SHAPE & ROLL:
COSMETIC SHELL

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BACKGROUND

Jaipur is one of the most well-known organizations for prosthetic devices developing countries. The Jaipur Foot is an easy to manufacture prosthetic foot that gives patients the ability to do many things that they could do with an actual foot (running, climbing, etc.). The Jaipur Foot is comprised of simple materials and can be colored to match the complexion of patients. It also allows for dorsiflexion like a biological foot.

Although the Jaipur Foot is indeed a remarkable device, it is not without its faults. The Jaipur Foot lacks toe support, resulting in a shortened stride while walking. Also, the use of different materials in the Jaipur Foot causes deterioration when they rub against each other. Additionally, the Jaipur Foot is quite heavy; its current design weighs roughly 800 g.

Photo of Shape and Roll Foot from Prosthetics Research Laboratory and Rehabilitation Engineering Research Program at Northwestern University Feinberg School of Medicine has been removed due to copyright restrictions.

Figure 1 - Shape & Roll Foot

To address the problems of the Jaipur Foot, the Shape & Roll foot (Figure 1) was created by a team of researchers at Northwestern University in 2004. It was created for use in low-income countries, as an alternative to the prosthetic feet commonly distributed. The S&R closely resembles the roll-over contour of a normal stride. The S&R is far lighter than the Jaipur Foot (made from polyethylene) and is low in cost to make.

Attempts to make a cover for the S&R have been less than successful. Although the S&R can operate without a cover, a cover is desired so that the device is well-received by patients living in developing countries. Previous attempts of Shape & Roll feet with cosmetic covers have still been heavy. One cosmetic shell design was tested by researchers at Cornell University, but it eventually wore out in a couple of months.

GOALS

Our main objective of this project was to create a cosmetic cover to coat the Shape&Roll prosthetic foot. This coating needs to be durable, and yet it also needs to be reasonably cheap. In order for this project to work, we need to find a way to bond the Shape&Roll to the cosmetic cover in a secure fashion to reduce the rate of deterioration and wear. We also need to find a material which is lightweight and flexible enough to avoid impeding the contour motion of the keel, and yet be durable enough to withstand continual use in undesirable environments.

Our second objective was to find a way to create a mechanical bond between the keel of the S&R and the cosmetic shell. Having a bond will reduce the amount of wear the Shape & Roll places on the cosmetic shell.

CONCERNS

- Using epoxy to bond S&R to sole – due to the difference in material (polyethylene vs. rubber), not sure if the epoxy will be able to bond the S&R to the keel.
- Using cosmetic shell – the pieces inside the shell are likely to rub against each other and cause wear. One proposed method to prevent this is thermoforming the inner pieces to make one unit. Heating plastic in a thermoform machine and vacuuming it over the pieces inside the foot should prevent shifting while walking and water damage. In addition, wrapping the thermoformed piece with thin rubber would further prevent damage and wear. Test trials would have to be done to see the effectiveness of this method. Exact methods to cover the hole of the shell have yet to be determined.

MATERIALS

NAME	SUPPLIER	PRICE	QUANTITY	PRODUCT NO.
Mold release	Anywhere	~$10	1 can	---
Foam Polyurethane	McMasterr-Carr	$27.86/sheet	1	8997K531
Neoprene rubber block	McMasterr-Carr	$4.63/block	1	1457T22
Super Glue	Loctite	$5.49	1	---
Tread rubber	McMasterr-Carr	$13.00/sheet	1 sheet	3727T242
Teflon PTFE sheets	McMasterr-Carr	$36.21 for 2’ sheet	1 sheet	8545K32
Epoxy	Anywhere	~$5	1 canister	---
Super Sculpey FIRM Gray polymer clay	Sculpey III	~$13/lb.	2 lbs	---
Putty polyurethane rubber	McMaster-Carr	$88.88	4 lbs.	8644K15
Liquid fiberglass resin	McMasterr-Carr	$31.79	1 kit	75325A1
Neoprene/Cork gasket sheet	McMaster-Carr	$29.80/sheet	1	9607K65

1. Polymer clay – the clay will be used to cast a mold of the foot. Polymer clay is relatively inexpensive and takes impression well.
2. Mold release - necessary to remove foot from clay without distorting the impression

3. Foam rubber – lightweight rubber that is good for shock absorption. Will be used as filler for spaces in the foot and for making the toes and filling in gaps.
4. Neoprene rubber – used for filler pieces
5. Tread rubber – sole of the foot due to roughness
6. Teflon PTFE – used to prevent seepage into cuts of the S&R
7. Epoxy - used as adhesive between S&R and sole
8. Putty polyurethane rubber – material used for cosmetic shell from the negative mold of the foot. When allowed to cure overnight, the shell can be used and filled with the S&R and filler components.
9. Liquid fiberglass resin – used to strengthen urethane. Polyurethane is not rigid when cured, so a layer of fiberglass resin will reinforce the rubber and add to its rigidity, as well as increase strength and durability.

PROCEDURE

Inner Core (Figure 2)

1. Use polymer clay to mold left and right sides of sample Jaipur Foot. Spray foot with mold release before applying clay to leave lasting impression when foot is removed.
2. 3D print a replica of each clay mold. Combine the replicas to have a negative mold of the foot.
3. Use the dimensions of the negative mold to cut out sole of the foot in the tread rubber.
4. Score the base of the S&R and adhere it to the tread rubber sole using epoxy. Set aside to dry.
5. Cut neoprene block into 2” pieces, resulting in 3 smaller blocks. Cut each smaller block into 0.125” thick sheets.
6. Use 24 2” x 0.125” neoprene rubber sheets to fill in the gaps on the sides of the foot. Use super glue to hold pieces together.
7. Use neoprene/cork gasket to fill in the toes.

Figure 2 - Inner Core

Outer Core

1. 3D print a replica of the same Jaipur Foot used for the inner core.
2. Mix putty polyurethane. Use gloves and wear clothing that covers skin.

3. Apply putty polyurethane onto replicated foot. Use mixing stick to smooth out lumps and air bubbles. Apply until desired thickness (0.25”).
4. Allow to cure (24 hours).

RESULTS

A polyurethane cosmetic shell for the S&R cover was successfully created (Figures 3 and 4). After curing, the shell was removed from the replicated foot. The inner core was place inside the foot and any remaining gaps were filled with polyurethane foam to reduce the amount of weight added to the foot.

Figure 3 - Cosmetic Shell (Side View)

Figure 4 - Cosmetic Shell

Testing of the foot was not possible. Due to the inability to order the polyurethane putty early. By the time the putty arrived, the time allotted for completion of the project had passed. Given the amount of material used, the cost of the first prototype is estimated around $35.

CHALLENGES

During this project, we ran into a variety of challenges and problems. Our original design included an ankle mechanism to allow extreme dorsiflexion, but this design was later dropped. Due to that, we needed to re-design the shape of the foot. We also ran into problems finding the polyurethane rubber to use as the cosmetic cover. We attempted to find non-solid forms (either liquid or putty), but found this to be difficult since most suppliers were out of stock and not going to restock for months. This restricted our work progress to only the inner core.

RECOMMENDATIONS

In future years for when this project is worked on, there are many things we suggest being attempted. First is to test the prototype we have created to see if it functions. The shape of the Shape & Roll is also very low to the ground, and should be modified to more closely resemble the shape of an actual foot. Also, when creating the cosmetic cover, we recommend attempting vulcanization. This will act to solidify and waterproof the entire foot, however we were unable to test this in class.

REFERENCES

1. The Shape & Roll Prosthetic Foot (Part I): Design and Development of Appropriate Technology for Low-Income Countries

2. The Shape & Roll Prosthetic (Part II): Field Testing in El Salvador

3. Jaipur Foot Manual

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