm Pieces: The forearm can be printed as one or two pieces. If it is printed as more than one piece you will glue the pieces together with 2-part epoxy or super glue. The only reason to use more than one piece is so it will fit on your printer bed. To get a rough idea to know if the part will fit on your printer, you can preview it specifically.

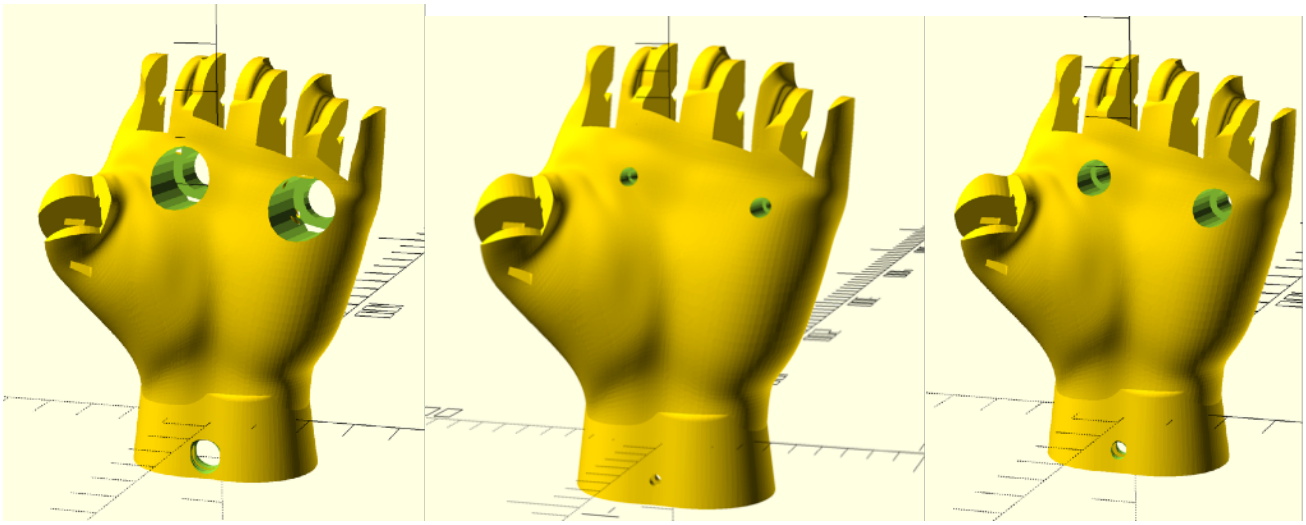
If you choose orthogonal view  and view from the front,  you can see the measurement markings in the arm.

If you select Arm Pieces "1" and Preview Part "Arm1", you get a view where you can estimate this arm would require a 31 centimeter long bed to print.



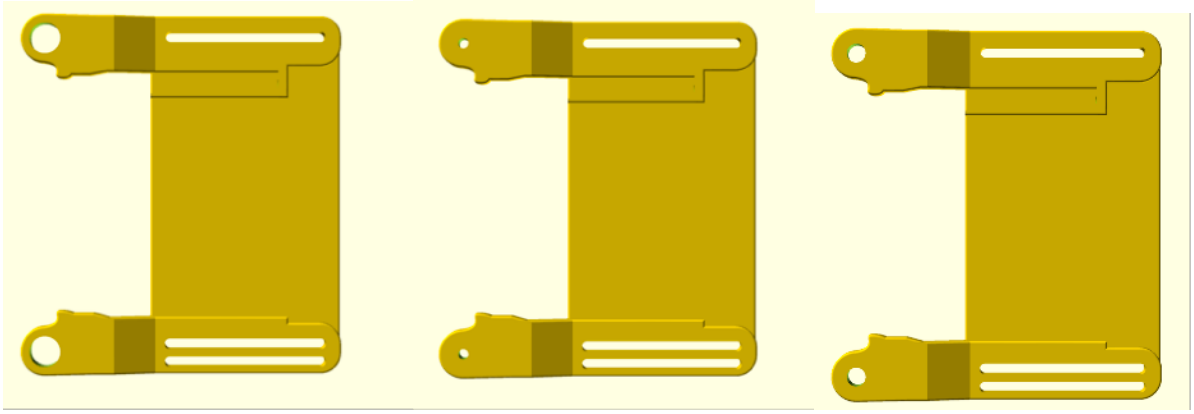
Palm Bolt Diameter: Choose a threading size for the bolts holding the palm together. All threads are rendered as standard ISO metric threading, so you can use manufactured bolts rather than the printed ones.

To Choose the palm bolt size, select “Palm” as the part to preview. If the hole looks too larger adjust to a different size bolt.



Preview of Palm Bolt sizes; too large, too small, and just right.

Elbow Bolt Diameter: Choose the threading size for the bolts holding the arm to the cuff. This is best decided while viewing the cuff from the top or bottom.

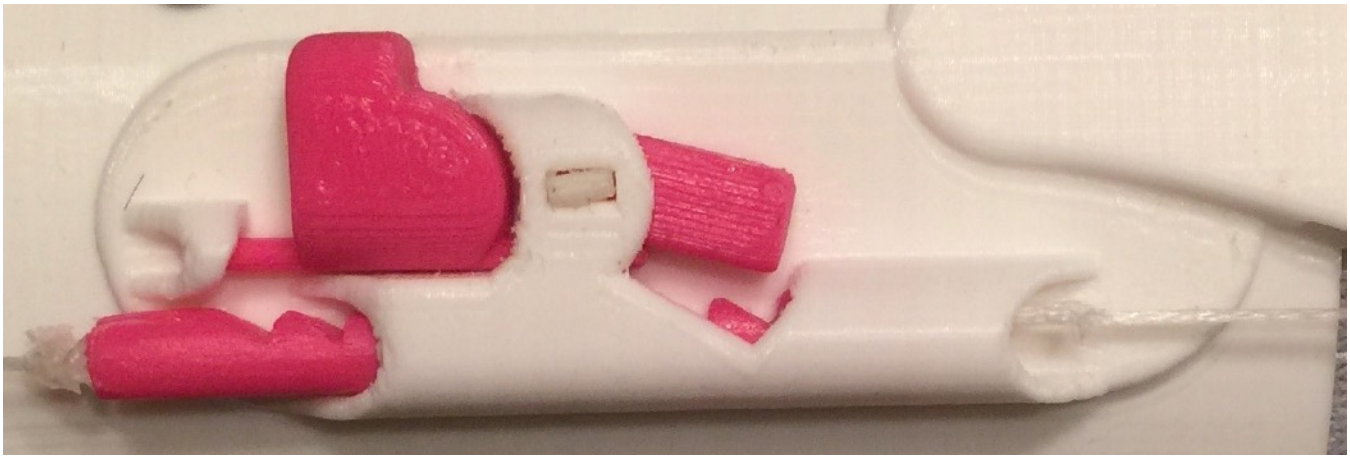


Preview of Elbow Bolt sizes; too large, too small, and just right.

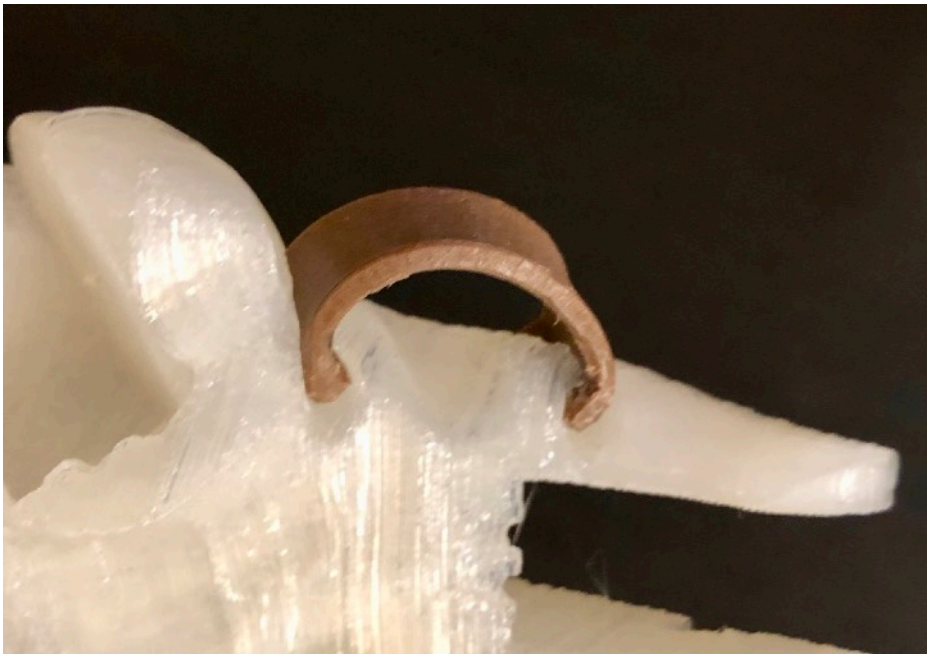
Tension Bolt Diameter: Choose the threading size for the bolt holding the string tensioner in place This is best decided while viewing the tensioner from the top. Choose a size where the slot to retain the nut has plenty of wall thickness around it.

Preview of Tensioner Bolt sizes; too large, too small, and just right.

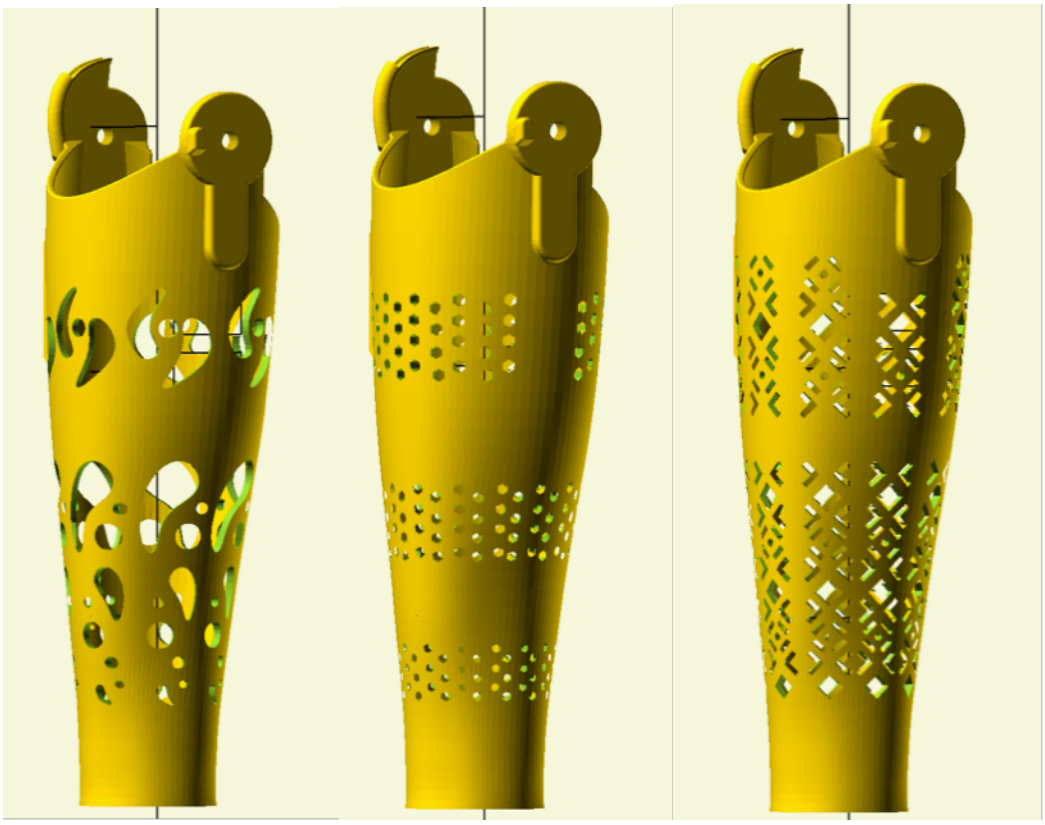
Grip Latch: Decide whether to include the Grip Latch or not. The grip latch mechanism is useful to hold a grip and retain usage of the elbow.



Pencil Holder : If chosen a cut out is made in the palm to slide a soft pencil holder.



Venting Holes: There are three different options for venting holes.



Render and Save STL files

You will have to select each part to preview then press Render, and then Save STL button.

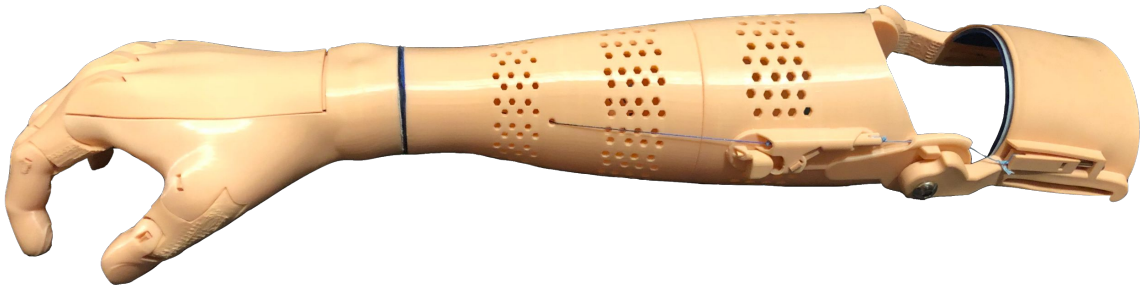
NOTE: The render button can take a long time for some parts **(20 minutes or more).**

Some of the parts render as empty and are **not necessary** depending on your parameters. For example, if you choose the arm as one piece then Arm2 is not necessary and will be rendered empty. If you choose not to include the GripLatch, then LatchHinge, LatchSlider, LatchPin, and Latch Teeth are not necessary and will render blank.

Have Fun

Printing and Assembly Guide

Kwawu Arm 2.0 Socket Version



Introduction

(Please read entire manual prior to assembling the Kwawu arm)

This document assumes you have already followed the instructions in the document **Using OpenSCAD to render Kwawu Arm 2.0 - Socket Version**. You should now have a collection of correctly sized STL files that are ready for printing. An experienced 3-D printer operator is recommended when printing the files.

It can take 30 to 40 hours of labor to assemble and fully prepare an arm for usage. Assuming most people reading this document are doing this project in their spare time, expect it to take several weeks. It is likely that the first arm you make may not fit or work exactly right when you try it on the recipient, so you may have to reprint a part and partially reassemble the arm. It's important to set this expectation for yourself and the person you are making the arm for. Explain to them that the whole process may take months.

Tools for Assembly - Required

We tried to keep the required tools list as short as possible.

Thick Cyanoacrylate (CA) glue such as Superglue for assembling the forearm and sealing the knots in the fishing line. Two part epoxy can be used to assemble arm pieces.

Phillips head screwdriver to fit the tensioner bolts.

Hexagonal Allen wrench for plastic bolts or Robertson square head drive for metal bolts. Which wrench you use will depend upon if you used metal purchased bolts or the 3D printed bolts and whether the bolts have a hex head or a square head.

Sharp knife or scissors to cut the fishing line

Pot of hot water for thermoforming.

Tools for Assembly - Recommended

Small flat file, small round file , medium half round file, sanding blocks or sandpaper to clean printed parts.

Toothpick or similar disposable fine tip to help spread the glue.

Utility knife or razor to help clean parts. A sharp razor is helpful to clean "stringing" off the flexible parts and is very useful for the hinges.

A pair of **needle nose pliers** can come in handy, particularly when removing scaffolding.

A **heat gun** is very useful for thermoforming if you used PETG to print the Arm and Cuff. If you used PLA, then **hot water** will be fine. To handle the hot plastic, consider using leather gloves with a heat gun and dishwashing gloves with hot water.

Plasti Dip - clear and Plasti-Dip Primer
This is painted on the fingertips and the entire palm grip area. It is durable when used with the primer.

A **thread tap tool** is handy. You can always heat a metal bolt and use it to clean the threads in the plastic, but a tapping tool is made to do this. You likely will only need a few sizes which correspond to the size of your palm, elbow, wrist, and tensioner bolts.

Galvanized Picture Hanging Wire and/or a T handle Ball End Allen Wrench
Both are very useful in clearing the string holes in the fingers and palm if they close up during 3-D printing. The wire helps pass the string in difficult places. Galvanized wire comes in many sizes at the local hardware store. It is generally stiff enough to force through the holes to open them up.

Non Printed Parts and Supplies

80-100 lbs Strength braided Fishing Line
Dyneema is the name of material used in recommended fishing line. For a 100% size hand you will need about 10 feet. Purchase extra to allow for adjustments in tensioning and restringing of the hand.

3/8" Thick Self-Adhesive Firm Foam
This lines the inside of the forearm and the cuff. Medical grade foam is better, as inexpensive foam can grow mold and deteriorate over extended use. Neoprene can be used as a washable and durable compromise.

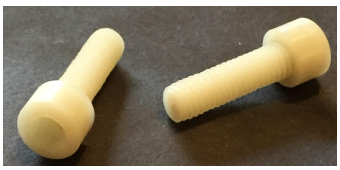
8 x Velcro straps, 8" to 12" long, 1" wide, non-elastic (often sold as cable straps) You may prefer 2" wide straps of the same type.

ThreadLocker Blue Gel
Recommended to put on the bolt threads so they do not work loose. You can use regular household glue if you do not have this.

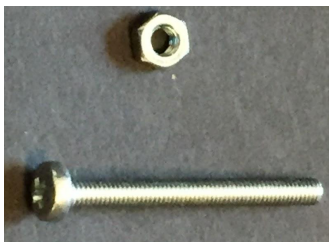
Non Printed Parts and Supplies

Metal or Nylon bolts

Elbow Bolts: It is recommended to use metal bolts instead of the 3-D printed ones. Most printers aren't precise enough to print the threads. If you do decide to use the 3-D printed screws for aesthetic reasons, all the bolt threads are generated as standard ISO metric sizes.



Palm bolts: It is recommended to use store bought nylon bolts because they are lighter than metal bolts and more durable than the 3-D printed ones.



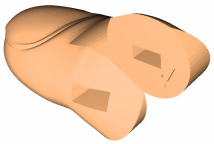
Tensioner Bolt and Tensioner Nut: It is recommended to use a metal bolt as the plastic bolt is likely to strip after many repeated uses.

To determine which size and length to purchase for the elbow, palm, and tensioner bolts, use the 3-D printed bolts and the parameters on OpenSCAD. It is helpful to bring the sample 3-D printed bolts with you to the store.
Both metal and nylon bolts can be cut if they are too long and if you have the proper tools. To cut a nylon bolt, you need a smaller size tap to fit down the cannula and stabilize the bolt.

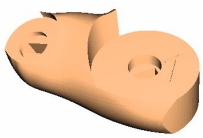
Parts List - Hand

Rigid Plastic (not shown to scale)

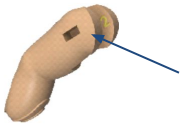
ThumbEnd (#1)



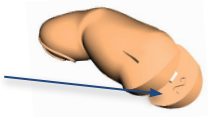
ThumbPhalnyx (#1)



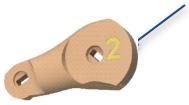
IndexFingerEnd (#2)



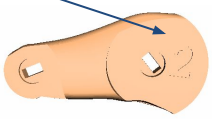
Part Number of each finger on inside



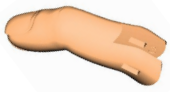
IndexFingerPhalynx (#2)



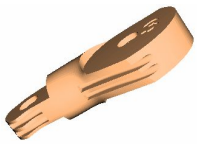
Part Number of each finger on inside



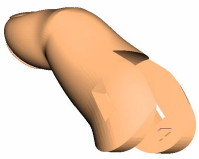
MiddleFingerEnd (#3)



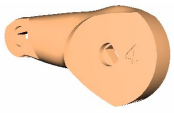
MiddleFingerPhalynx (#3)



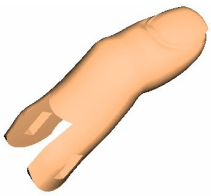
RingEnd (#4)



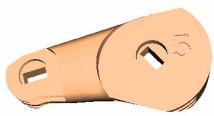
RingPhalynx (#4)



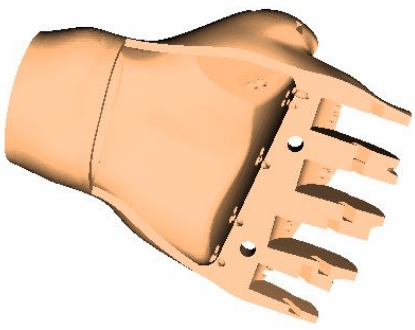
LittleFingerEnd (#5)



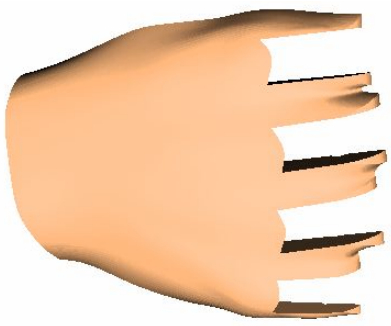
LittleFingerPhalynx (#5)



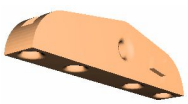
Palm 1



PalmTop



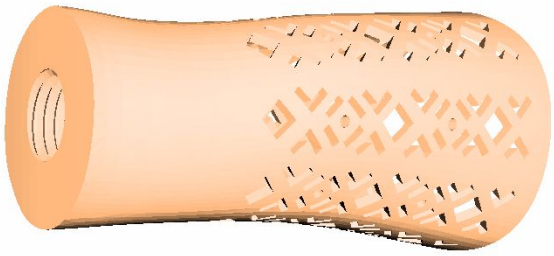
WhippleTreePrimary



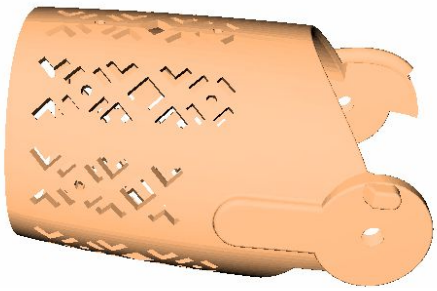
WhippleTreeSecondary

Parts List - Arm

Rigid Plastic (not shown to scale)

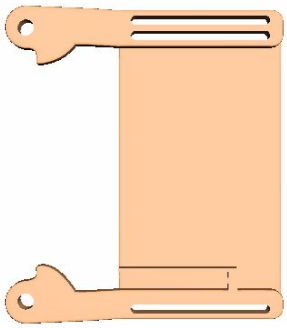


Arm1

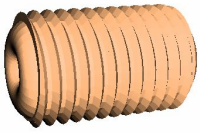


Arm2

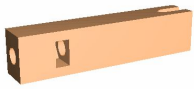
Cuff



Wrist Bolt

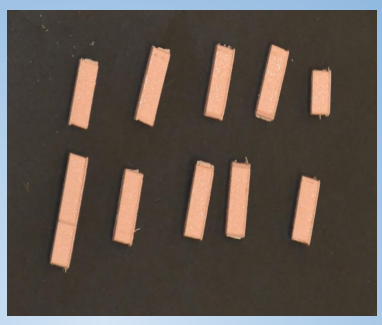


Tensioner

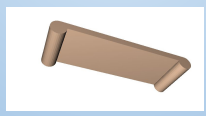


Flexible Printed Parts

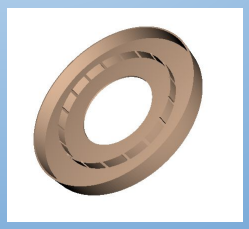
Hinges



Pencil Holder Cover

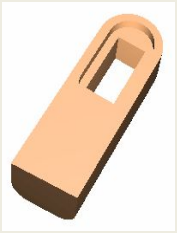


Wrist Compression Bushing (can be cut out of foam or printed)

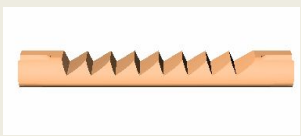


Latch Components (optional)

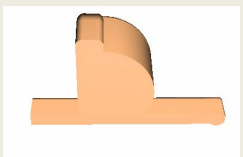
LatchPin



LatchTeeth



LatchSlider



One Flexible Hinge

Printing Settings and Suggestions

Most parts can be printed in PETG, except the hinges which must be printed in a flexible material like TPE or TPU. Some of the parts requiring thermoforming like the cuff can be printed in PLA, though PETG is still recommended.

Experiment with different materials if you like. It is recommended to print the palm and finger parts in PETG. PETG does not deform in hot water like PLA, it's harder than PLA and comes in food safe versions. This makes the hand safer and easier to use for eating and able to wash in hot water. You can thermoform PETG with a heat gun.

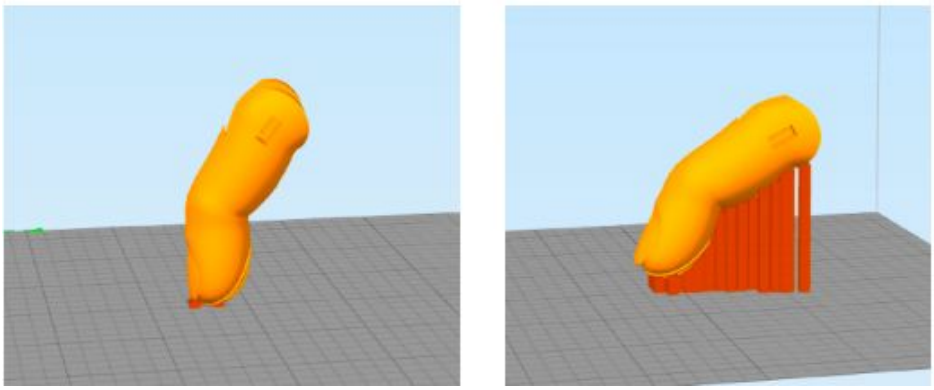
A note on Flexible Material :

We recommend a flexible material with a Shore A Hardness of about 85A.
Most newer TPU is a Shore A Hardness of about 94A, which was produced because it is easier to print. The original softer style used to be called TPE, ThermoPlastic Elastomer, and the newer harder style was called TPU, Thermoplastic PolyUrethane. The only real difference is that each is mixed to a different hardness. It is recommended use the brand names NinjaFlex and FilaFlex. The brand NinjaFlex is the original material from a company called NinjaTek. They have since come out with several other flexible filaments all with different properties, so be sure to get the one with Shore A Hardness of 85A. Likewise, FilaFlex is a company whose original product was Shore Hardness 82A. They have since come out with FilaFlex Medium which is Shore A Hardness 95A, so be sure to get the softer filament. It is a little more difficult to print, but produces better flexible hinges.

Printing Settings and Suggestions

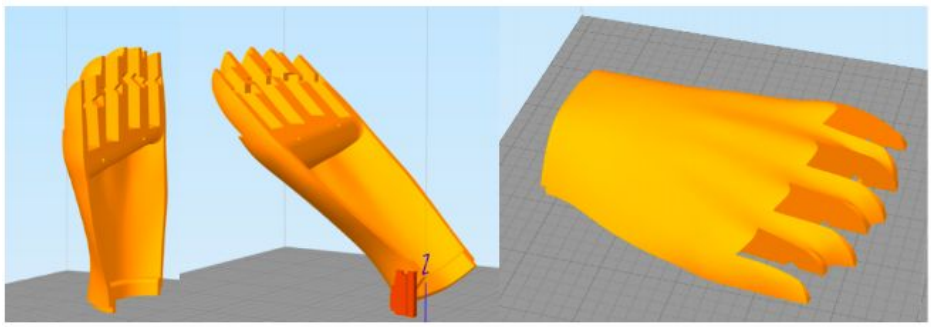
Rigid Hand Parts: ***Palm top and bottom, arm, all the finger pieces.***

- 3 or 4 outer layers which includes top, bottom layers and outer perimeters.
- 35% honeycomb infill.
- Can be material other than PETG, such as ABS or PLA. PETG may be preferred because it is stronger and can therefore be made thinner and lighter than PLA. Also, a hand made of PETG can be detached and washed easier than other materials.
- Printing the finger pieces can benefit from adding scaffolding. Generally it is better to use a slicing program that will let you manually place the scaffolding for these parts. If you are having trouble with the fingers coming loose from the base plate, try learning them back to a 45 degree angle and adding more scaffolding. This may be more reliable for some printers.



Two orientations for printing finger parts. Use more scaffolding if the part comes loose from the base plate.

Note: If scaffolding is used, it is best to be manually added than be auto-generated by the printing software. Auto-generated scaffolding can block holes and make it very difficult to string the hand.



Three orientations to print the Palm Top. The 45 degree angle was suggested by Krzysztof Grandys and is a preferred orientation for best look and strength.

Printing Settings and Suggestions

Thermoformed Parts: ***Cuff***

- 3 or 4 outer layers, that includes top, bottom layers and outer perimeters.
- 35% honeycomb infill.
- We recommend using PETG unless you don't have a heat gun to thermoform (then use PLA).
- The cuff requires scaffolding to print. Most slicers will automatically generate scaffold that will work.

Structural Parts: ***Whippletrees, Tensioner, (and Bolts)***

- 4 or 5 outer layers, that includes top, bottom layers and outer perimeters.
- Near 100% infill for strength.
- These are recommended to be PETG or ABS for added strength.
- You do not have to print the bolts. All the bolts and threading are printed as standard ISO metric sizes. It is recommend you print the bolts only to aid in finding the correctly sized metal and nylon bolts.

Flexible Parts: ***All the Hinges and Pencil Holder Cover***

- 4 or 5 outer layers, that includes top, bottom layers and outer perimeters.
- Use enough outer layers to get near 100% fill for strength and proper spring behavior.
- Must be a flexible material such as TPE or TPU. Brand names for TPE are NinjaFlex and FilaFlex . Use the softer type filament Shore A Hardness of 85A (see note on page 8).
- These parts are small and intended to be easier to print than most parts. However, printing with TPE or TPU is NOT easy. The best advice is to print very slow, like 900mm/min and hot around 230℃.
- You want these parts to fit snugly in the finger slots. Because printers behave differently for these materials than the rigid plastics you may have to print these smaller or larger, sometimes as small as 90% or as large as 110%.

How does the Arm Work?

Familiarize yourself with the function of the arm prior to building. The fingers are supposed to close with the thumb first and the pinky last. When the fingers close in order, you get the precision of the thumb and index finger first, while the remaining fingers are still out of the way. This enables you to pinch or to pick up finer objects. If you continue to close the grip the other fingers engage as would happen around a bottle or baseball. The wrist compression bushing allows the recipient to adjust the position of the hand by 1/4 turn in either direction and still hold position.

The **latch** allows the grip to stay closed tight with the elbow moving freely. With the latch open, the grip opens and closes with the elbow movement. With the latch closed, the string is held as the elbow closes. This allows the user to hold a grip while still using the elbow motion. An example where the latch is useful is when the user needs to hold a spoon while eating or a grabber bag while walking. Move the latch slider back to the open position to release the grip.

This video is a great demonstration of the function of the arm: Kwawu Arm 2.0 Demonstration (https://www.youtube.com/watch?v=o5p5qpXizaQ)

Phases of Assembly

Kwawu Arm 2.0 Socket Version

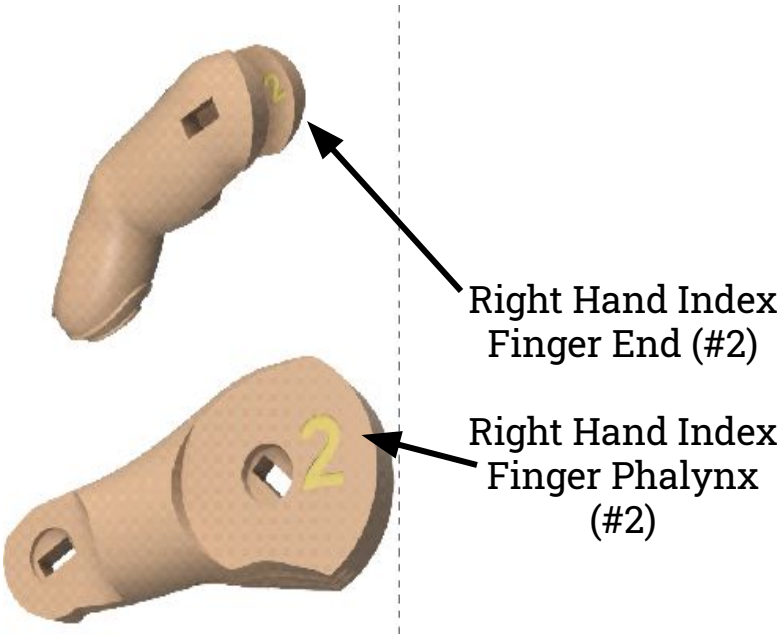
Phase 1: Preparation

Identify and Arrange Parts (see parts list)

Identify the correct parts for the fingers and palm and arrange them in order.

The finger pieces have numbers embossed in them. These correspond to the finger numbers 1 to 5 starting with the thumb.

The location of the number on the fingers will verify that you have a Right or Left Hand.

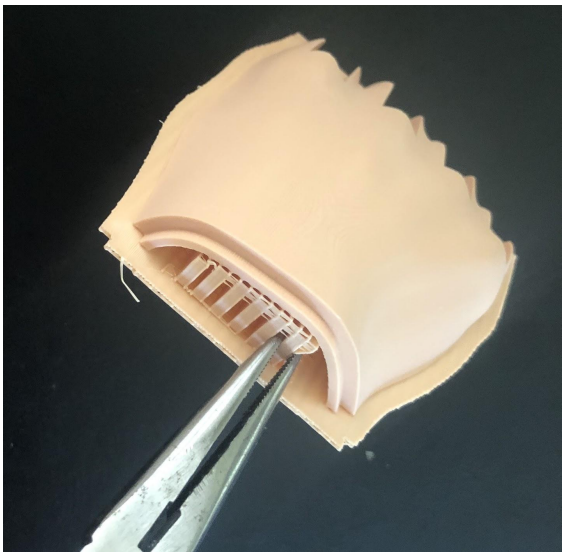


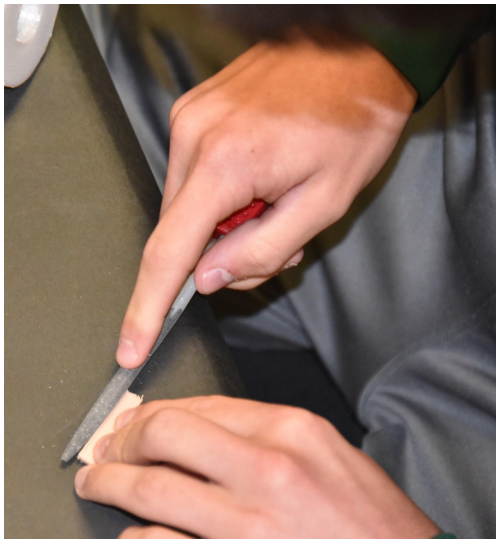
Phase 1: Preparation

Remove Scaffolding, Sand, File and Smooth Parts

Thoroughly Remove the Scaffolding

This is an important step. Make sure you remove all scaffolding in the corners and edges.





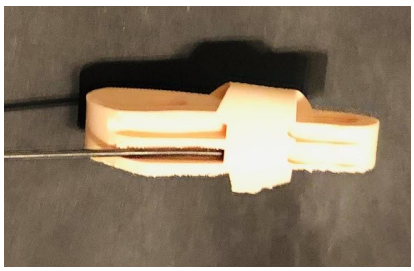
Sand, File and Smooth Parts

Sand, file and generally finish the parts. If you oriented the finger phalanx as suggested during the printing process, you will need to sand the curved back end of the parts. The added supports and spreading will mean the back is not round.

Phase 1: Preparation

Clean Holes and Threads

In smaller printed hands the holes for the strings can close during the printing process. Galvanized picture wire is generally stiff enough to force through the holes to open them up. You can also force the wire through the opening, heat it with a solder iron, and move it around to smooth the inside of the channels.

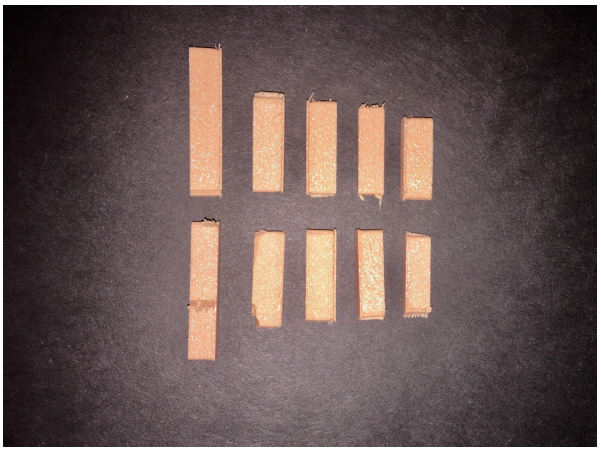


Clean the threads with a metal bolt or a tap tool. The top of the palm has threads matching what was set by OpenSCAD. Try screwing the bolts into just the palm top. You may need to heat the bolt to help clean the plastic threads.

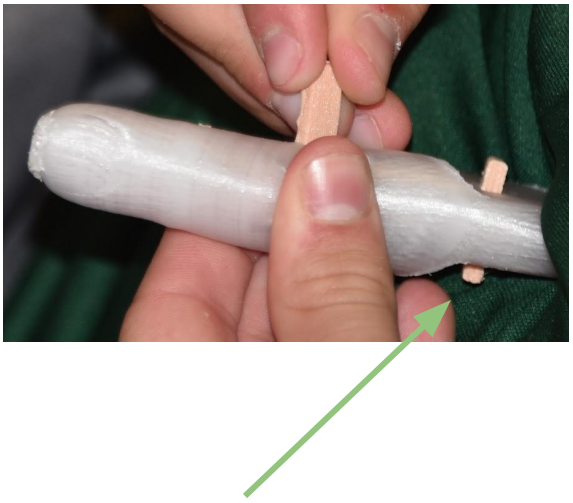
Phase 2: Hand

Assemble Hand

Choose the best size hinge to fit in each slot to secure the fingers to the palm. The finger hinges only vary in length but not width. The longest ones go in the base of the thumb. Trim the width if needed.



Each hinge should fit snugly. Make sure the hinges are seated properly on both sides of the fingers. Make sure the knuckle hinges are seated properly on both sides of the palm - this is easier to do prior to stringing. If they are not seated properly , then the palm top won't fit snugly.



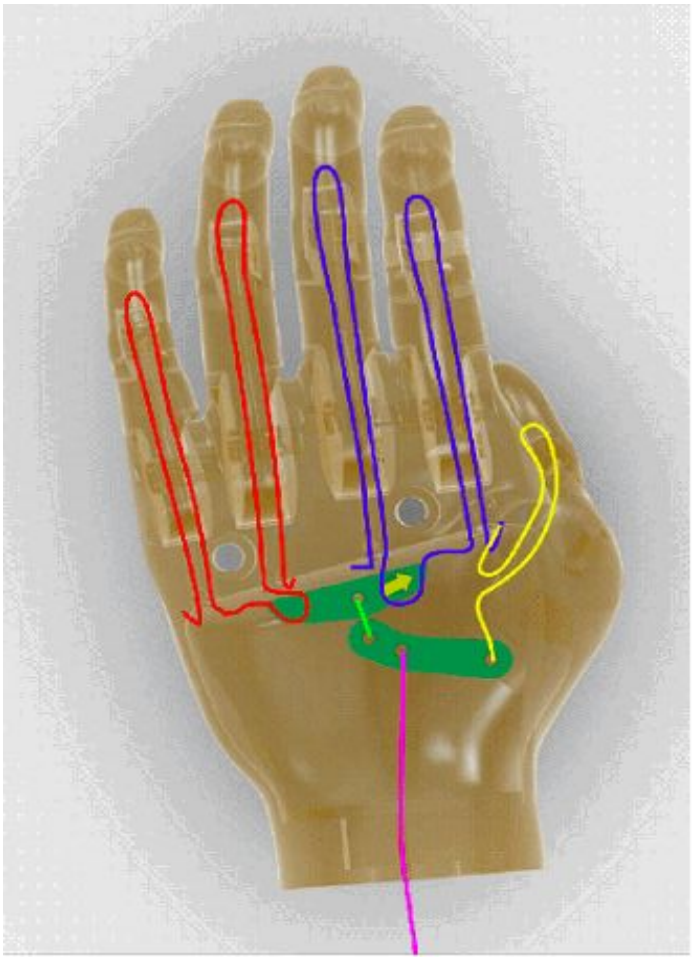
Tip: You may need to remove the hinges in the fingers for access to stringing in the next step so save the final trimming of the hinge lengths until after the arm is assembled.

Tip: Depending on your printer you may need to print the hinge slightly larger or slightly smaller to get a snug fit. We recommend printing them slightly larger and then thinning them out and/or shortening them with a utility knife.

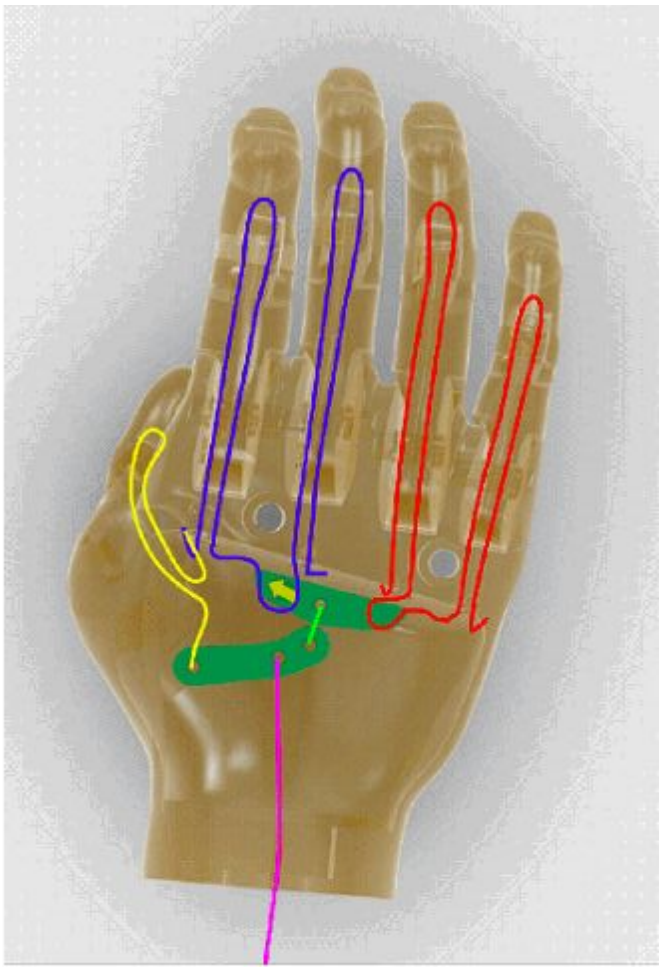
Phase 2: Hand

Stringing the Hand

Tip: Some general advice before you string the hand:
1. Make sure that the channels for the string are not blocked by scaffolding or excess plastic. Be sure that there are no sharp edges that may fray the string.
2. Don't tie the final knots initially - you will need to retension everything at the end. When you tie a final knot, using alternating half hitches will make it more stable. There are knot tying videos on the internet.



Left Hand

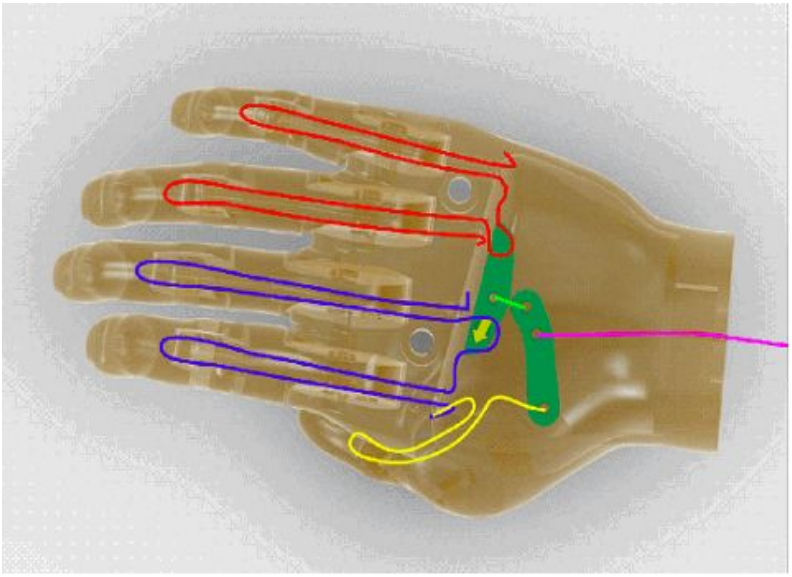


Right Hand

Phase 2: Hand

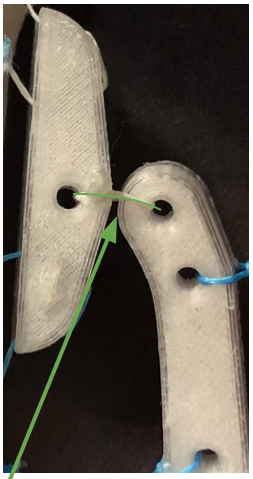
Stringing the Hand

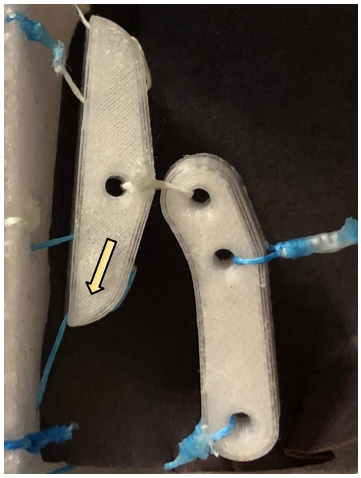
Note: Each of the colored strings in the picture is a single different string.



A: Tie the Primary and Secondary Whippletrees Together

1. Align the Whippletrees as shown in the diagram with the embossed arrow on the primary whippletree pointing towards the thumb (see yellow arrow in this diagram).
2. As illustrated by the green string in the diagram (and the green arrow), tie the 2 whippletrees together. Tie them as tightly together as you can.

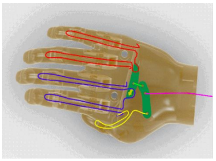


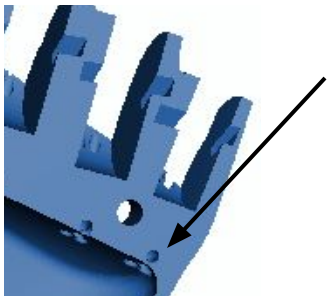


Phase 2: Hand

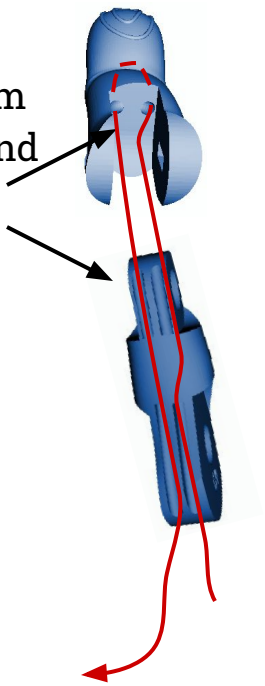
Stringing the Hand

B: String the Ring and Pinky Fingers (Red String in Diagram)

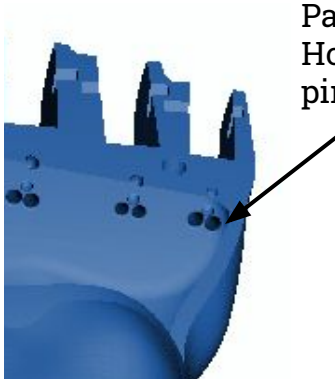




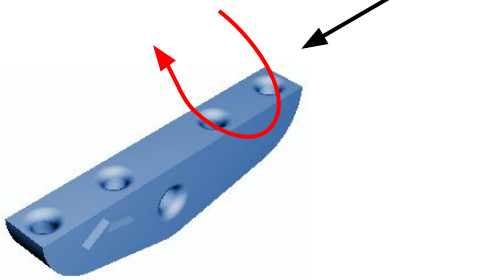
1. As illustrated by the red string in the diagram, tie one end of the string securely to the tie-off loop at the base of the pinky finger.



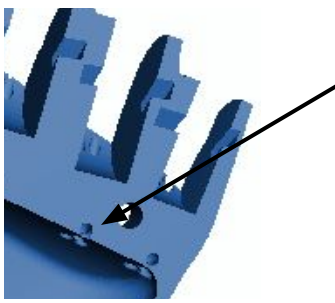
2. Feed the string through the palm hole and up the pinky. Loop around the tip and back down the pinky.



3. Feed the string through the next palm hole and through the longer end of the primary whippletree. (The end opposite the arrow - see diagram).



4. Feed the string through the next palm hole, up the ring finger, around the tip and back down the ring finger and out the second ring finger palm hole.

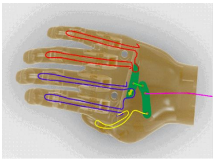


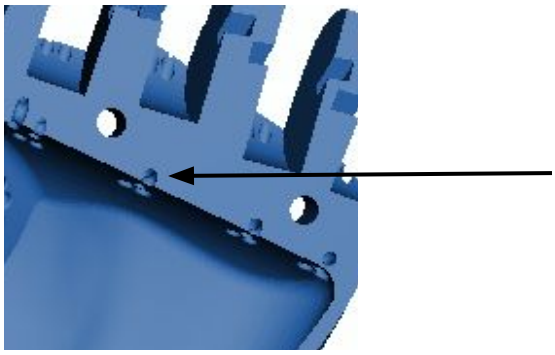
5. Feed the string through the tie off hole (at the base of the ring finger) and secure it, don't tie it. You will need to tension it later.

Phase 2: Hand

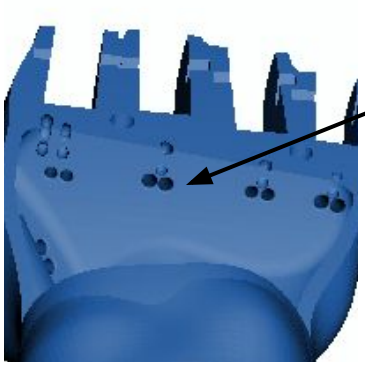
Stringing the Hand

C: Stringing the Middle and Index Fingers (Blue String in Diagram)

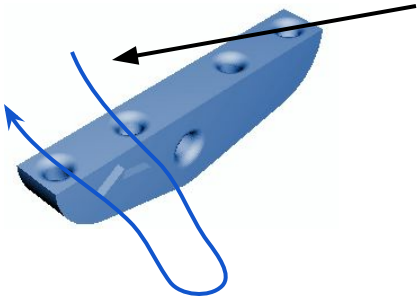




1. As illustrated by the blue string in the diagram, tie one end of the string securely to the center tie-off loop at the base of the middle finger.

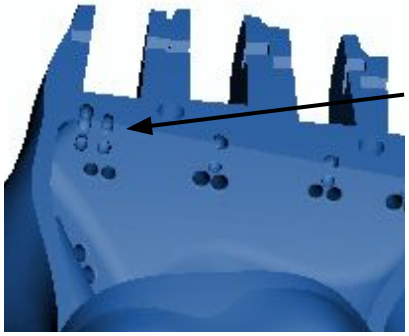


2. Feed the string through the first middle finger palm hole, up the middle finger, around the tip and then back down the middle finger and through the second middle finger palm hole.



3. Loop the string through the shorter end of the primary whippletree. (The end with the arrow on it)

4. Feed the string through the first index finger palm hole, up the index finger, around the tip, back down the index finger and through the next palm hole.

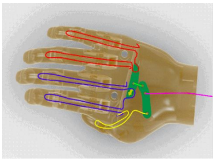


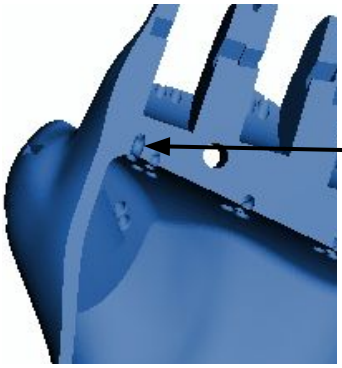
5. Pass the string through the index finger tie off hole. Secure it but don't tie it. You will need to it tension later.

Phase 2: Hand

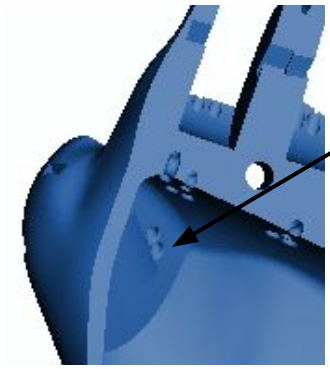
Stringing the Hand

D: String the Thumb (Yellow String in Diagram)

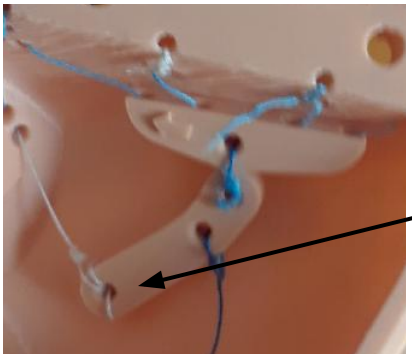




1: As illustrated by the yellow string in the diagram, securely tie the string in the tie-off loop closest to the thumb.



2: Feed the string through the thumb palm hole, up the thumb, around the tip and back down the thumb and out the second palm hole.

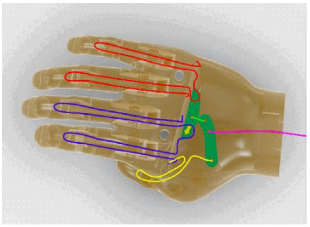


3: Pass the string through the closest hole on the secondary whippletree. Secure it but don't tie it tight yet.

Phase 2: Hand

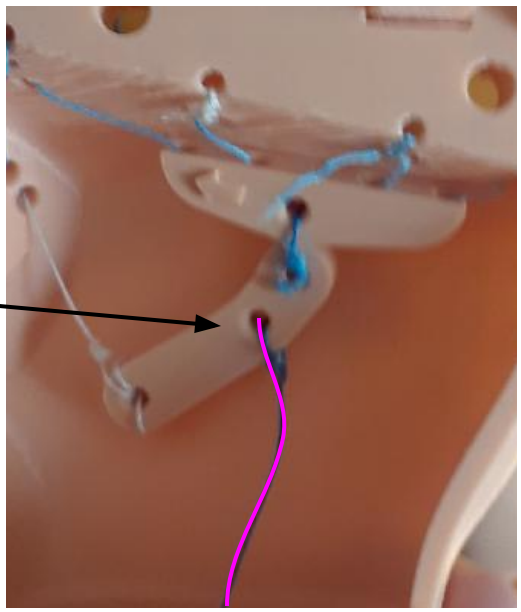
Stringing the Hand

E: String the Back of the Secondary Whippletree (Pink String in Diagram)



1: Cut a piece of string long enough to reach from the palm to the top of the cuff. (Give yourself extra).

2: As illustrated by the pink string in the diagram, tie one end to the middle hole in the secondary whippletree.

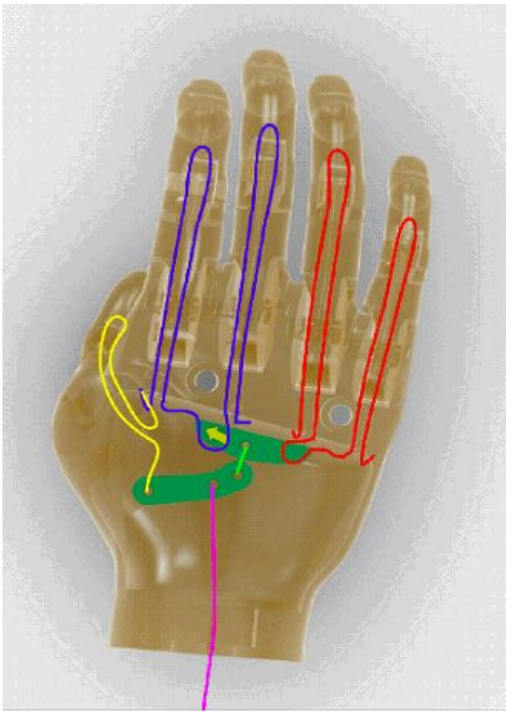


3: Leave this string loose in the hand, to string down the wrist later.

Phase 2: Hand

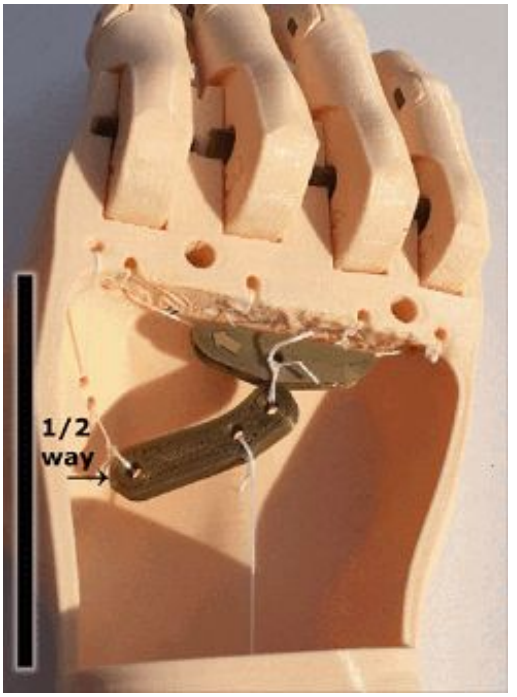
Tensioning

A: Set the Correct Positions of the Whippletrees



1. Make sure the hand is in the neutral relaxed position and the fingers are not bending inwards as you tension.

2. **Primary Whippletree**: Pull the finger strings (the red and blue strings) as tight as you can without bending the fingers inwards. Make sure there is no slack in the string and that the whippletree is tight up against the inside wall of the palm and centered between the 3rd and 4th fingers. The arrow on the primary whippletree should be pointing to the thumb.



3. **Secondary Whippletree**: The end of the secondary whippletree with the yellow string connecting to the thumb should be **halfway between** the knuckles and wrist with the fingers relaxed. (see diagram). This allows extra string that enables the user to push open the thumb to grab larger objects.

Phase 2: Hand

Tensioning

B: Test the Finger Movements and Tie Knots

1. The Whippletrees are shaped to close the fingers in order, thumb first pinky last. Check that the fingers are closing in the correct order prior to final knot tying. When the fingers close in order, you get the precision of the thumb and index finger first, while the remaining fingers are still out of the way. If you keep closing the grip the other fingers engage as would happen around a bottle or baseball.

C: Glue Knots

1. Once all the strings in the hand are tied tightly and tensioned correctly, put super glue on each knot. Be careful not to get the glue on any of the PLA parts. Wait for the glue to set and **dry for 4 hours** before putting a large force pulling on the main string.

Tip: Sometimes you may need to pass a string a second time if the tension isn't exactly right. Here are some tips that might help:

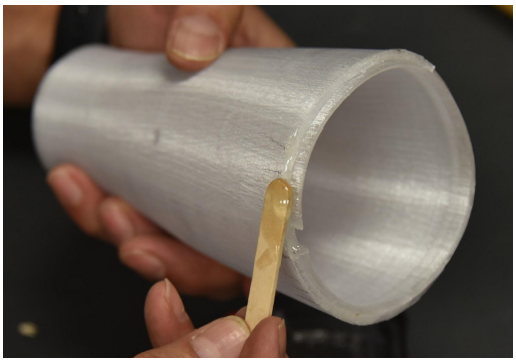
- *Tie one end of the new string to the other end of the used string and pull through all the channels.*
- *Pass a **loop** of string or wire through a hole (in the opposite direction) that's difficult to pass. Thread the proper string through the wire loop and pull back through the hole.*

Phase 3: Forearm

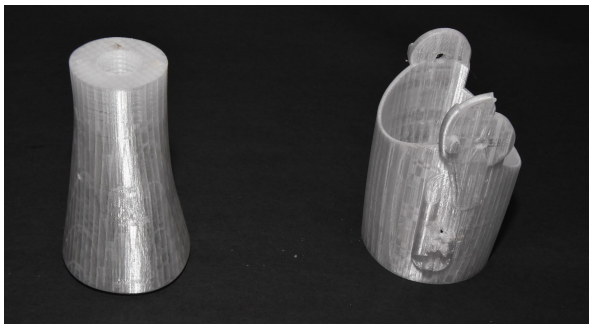
Forearm Assembly

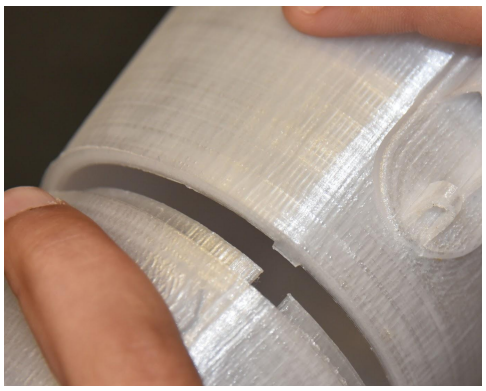
Glue Forearm Together

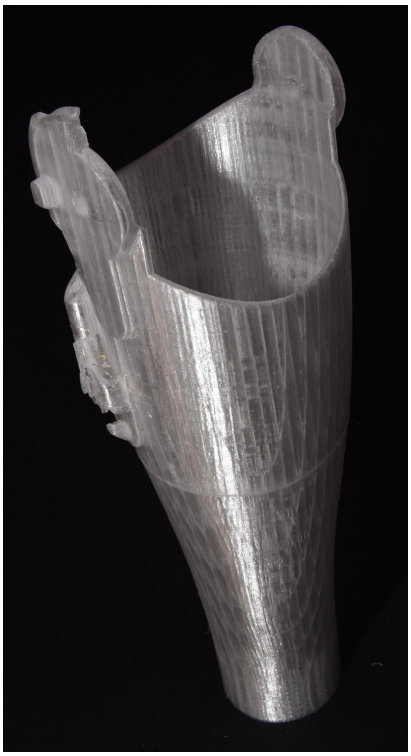
If you are lucky enough to have a big printer and printed the whole forearm in one piece you can skip this section.



1: Use the Superglue or two-part epoxy to adhere the two forearm pieces together. Use a toothpick to spread a small amount of glue along the connecting edges of the arm pieces. Two part epoxy sometimes works better than superglue, depending on the type of plastic.



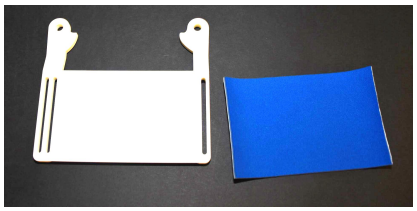


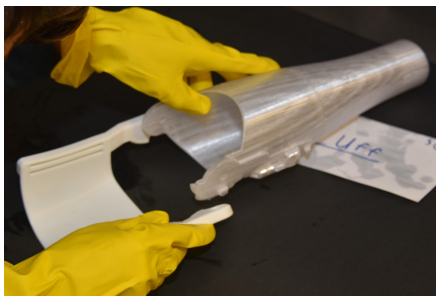


Phase 3: Forearm

Thermoforming the Cuff

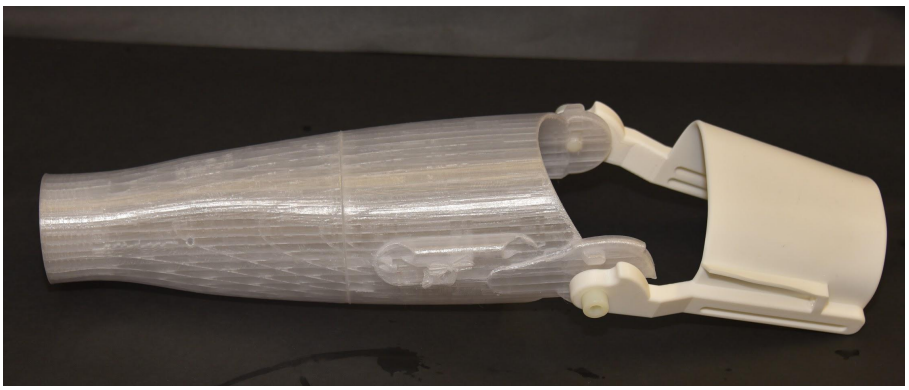
Thermoforming is heating and molding the plastic cuff to fit the recipient's upper arm. Since there is no form for the cuff, thermoforming must be done manually. You can find thermoforming videos online for the type of plastic you have. PLA can be thermoformed using boiling water, while PETG will require a heat gun to thermoform. The cuff in the pictures shown is PLA, so boiling water is used.





1. Before thermoforming, trace and cut the foam to fit inside the cuff. **DO NOT ADHERE** the foam until after thermoforming.

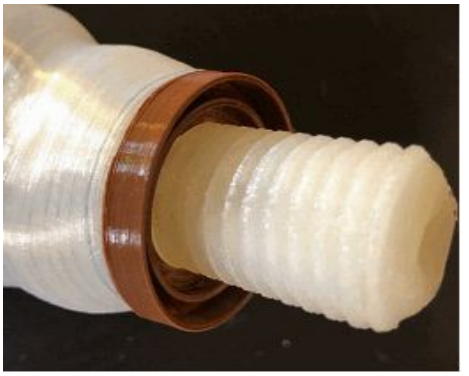
2. When you thermoform the cuff use the end of the forearm to make sure the bolt holes line up. Heat the plastic until it is soft, form it, and wait for the plastic to cool in its new shape. Repeat until the desired shape is created. Make sure the slot for the tensioner in the cuff is on the same side as the latch and the forearm hole.



Phase 4: Putting it all together

Attaching Hand to Arm

Prepare hand for attachment



Screw the wrist bolt into the hand.

Tip: If the center hole of the wrist bolt is clogged with scaffolding, you can free it up with a drill bit or pliers. Make sure there are no sharp edges that will cut the string.

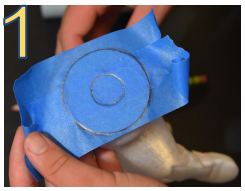
Tap used to clear threads in forearm

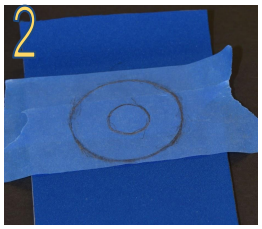
Tip: Now is a good time to make sure the threads in the wrist and forearm are tapped free of debris.

Phase 4: Putting it all together

Attaching Hand to Arm

Wrist Compression Bushing

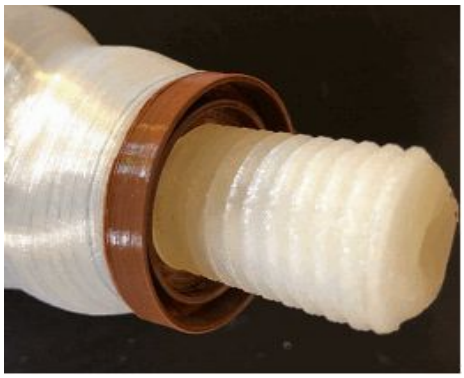


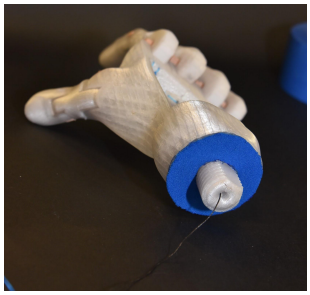


If you didn't 3-D print the wrist compression bushing, trace and cut a washer out of the foam that you are using for the lining.

Tip: The Wrist Compression Bushing allows the recipient to adjust the position of the hand by 1/4 turn in either direction and still hold position. You can cut a washer out of the foam you are using for the lining rather then the TPU printed bushing. The important thing is that the foam provides enough compression to hold the hand at various angles.

3. Put the 3-D printed Wrist Compression Bushing (or foam washer) over the wrist bolt. Make sure the flat side of the plastic bushing is towards the hand and the open side towards the arm. The outer rim of the bushing will fit over the arm covering the gap.





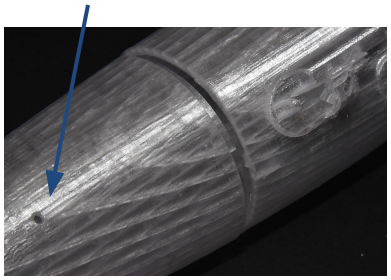
Phase 4: Putting it all together

Attaching Hand to Arm

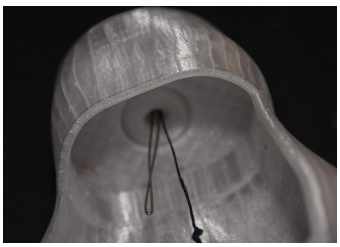
Attach Cuff to Arm

1. Feed the string from the back of the whippletree through the hole in the center of the wrist bolt and through the hole in the forearm.

Hole in forearm

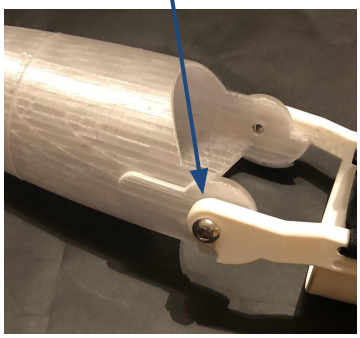


Tip: If you are having trouble passing the string, fashion a wire loop, pass it through the hole, feed the string through the loop, and pull the string back out through the hole.



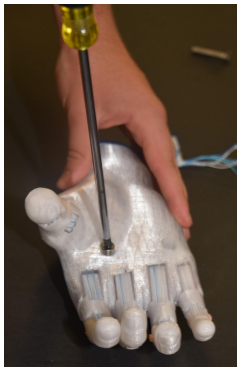
Tip: If the hole in the forearm is filled with plastic, clean it up with a drill bit. Be careful there are no rough spots that will fray the string.

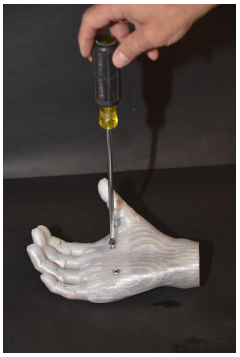
Elbow Bolts



2. Screw the wrist bolt into the arm.

3. Attach the cuff to the arm with the elbow bolts. Metal bolts are recommended.

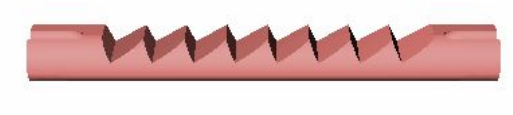




4. Attach the Palm Top to the hand: screw the top and bottom of the hand together using the palm bolts. Nylon bolts are recommended. Double check that the knuckle hinges have seated properly on both sides of the palm - this is easier to do prior to stringing.

Phase 4: Putting it all together

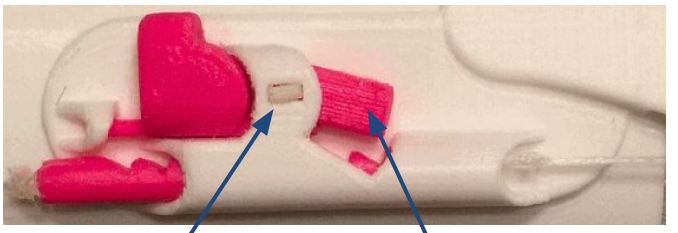
Assembling the Latch (optional)

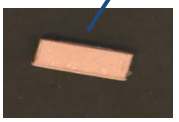


Latch Teeth

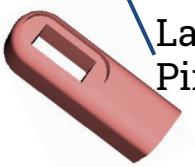
1. Make sure the latch teeth slide through the channel easily without hindrance. If it doesn't slide easily, smooth out the inside of the channel with a small round file.

2. Assemble the latch pin and one flexible hinge. Test that the latch pin snaps closed and pushes open smoothly.





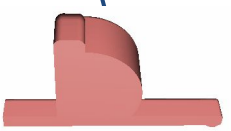
Hinge



Latch Pin

3. Move the latch teeth through the channel with the latch pin working. The latch pin should click and catch on each tooth securely as the latch teeth pass through the channel. If not, take the hinge out and clean/sand all the contact areas until it moves smoothly.

4. Remove the latch pin, hinge, and latch teeth.

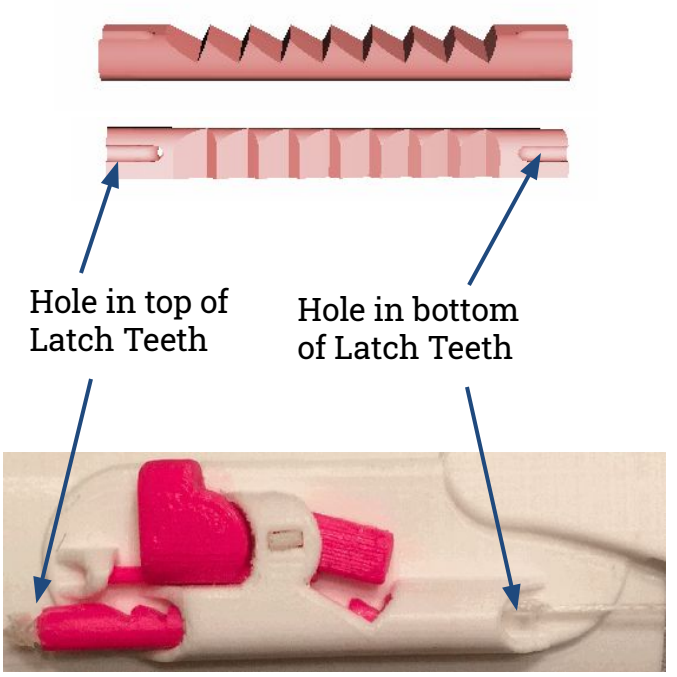


Latch Slider

5. Put the latch slider in place (without the latch pin/hinge). The latch slider is supposed to be a tight fit and will take some gentle persuasion to get in place.

Phase 4: Putting it all together

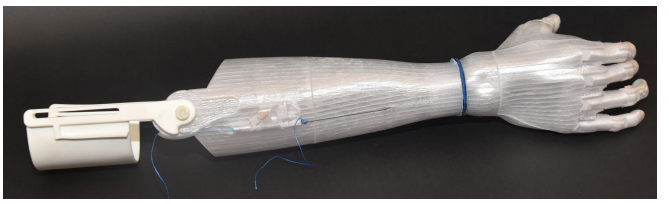
Assembling the Latch (optional)



6. Once the latch sider is in place put the latch pin and hinge back in.

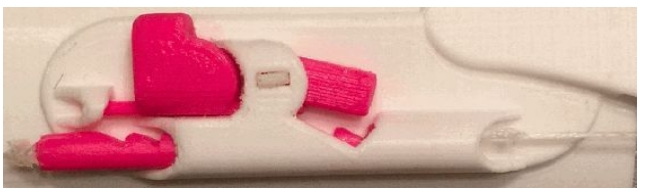
7. Cut a string long enough to reach from the top of the latch to the tensioner on the cuff. Give yourself extra length.

8. Tie string to the top of the latch teeth. Pull this string through the slot and hold the latch teeth at its lowest position (closest to the fingers) **just before any tooth would catch**.



9. Keeping the latch in its lowest position, tie the string from the hand to the bottom of the latch teeth. This string should be tight, with the fingers relaxed with no latch teeth catching.

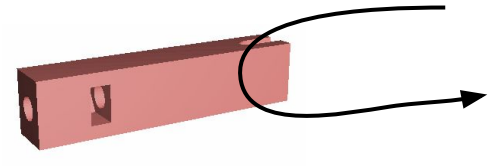
With the latch closed the string is held as the elbow closes. Now the grip is held tight and the elbow can move freely. This allows the user to hold a grip while still using the elbow motion. For example to hold a spoon while eating or a briefcase while walking. Move the latch slider back to the open position to release the grip.

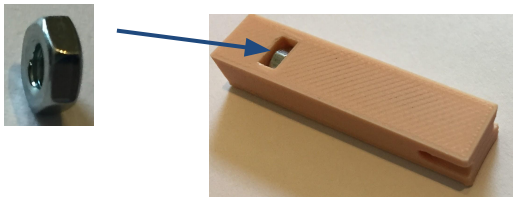


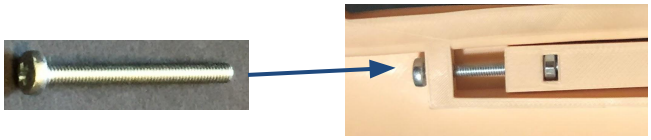
With the latch open the string moves freely and the grip opens and closes with the elbow movement

Phase 4: Putting it all together

Final Tensioning and Knotting







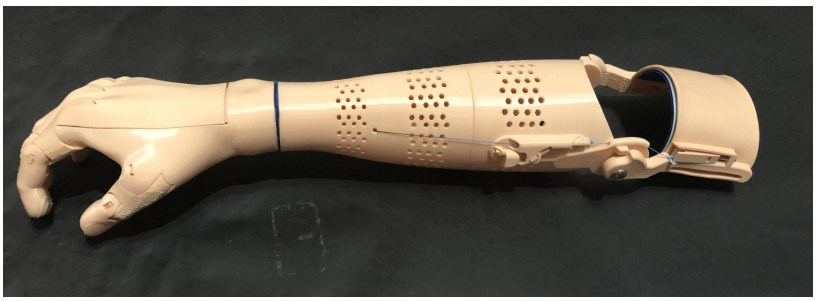
1. Pass the string from the latch through the tensioner and secure but don't tie it yet.

2. Use a metal bolt and a nut to secure the tensioner to the cuff. Drop the metal nut in the slot and then place a screw through the end of the tensioner and through the nut. Do not seat the screw all the way to allow later adjustments in tensioning.

3. With the fingers fully open and the elbow fully extended, pull the string on the tensioner tight and tie a knot.

4. Trim any leftover string and put super glue on all the knots. Make sure not to super glue the latch tooth part in place. Let the glue dry for 4 hours.

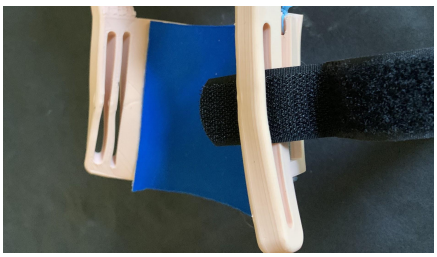
The arm grip should be fully functional now!



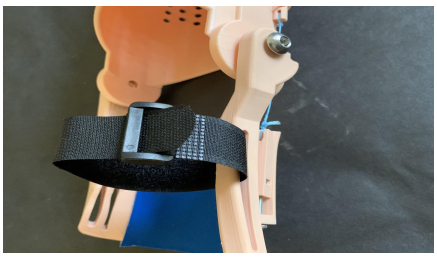
Phase 5: Final Steps and Fitting

Straps, Finger Tips, and Palm Grips

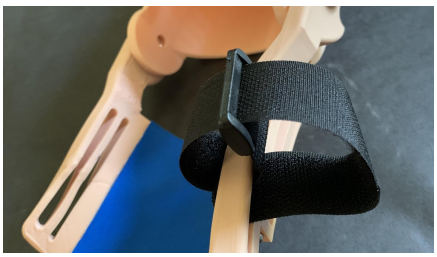
Velcro Straps



1. Feed a velcro strap through the thumb side of the cuff from the outside with the fuzzy side up.



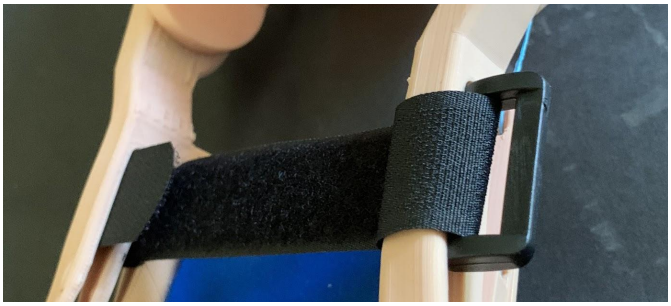
2. Feed the strap through the buckle then feed it back through the cuff slot.



3. Twist the buckle upwards and feed the strap through the forearm slot but not back through the buckle.

4. Use the same technique to attach velcro straps to the other slots in the cuff. The cuff should have at least two 1-inch wide straps, although you can use wider velcro straps if they fit.

Tip: if the strap is too long, you may not be able to use the buckle. In this case you will have to loop the velcro through the arm slot and sew it to hold it tight.



Phase 5: Final Steps and Fitting

Straps, Finger Tips, and Palm Grips

Finger Tips and Palm Grip

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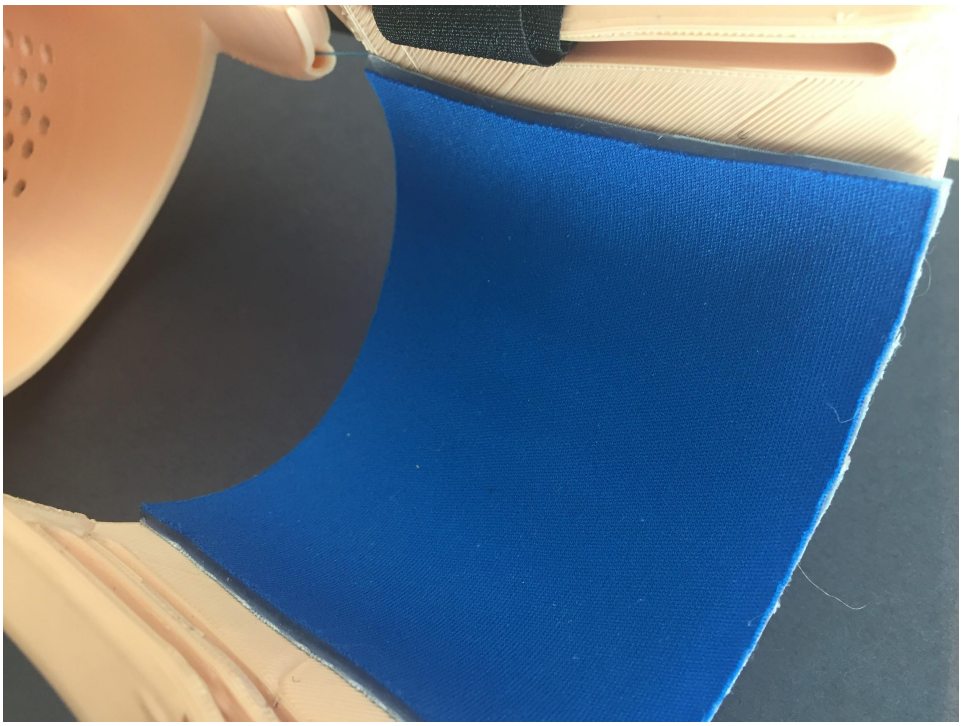
Follow the instructions for the Plasti Dip Primer and the Plasti Dip to paint on the fingertips and the entire palm grip area. The primer helps with durability. Follow the instructions to use a brush and paint two layers of Plasti-Dip.

Lee Tippi gel fingertips can be stretched over each finger and thumb tip to provide a soft and tacky surface for an improved grip. Lee Tippi gel finger tips provide a very good grip although they tend to wear out in a few months.

Phase 5: Final Steps and Fitting

Padding and Fitting

It is recommended to not insert the padding on the forearm until you are fitting the recipient. With the recipient present, you may want to adjust the fit of the arm by thermoforming it some more. Usually the heat required to thermoform the arm will not damage the padding, but it may be easier to adjust without the padding. Fitting the arm and training to use the prosthesis should be done by someone with medical experience with prosthetics. The padding was cut to fit the cuff when it was flat, prior to thermoforming. After thermoforming, peel the back off the padding and stick it to the inside of the cuff. The padding for the forearm will have to be cut and fit inside the upper portion of the arm.



Have Fun!