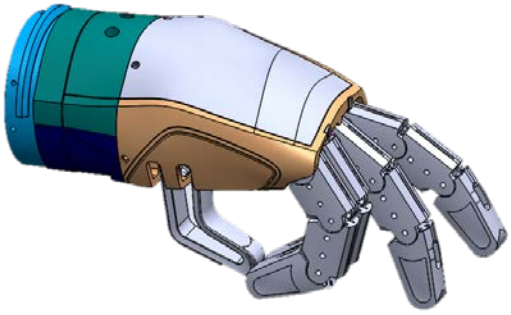
Design for a Low-Cost 3D Printed Electro-Mechanical Prosthetic Hand

Assembly Instructions Manual



Although the images in the following sections are for a previous version, the updated version assembly can be deduced easily from the below instructions.
In addition, you can find the printing orientation recommendation at **appendix A**

Step 1: Finger Module

Tools and materials needed:

- Nippers
- Soldering iron and solder
- Common Filament (Ø1.75 [mm])
- Flat file
- Drill (optional)
- Wire (see Electronic Specifications)
- Nylon thread 0.6[mm]
- Hex headless screw M3x4 or M3x5 x4 for each finger
- Thick filament (Ø2.8 [mm])

Parts needed:

All the quantities are for one finger only, i.e. in total it is necessary four times the amount listed below

Part	Quantity	Printing details	Time/weight	Comment
Proximal Phalange	1	*support* yes *infill* 80% *Layer thickness* 0.15[mm] *quality* fine	**Time** 54.3min **Weight** 4.0g	With support it is possible to obtain a better quality for the gear, but it takes time to clean inside and it is hard to make it even and smooth (fundamental for the functioning of the gears inside). Use "edit support" if possible**.
Middle Phalange	1	*support* yes *infill* 80% *Layer thickness* 0.15[mm] *quality* fine	**Time** 40.7min **Weight** 3.0g	With support it is possible to obtain a better quality for the gear, but it takes time to clean inside and it is hard to make it even and smooth (fundamental for the functioning of the gears inside). Use "edit support" if possible**.
Distal Phalange	1	*support* yes *infill* 80% *Layer thickness* 0.15[mm] *quality* fine	**Time** 46.8min **Weight** 3.9g	With support it is possible to obtain a better quality for the gear, but it takes time to clean and it is hard to make it even and smooth (fundamental for the functioning of the gears inside). Use "edit support" if possible**.
Finger Motor Chassis	1	*support* no** *infill* 80% *Layer thickness* 0.15[mm] *quality* fine	**Time** 1.8h **Weight** 8.2g	Use "edit support" if possible**.

Gear Finger	3	*support* no *infill* 99% *Layer thickness* 0.15[mm] *quality* fine	**Time** 9.2min **Weight** 0.5g
Gear Finger NR	1	*support* no *infill* 99% *Layer thickness* 0.15[mm] *quality* fine	**Time** 7.3min **Weight** 0.3g
Pinion D (or Pinion)***	1	*support* no *infill* 99% *Layer thickness* 0.15[mm] *quality* fine	**Time** 13.8min **Weight** 0.7g
Single Pulley	1	*support* no *infill* 80% *Layer thickness* 0.15[mm] *quality* fine	**Time** 38min **Weight** 2.5g
Pulley Clip	1	*support* no *infill* 99% *Layer thickness* 0.15[mm] *quality* fine	**Time** 8.1min **Weight** 0.4g
Micro Metal DC motor*	1	-	-

*See motor specifications in the electronic file.

**Use edit support in order to leave support only below the outer part of the gear and print without support inside the phalange/motor chassis.

***If the tolerance of the D-shape is too tight and the motor' shaft does not fit, you can use the pinion part with a circular-shape. Notice the high load on the contact surface between the screw and the shaft can damage the part more quickly without the D-shape hole.

Instructions:

Remove support where it is present and clean all parts (with a file if needed), use a drill to open the holes if necessary.

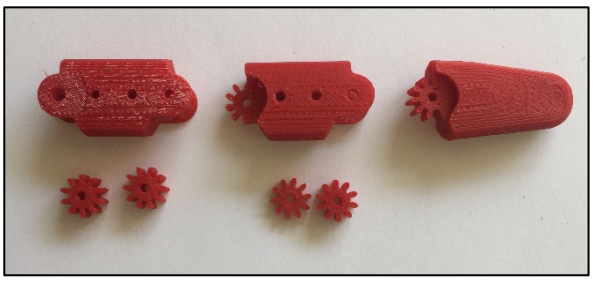


Figure 1

a) Fingers:

1. Insert two Gear A (thick ones) in the Proximal Phalange and put the filament through the holes of the phalange and the gear to hold them in place.

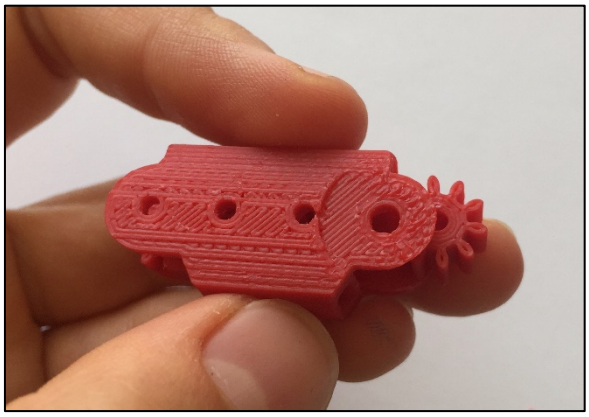


Figure 2

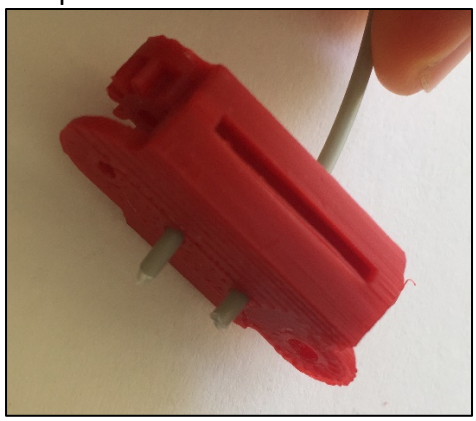


Figure 3

2. Cut the excess filament of filament with the nippers.
3. Insert Gear A (thick) in the Middle Phalange on one side and Gear B (thin) from the other side. Put the filament through the holes of the phalange and the gear to hold them in place and cut the excess filament as before.

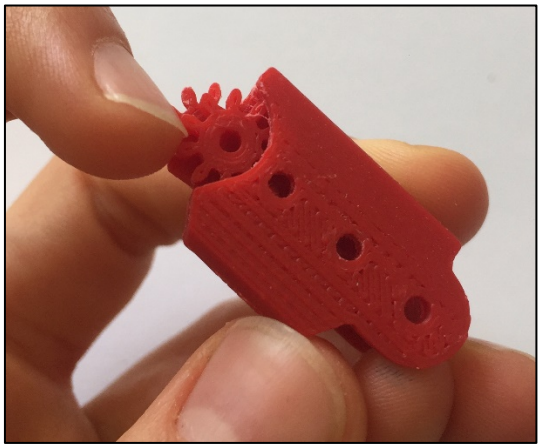


Figure 4

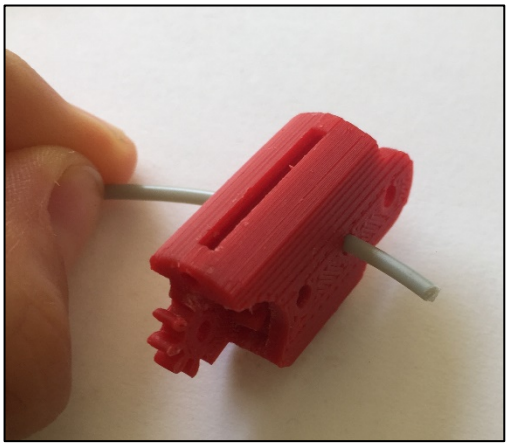


Figure 5

4. Insert a filament to connect the Middle Phalange to Proximal Phalange and Distal Phalange. Cut the excess filament with the nippers.

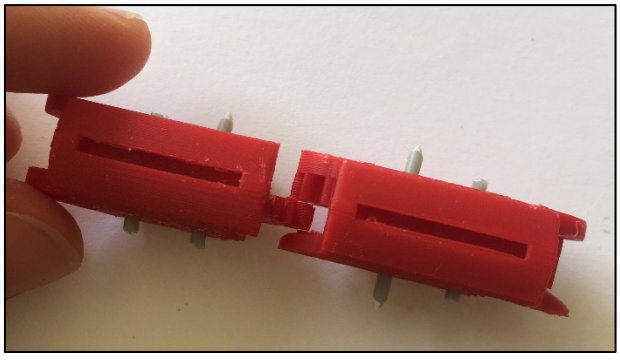


Figure 6

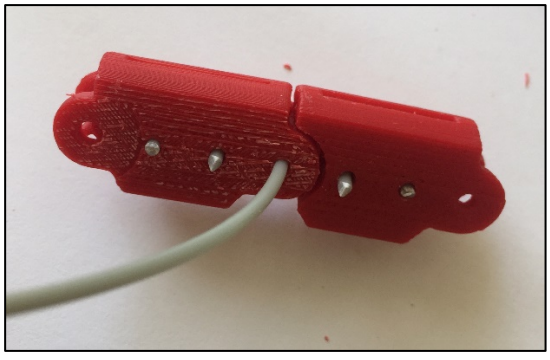


Figure 7

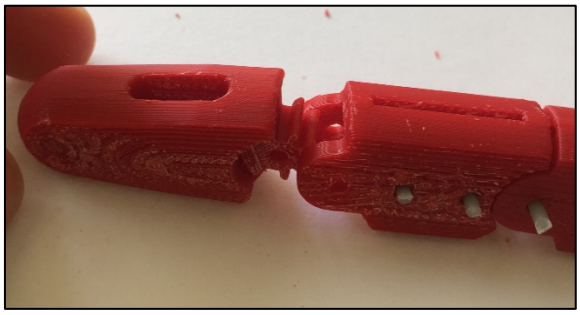


Figure 8

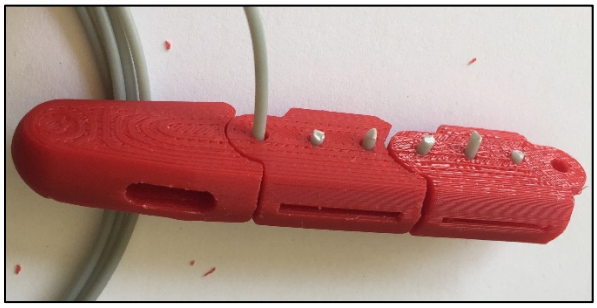


Figure 9

5. Check that there is a smooth fit between all the gears and joints. Check manually bending the finger a few times: hold at the proximal phalange and give it a quick short whipping movement - all the finger joints should be bent.

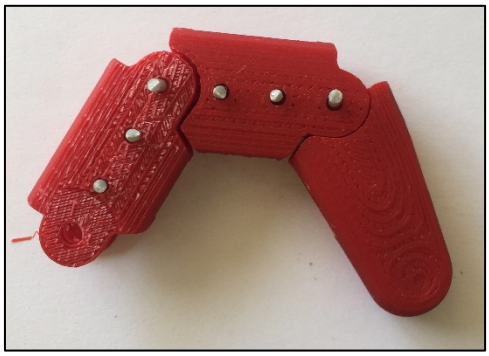


Figure 10

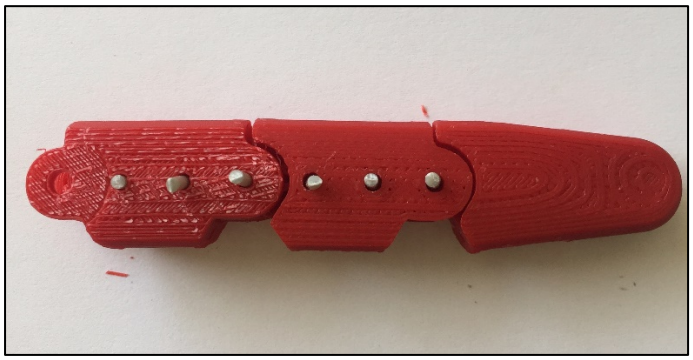


Figure 11

6. Use the solder iron to melt the cut edges of the filaments to fix them in place. If necessary, file the surface to make it smoother.

Figure 12

b) Motor chassis:

1. Insert a long nylon thread through the hole of the pulley form outside towards the center.

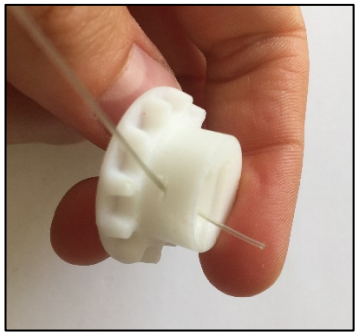


Figure 13

2. Make a knot with the part of thread that is in the center and put the thread through the hole again and pull it outward.

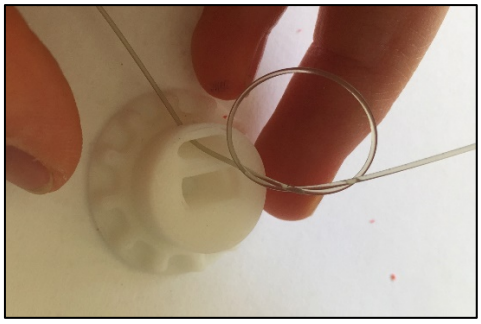


Figure 14

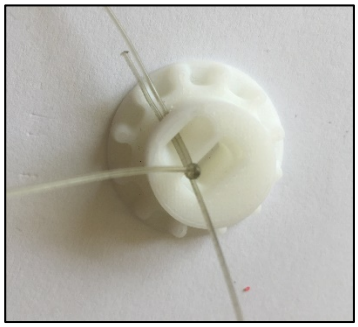


Figure 15

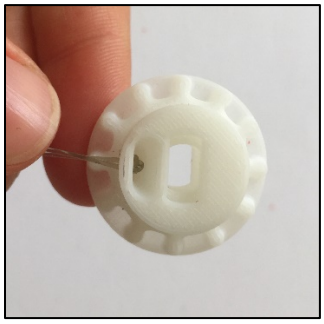


Figure 16

3. Solder the back of the motor to two wires (it is possible to put the wires through the small holes to improve the connection).

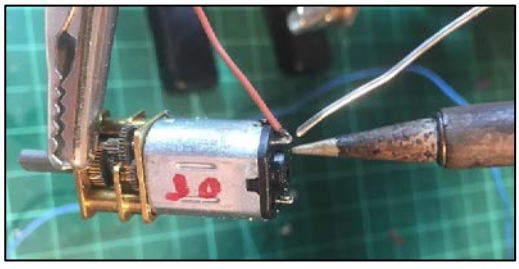


Figure 17

4. Insert the Hex headless screw M3x4 in the pinion (screw until the end to create the thread in the pinion and then unscrew it to remove. Make sure the pinion enters perfectly perpendicular to the shaft. (see Appendix B – Pinion Screw guide)

5. Fit the pinion on the motor's shaft and insert the hex headless screw as tight as possible.

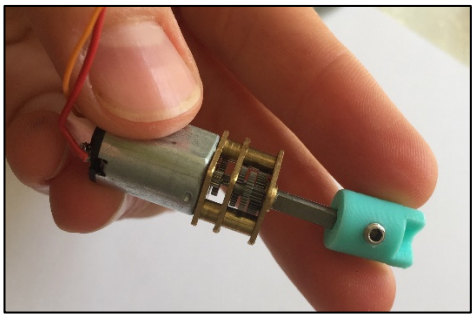


Figure 18

6. Locate the motor with the pinion and place the pulley in the motor chassis, arrange the position of the pinion such that it fits in the pulley.

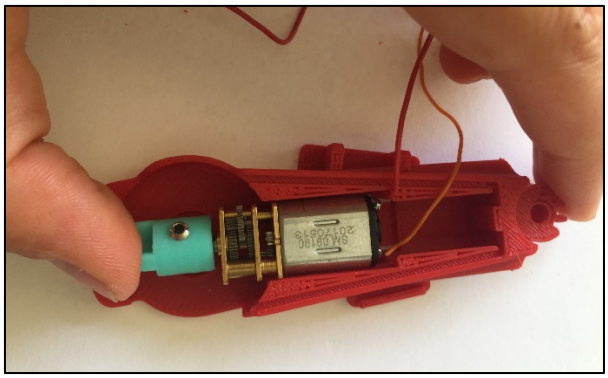


Figure 19

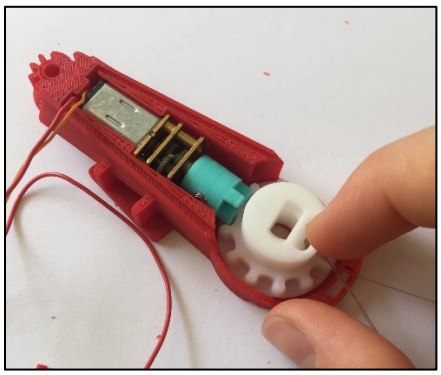


Figure 20

7. Be careful when placing the pulley, to adjust hole with the nylon thread such that it does not interfere with the pinion during the full movement of the fingers.

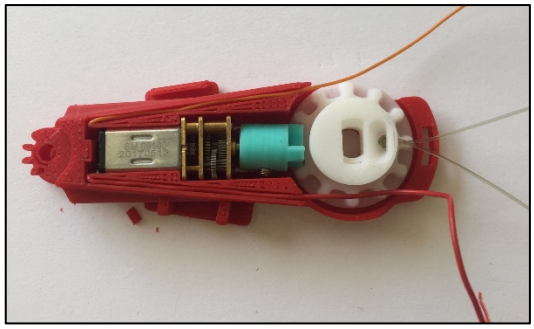


Figure 21

8. Insert the Pulley clip from the outside of the Motor chassis to hold the pulley in place.

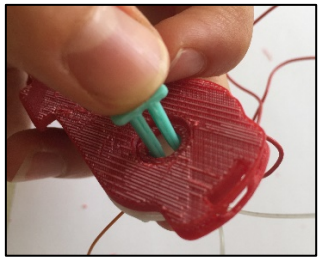


Figure 22

9. Put the wires through the tunnels of the motor chassis in order to go towards the back of the hand and insert them in the hole at its end.

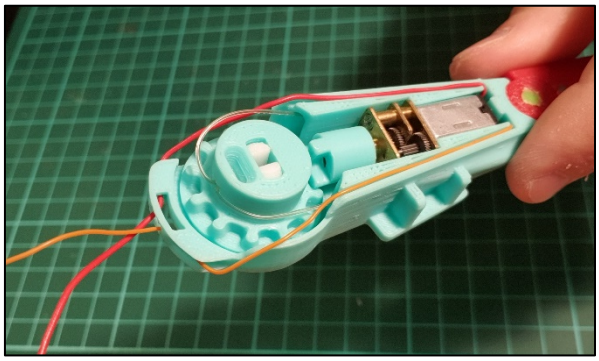


Figure 23

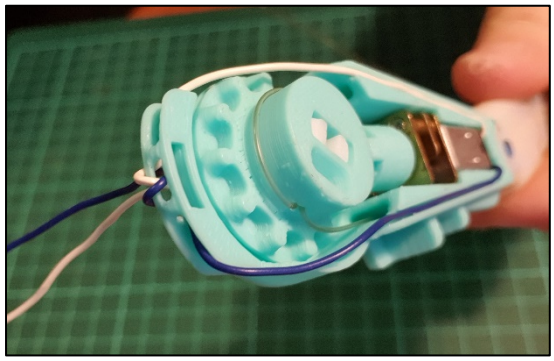


Figure 24

c) Assemble whole Finger Module together:

1. Pass the nylon thread around the pulley and then inside the tunnels of the Motor chassis.

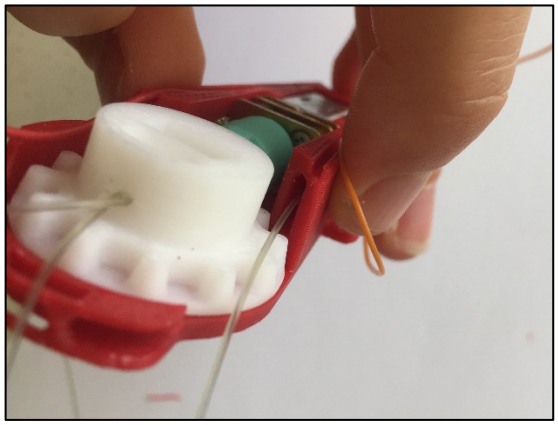


Figure 25

2. Insert the thick filament (Ø2.8 [mm]) in the bigger hole of the Proximal Phalange and of the Motor Chassis to connect them and cut the edges with the nippers and use the solder iron to melt the edge and make it smooth.

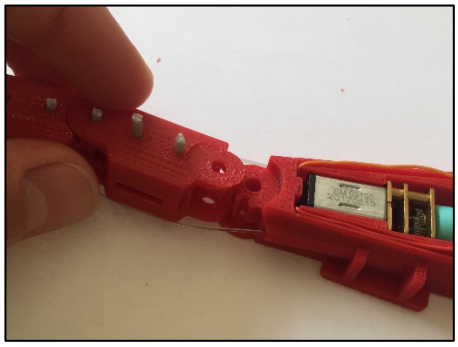


Figure 26

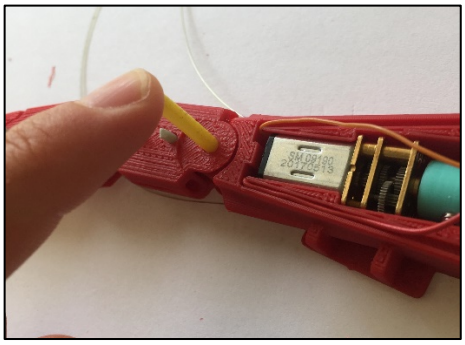


Figure 27

Figure 28

3. Put the nylon thread through the upper and lower tunnel holes of the Phalanges.

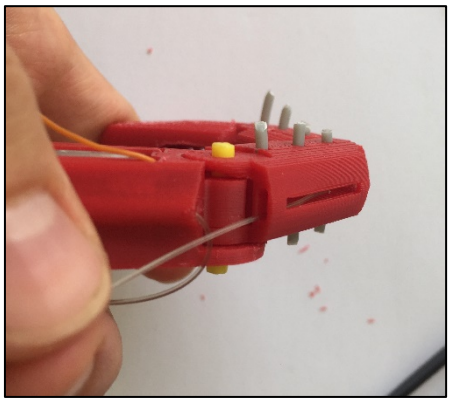


Figure 29

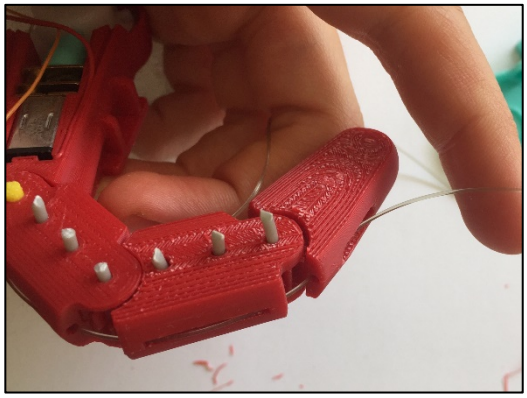


Figure 30

4. Pull the thread in and out the holes at the end of the Distal Phalange to make it as stretched as possible.

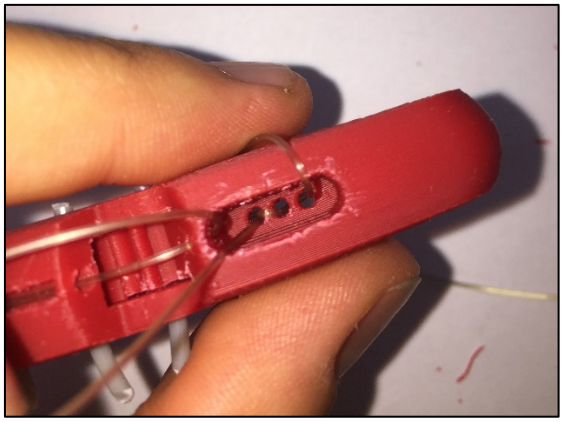


Figure 31

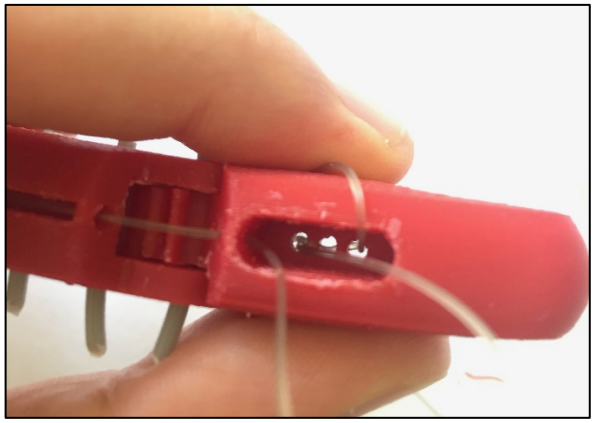
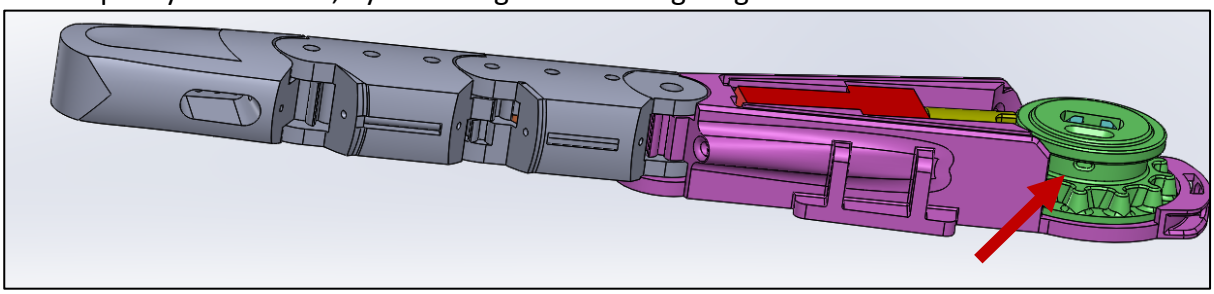


Figure 32

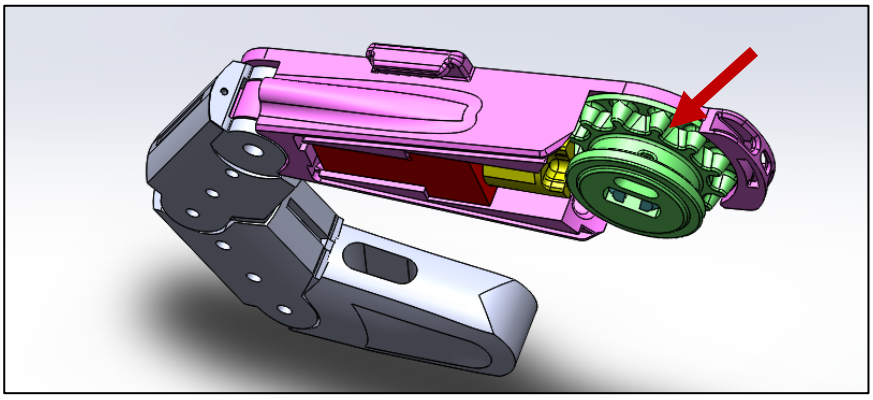
5. Make several knots to fix the thread as tight as possible to prevent it from loosening during the movement.

[**Recommendation**:

- Connect the finger module to the Hand Circuit or other DC power supply at the motor rating. Open and close the finger. Make sure there is no excess thread if there is – tied it again.
- Check out the pulley orientation, if the hole of the thread is too close to the pinion adjust the pulley orientation, by removing and inserting it again:

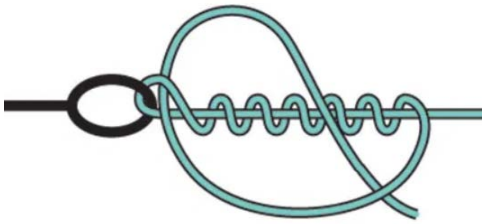


Pulley's hole orientation at open state



Pulley's hole orientation at closed state

- Use a clinch knot:



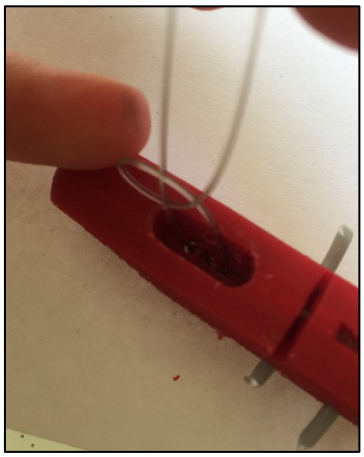


Figure 33

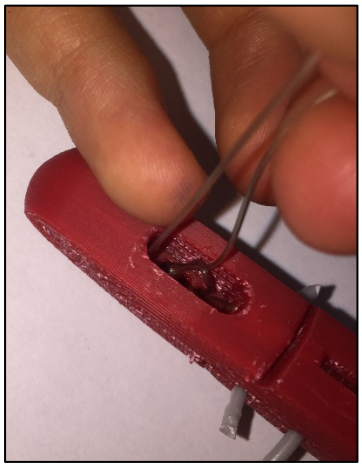


Figure 34

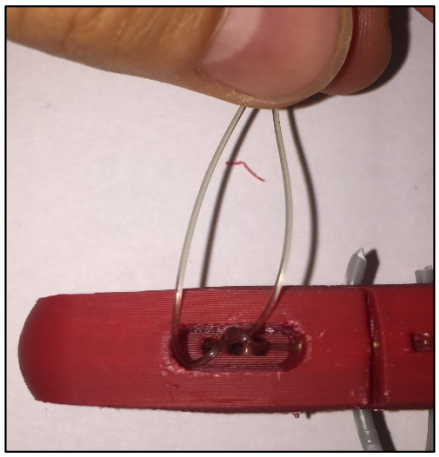


Figure 35

Repeat the same procedure for all of the four fingers.

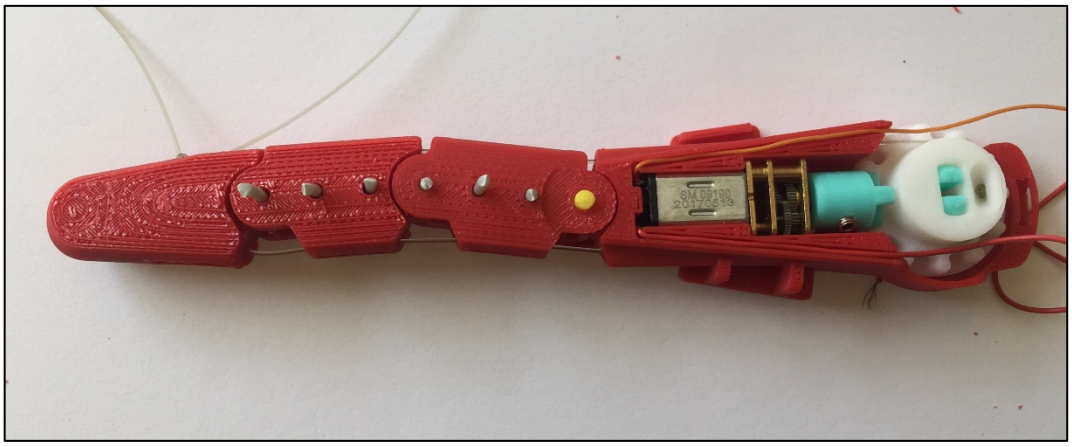


Figure 36

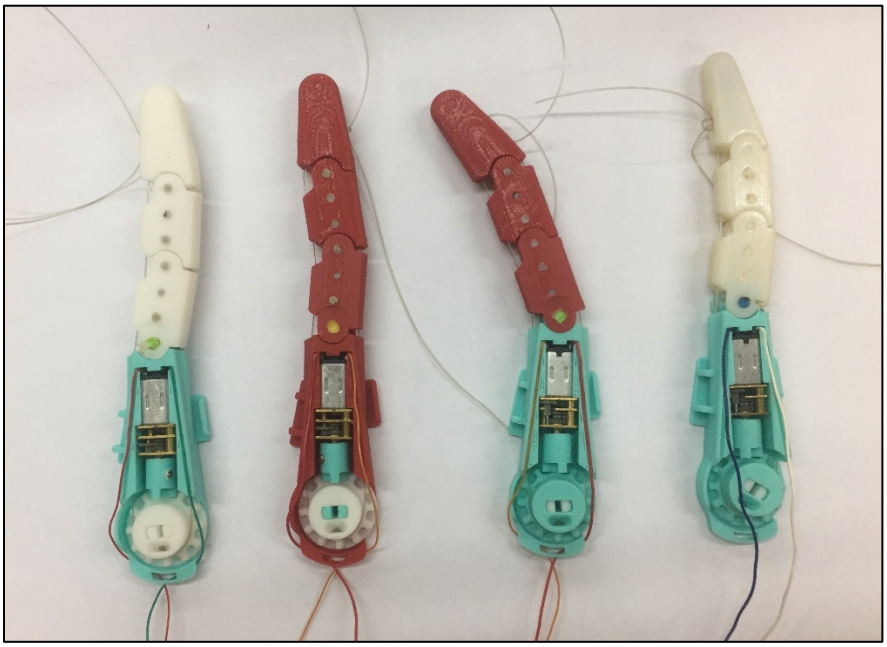


Figure 37

Step 2: Palm

Tools and materials needed:

- 1 Rod for thumb Ø4x30 [mm] (length 29-34[mm] are also optional)
- 2 Magnet N52 Ø6x4
- 1 Machined screw M2x8 [mm] (length 8-12[mm] are also optional) for finger module holder

Parts needed:

Part	Quantity	Printing details	Time/weight	Comments
Palm Cover	1	*support* yes *infill* 80% *Layer thickness* 0.20[mm] *quality* normal	**Time** 1.8h **Weight** 14.3g	Use "edit support" if possible to delete the support from the nut's holes.
Palm	1	*support* yes *infill* 80% *Layer thickness* 0.15[mm] *quality* fine	**Time** 6.0h **Weight** 41.6g	
Finger module holder	1	*support* yes *infill* 80% *Layer thickness* 0.20[mm] *quality* normal	**Time** 41.7min **Weight** 4.4g	
Thumb	1	*support* no *infill* 80% *Layer thickness* 0.20[mm] *quality* normal	**Time** 42.8min **Weight** 6.2g	
Finger Module	4	-	-	

Instructions:

First of all, remove support where it is present and clean all parts (with a file if needed), use a drill to open the holes if necessary.

1. Insert one magnet in the thumb and one in the palm. Make sure it is flush against the surface and the two magnets repel each other when the thumb is at 45 degree.

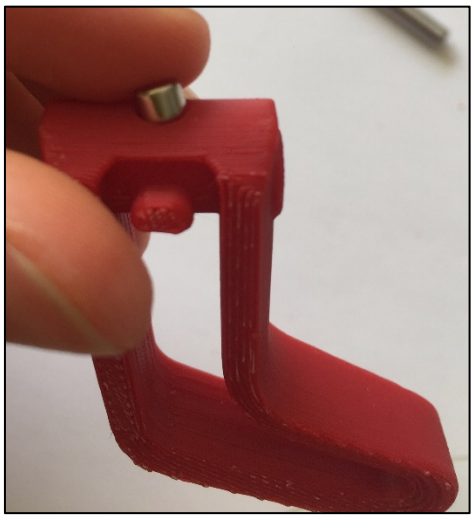


Figure 38

Figure 39

2. Put the thumb in place and insert the rod to connect it to the palm.

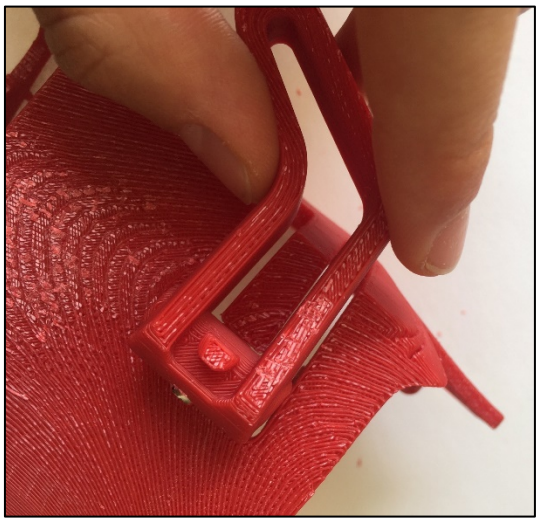


Figure 40

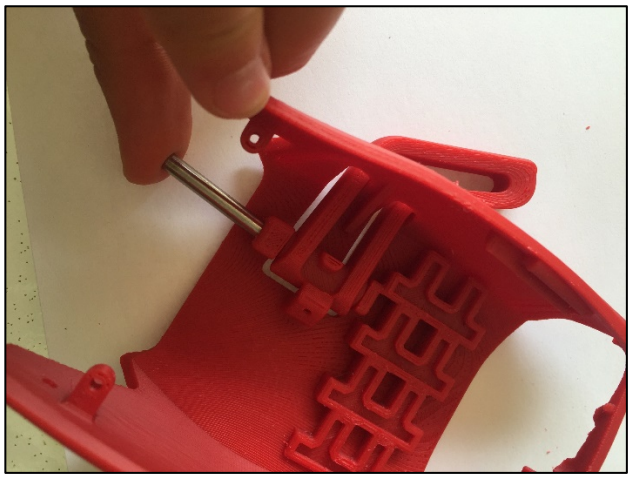


Figure 41

3. Insert the nut in the upper hole of the palm.

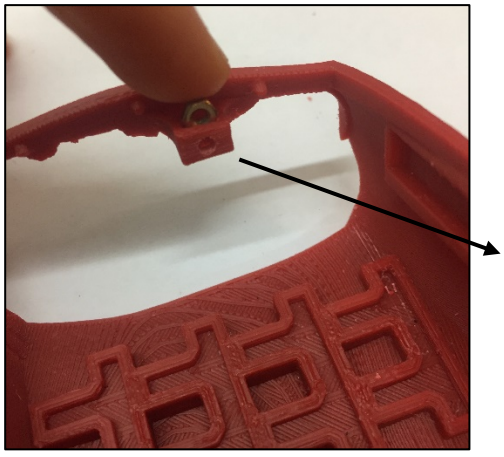
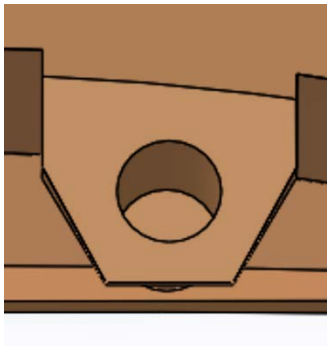


Figure 42



Pay attention to the orientation of the nut

4. Place each Motor Chassis in its location on the palm, starting from the outer finger (the furthest one from the thumb). Insert the fingers when they are fully extended.

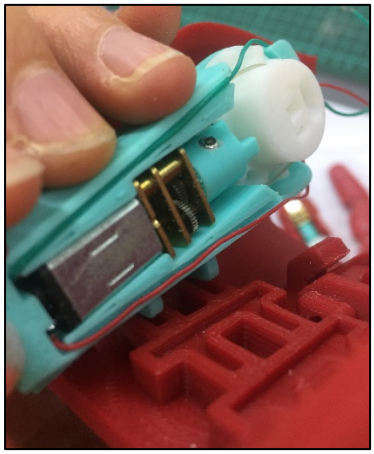


Figure 43

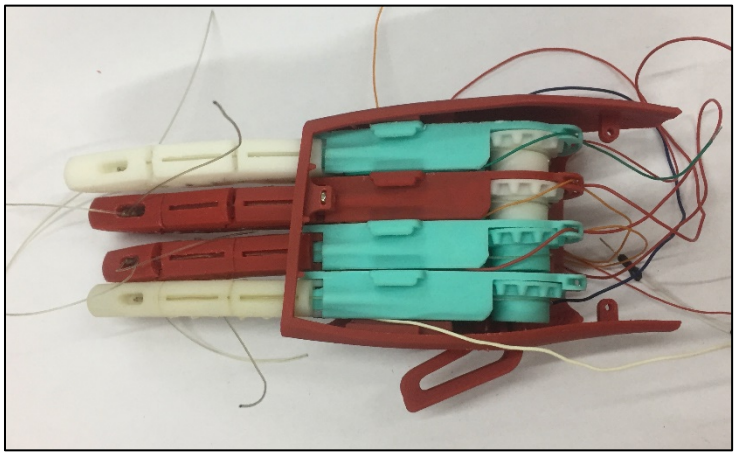


Figure 44

Remark: make sure that the proximal phalange and the motor chassis have been filed accurately to remove all the support so they do not touch the palm's arch above.

5. Still holding the finger modules in position, introduce the Finger Module Holder through the slide rails of the palm and insert each Motor Chassis in the right place.

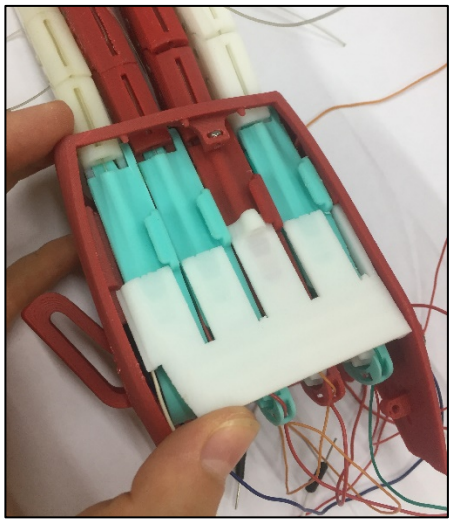


Figure 45

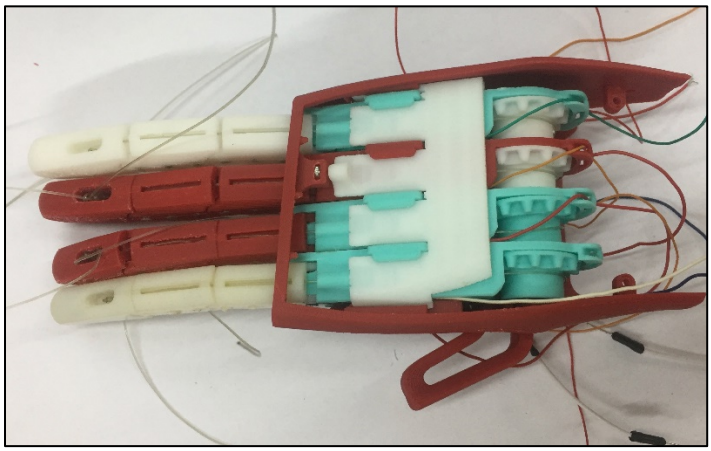


Figure 46

6. Screw the Finger Module Holder with the palm with one M2x8.

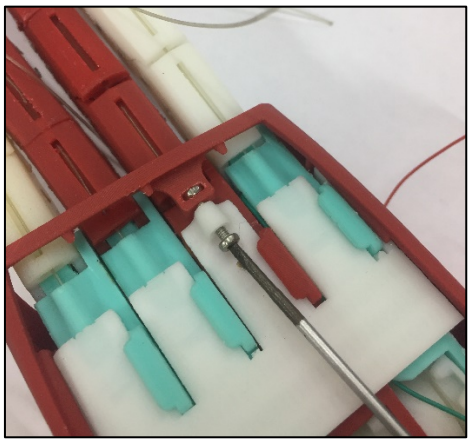


Figure 47

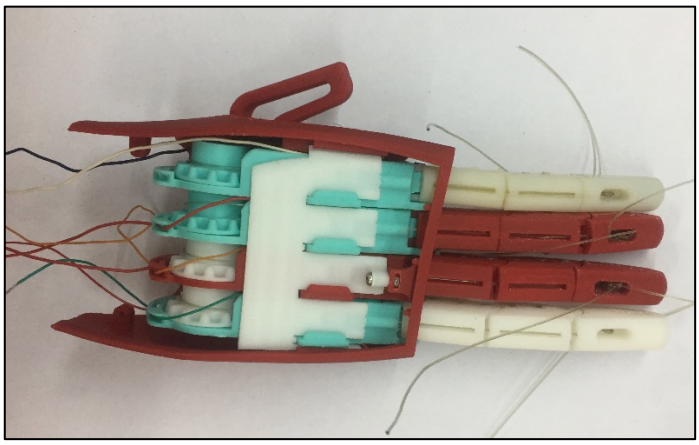


Figure 48

7. Slide the Palm Cover onto the Palm and fit the snap connectors.

Step 3: Wrist

Tools and materials needed:

- 6 Screws M2x8
- 2 Machine screws and nuts M3x40 [mm]
- Thick filament (Ø2.8 [mm])
- 1 Hex headless screw M3x4 or M3x5
- Silicon tube (outer diameter of the tube: 8 [mm])

Parts needed:

Part	Quantity	Printing details		Time/weight	
Rotator Housing	1	*support*	yes		
		infill	99%	**Time**	4.2h
		Layer thickness	0.15[mm]	**Weight**	25.3g
		quality	fine		
Rotator Upper Adaptor	1	*support*	yes		
		infill	80%	**Time**	2.5h
		Layer thickness	0.20[mm]	**Weight**	27.1g
		quality	normal		
Rotator Lower Adaptor	1	*support*	yes		
		infill	80%	**Time**	2.2h
		Layer thickness	0.20[mm]	**Weight**	23.2g
		quality	normal		

Wrist Cover	1	*support*	no	**Time** 35.2min **Weight** 6.1g
		infill	65%	
		Layer thickness	0.20[mm]	
		quality	normal	
Rotator Base	1	*support*	yes	**Time** 1.1h **Weight** 9.7g
		infill	80%	
		Layer thickness	0.20[mm]	
		quality	normal	
Planetary Gear	3	*support*	no	**Time** 16.3min **Weight** 0.8g
		infill	99%	
		Layer thickness	0.15[mm]	
		quality	fine	
Wrist Pinion D** (or Wrist Pinion)	1	*support*	no	**Time** 18.3min **Weight** 1.0g
		infill	99%	
		Layer thickness	0.15[mm]	
		quality	fine	
Micro Metal DC motor*	1	-		-

*See motor specifications in the electronic file.

**If the tolerance of the D-shape is too tight and the motor' shaft does not fit, you can use the pinion part with a circular-shape. Notice the high load on the contact surface between the screw and the shaft can damage the part more quickly without the D-shape hole.

Instructions:

a) Wrist Motor Housing:

1. Solder the wires to the motor.

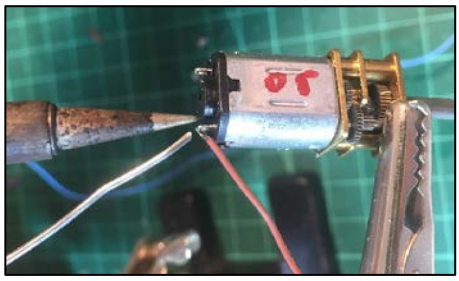


Figure 52

2. Insert the motor into the rotor base.

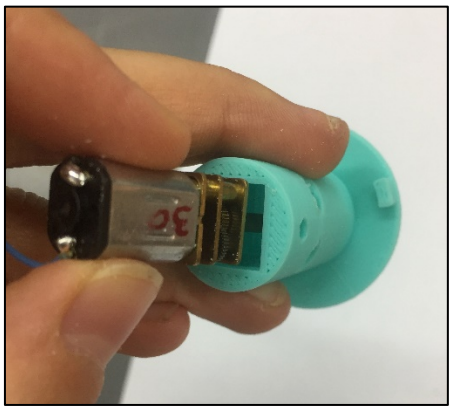


Figure 53

3. Stop the motor using a thick filament and cut its edges.

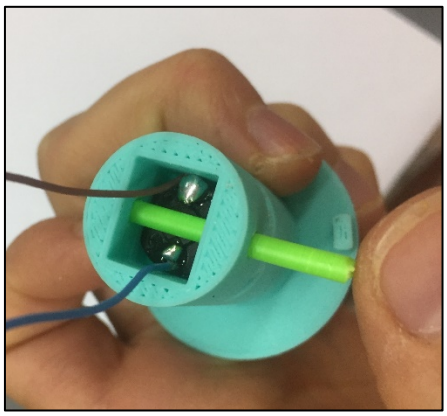


Figure 54

4. Screw the Hex headless screws M3x4 (screw until the end to create the thread in the pinion and then unscrew it to remove it), insert the pinion on the motor shaft and screw again the hex headless screw very tight.

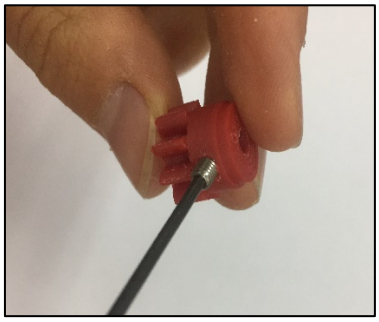


Figure 55

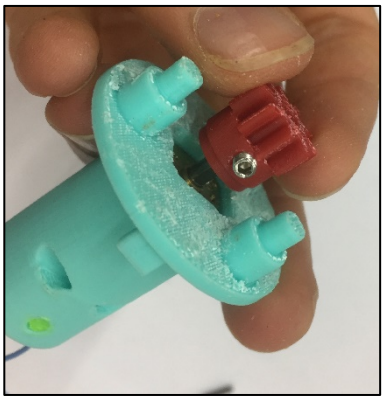


Figure 56

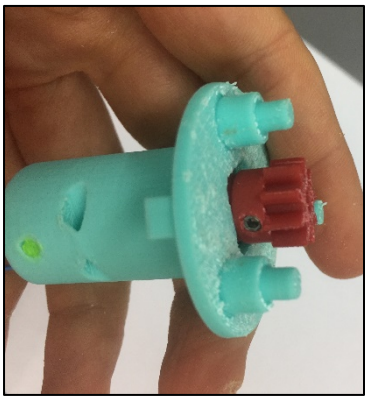


Figure 57

Remark: If using a flat cable, or the if wires of the wrist are connected to the ones of the fingers, first insert the Rotator Housing into the cables and then place the motor into the Rotor Base.

5. Insert the Rotor Base into the Rotator Housing. Notice that the stopper of the Rotator Base is within the tunnel of the Rotator Housing.

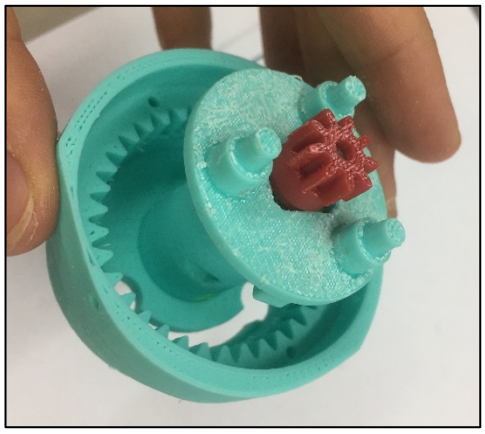


Figure 58

6. Place the three Planetary Gears around the pinion.

Figure 59

Figure 60

7. Place the Wrist Cover on top and stop it with two screws M2x8.

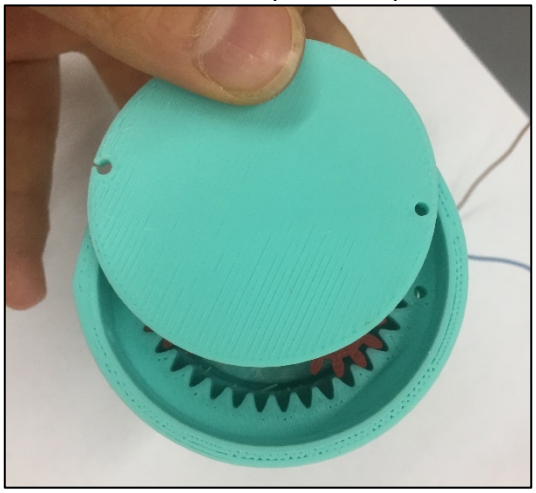


Figure 61

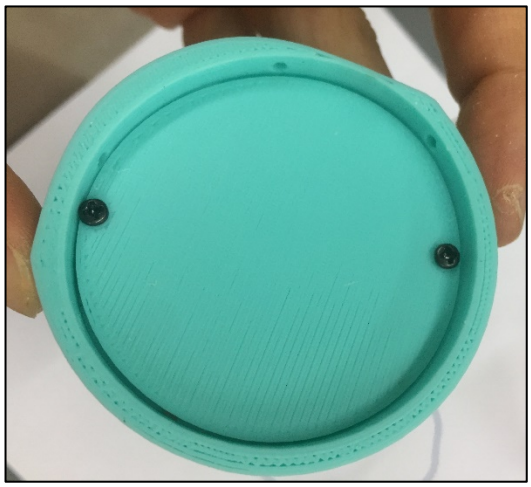


Figure 62

8. Add two silicon circles in the back-holes of the Rotor Housing.

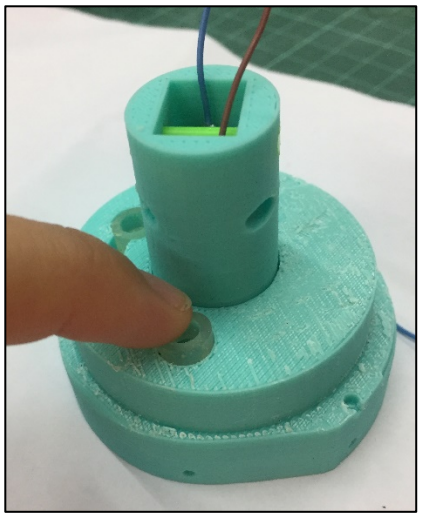


Figure 63

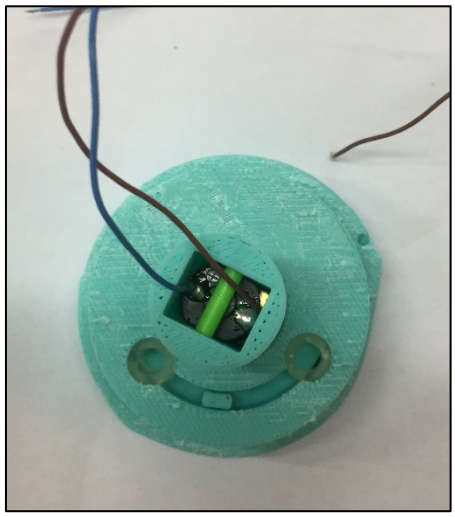


Figure 64

9. Locate the Upper Rotator Adaptor around the Rotor Housing and Base. Make sure that the Upper Adaptor is placed such that it corresponds to the top part of the Rotor Housing.

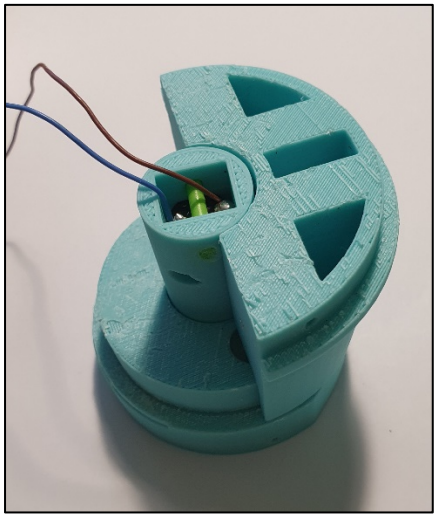


Figure 65

10. Insert the two machine screws in the Upper Adaptor and in the Base and add the nuts. Finally insert them into the Lower Adaptor.

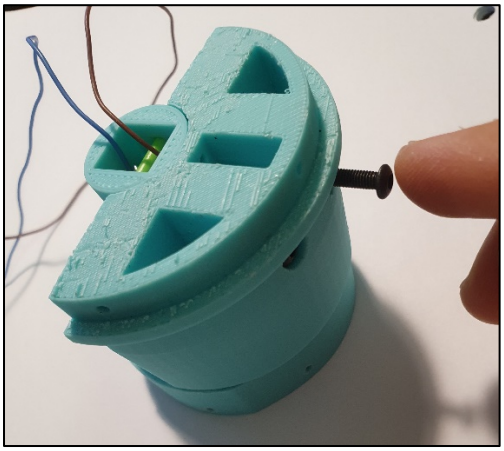


Figure 66

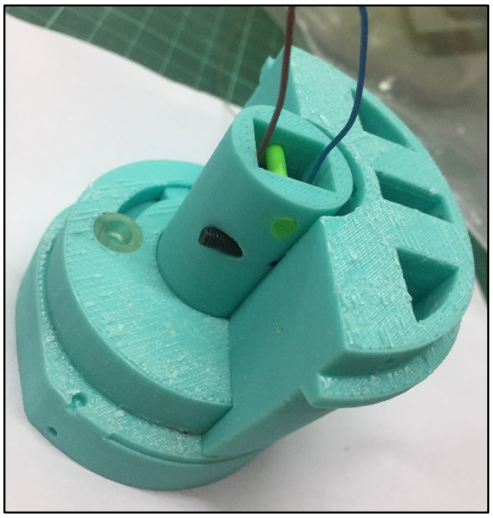


Figure 67

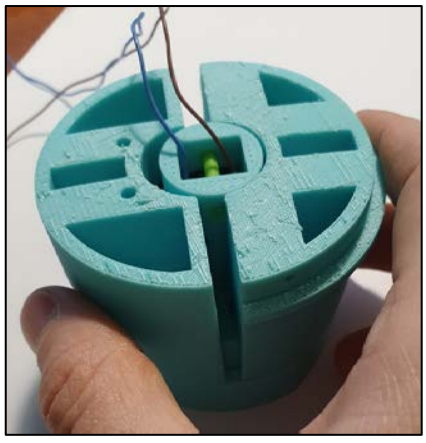


Figure 68

11. Insert 2 nuts and tight the machine screws.

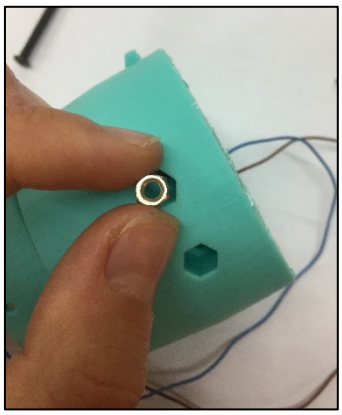


Figure 69

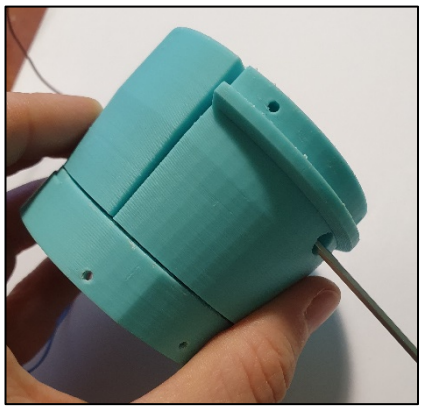


Figure 70

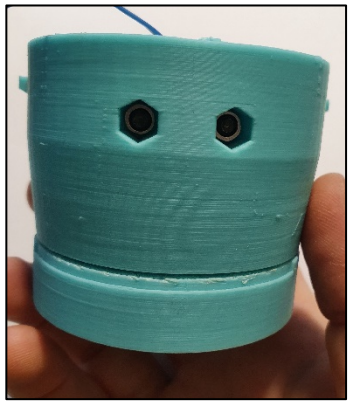


Figure 71

b) Wrist Motor and Palm:

1. Insert the wrist Rotator Housing between the palm and the palm's cover.

2. Screw M2x8 in each of the 4 holes to attach the palm to the wrist.

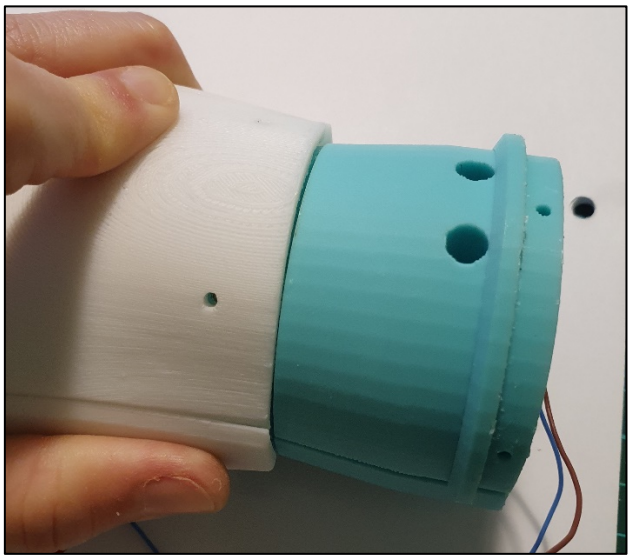


Figure 72

Figure 73

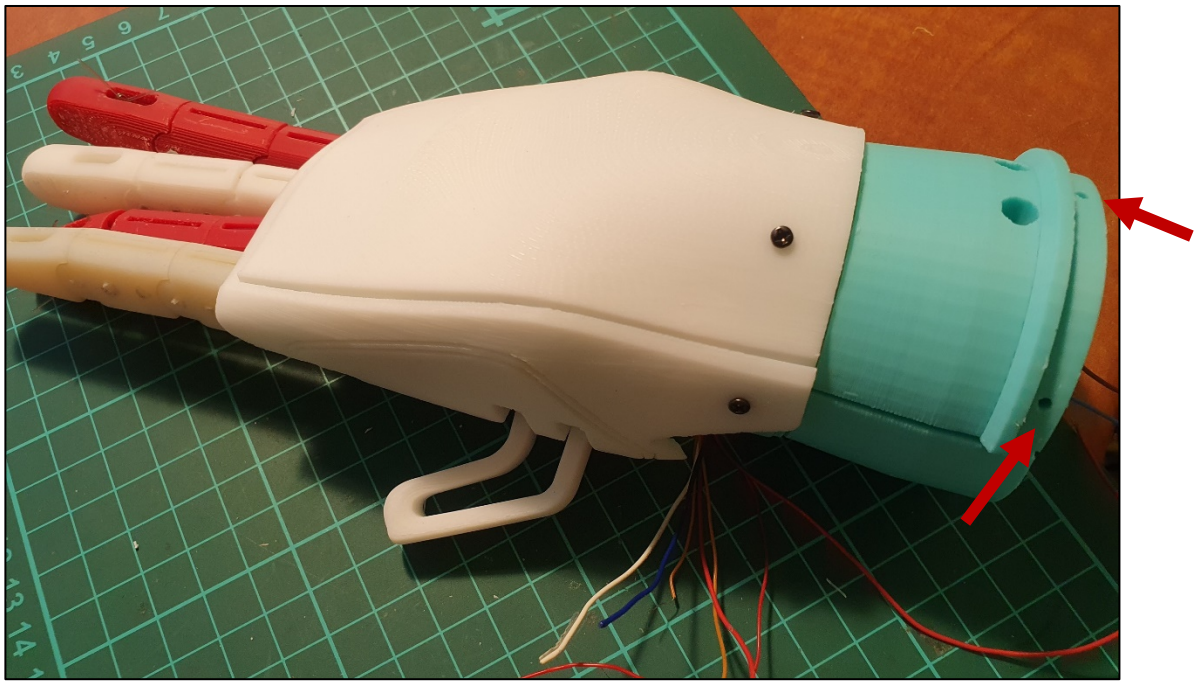


Figure 74

The hand socket can be connected to the assembled palm by the three M2 screw holes marked at the above figure.

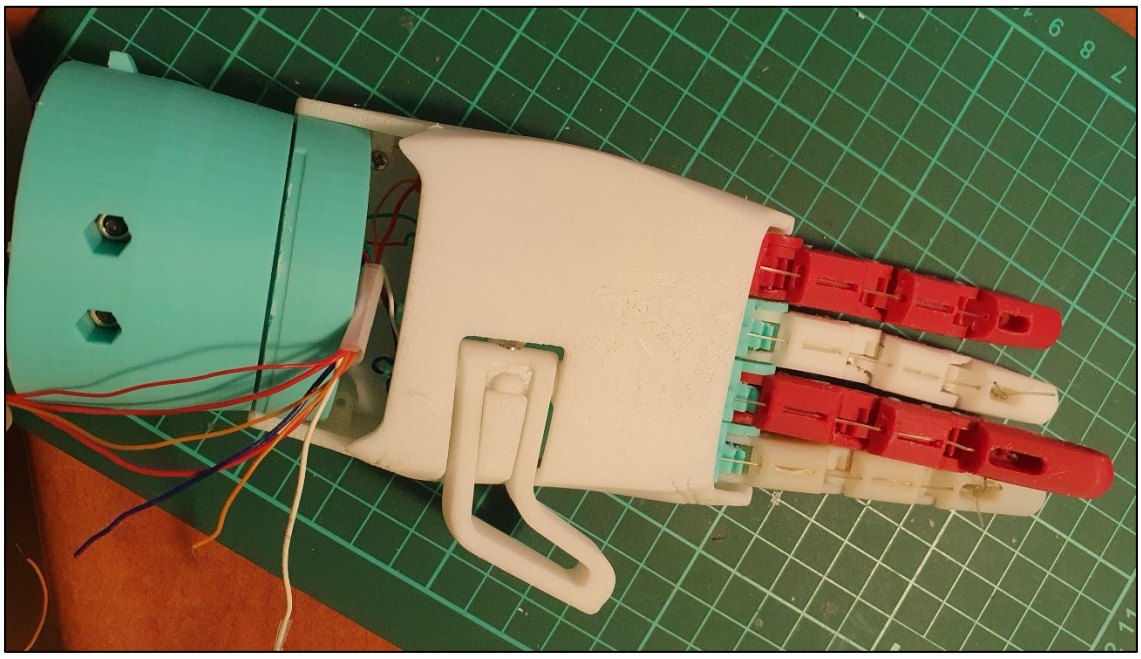
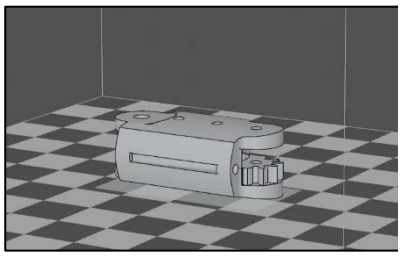


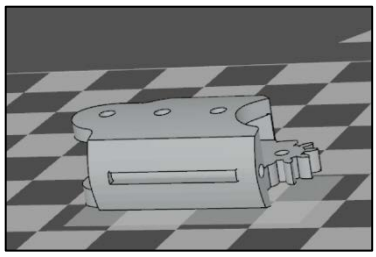
Figure 75

Appendix A: Printing Orientation

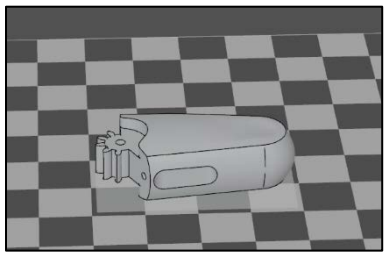
Finger Module:



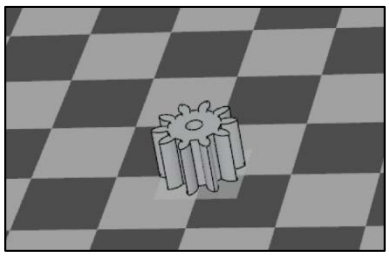
Proximal phalange



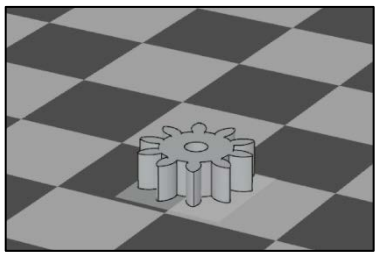
Middle Phalange



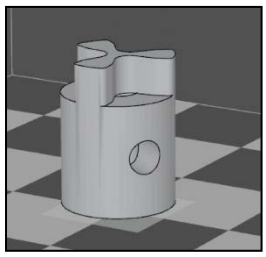
Distal Phalange



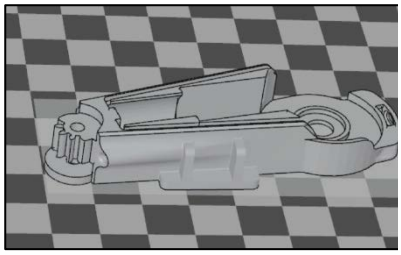
Gear A



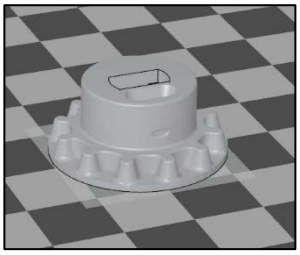
Gear B



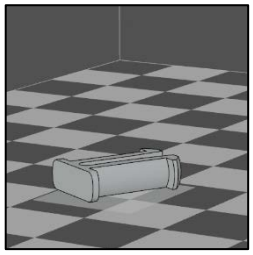
Pinion



Finger Motor Chassis

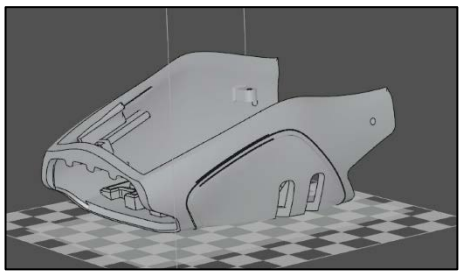


Single Pulley

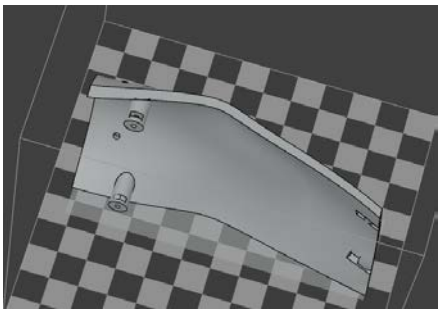


Pulley Clip

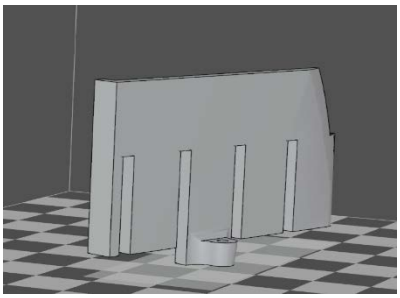
Palm:



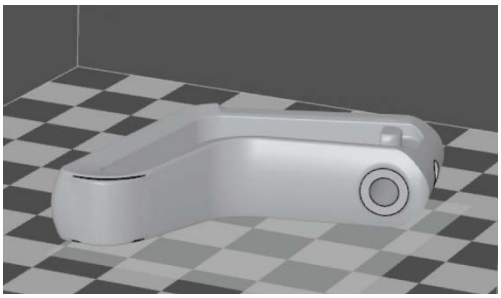
Palm



Palm Top Cover

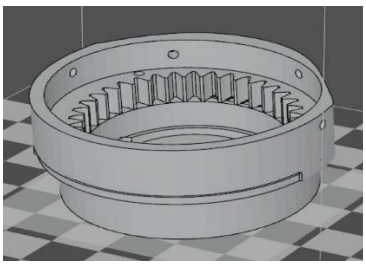


Finger Module Holder

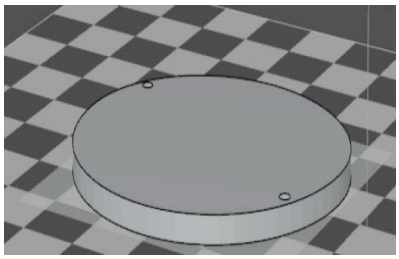


Thumb

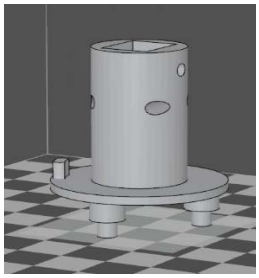
Wrist:



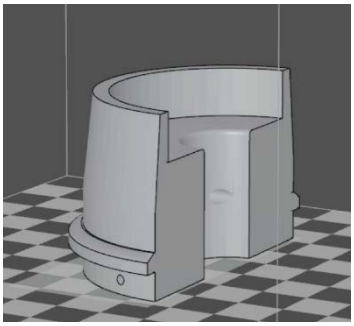
Rotator Housing



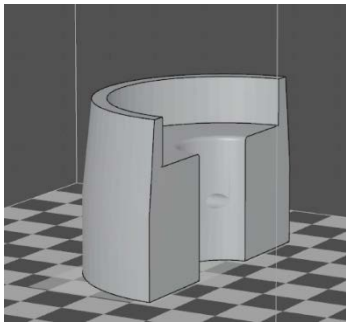
Gear Cover



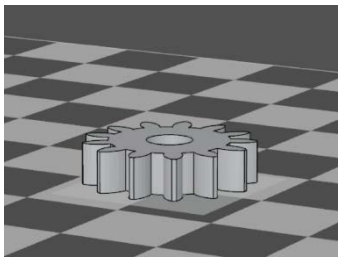
Rotator Base



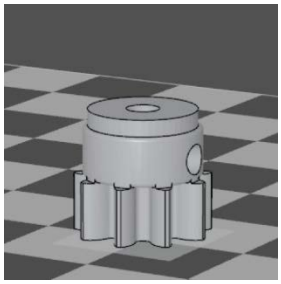
Rotator Upper Adaptor



Rotator Lower Adaptor



Planetary Gear



Pinion (Z9 M1.25)

Appendix B: Pinion Screw Guide

The screw in the pinion is the more sensitive component of the design, since it receives all the stress from the motor's shaft.
Therefore, it is important that the screw is inserted perfectly perpendicular to the hole. In order to do so, use the pinion screw guide as follows:

1. Locate the screw guide on a piece of wood and stop it with two screws to make sure it doesn't move.
2. Place the V-shaped part of the pinion on the designated slot of the guide.
3. Insert a screwdriver into the tunnel and insert the hex headless screw M3x4

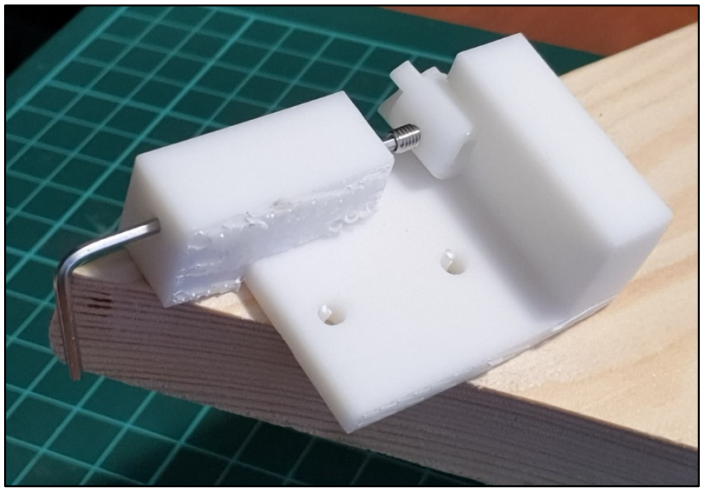


Figure 76

- Printing details:

support	yes*
infill	65%
Layer thickness	0.2 [mm]
quality	normal

* No support in the "V-shape" and inside the hole (use "edit support")

- Printing orientation: