CUSTOM SILICONE SOCKETS FOR MYOELECTRIC PROSTHESES
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History of Transradial Interface Design

Sockets for myoelectric prostheses have not changed significantly over the past 30 years. The Otto Bock Muenster style socket (MyoBock) was developed in the late 1960’s by Fruzinsky based on the original Muenster design of Hepp and Kuhn\(^3\). This socket was designed to compliment the newly available myoelectric components of the time that allowed for self-contained, self-suspending transradial prostheses. The Northwestern University socket was first introduced by Billock\(^1\) in 1972. Elements of these two socket designs represent the critical design elements of state-of-the-art transradial interface designs even today. Flexible thermoplastics have helped to improve the dynamics of these socket systems, however, the socket design did not change significantly as a result of the more flexible materials. It should be noted that these flexible materials are non-elastic.

Influence of Silicone Sockets and High Definition Silicone Hand Prostheses

Over the past ten years roll-on silicone sockets gained favor in fitting some patients with myoelectric sockets.\(^2,4\) One benefit of 3S socket technology is that a true suction suspension can easily be achieved. Suction suspension is particularly advantageous for fitting the long transradial limb because forearm rotation can be preserved due to the low and flexible trimlines that silicone suction allows, obviating the need for supracondylar trimlines which block all physiological forearm rotation. With the introduction of snap electrodes, electrode contact with the skin was ensured due to the elastic properties of the liner to which the snaps are attached. Two drawbacks of myoelectric fittings using roll-on designs are the need for some type of locking mechanism, and the nuisance of having to attach each of the electrodes separately as part of the donning process.

Concurrently there has been a proliferation of manufacturers of high definition silicone hands that offer excellent appearance and are also suspended by suction. These high definition silicone hands, when fitted to long transradial residual limbs, provided a suction silicone socket as a structural component of the hand prosthesis. Because the silicone socket is a structural component of the prosthesis it does not require a means of locking it to the prosthesis as does the roll-on-silicone socket design. These silicone hand prostheses are donned by lubricating the skin and then sliding into the prosthesis while working any air out by pressing the flexible walls in such a way to direct the air to the proximal trimline.

Custom Silicone Technology

With the introduction and commercial availability of custom silicone sockets (available through Otto Bock Custom Silicone Services, Toronto), the materials and
fabrication methods are now available to produce sockets that combine many of the desirable features of the above outlined silicone designs. Material thickness, stiffness, and color can be precisely controlled. It is also possible to incorporate hardware such as electrode mounts, screw attachments, zippers, and wrist mounts into the silicone during fabrication. To date patients with transcarpal, wrist disarticulation, long transradial, elbow disarticulation, and long transhumeral amputees have been fitted by Uellendahl, however, this paper will focus on below-elbow applications.

CONSTRUCTION METHODS

Total Silicone Myoelectric Prosthesis

Features:
- very flexible, easy for donning
- all-in-one (electrodes, wires, battery, charge plug are all encased)
- 2 wrist plates and 3 spacers that create a negative space (used to hold battery, 4-in-1 connector, charge plug) were used.
- Liner was made with most proximal wrist plate embedded within the silicone

Technical Issues:
- Inner hand was hard to attach
- Very time consuming fabrication
- Although the all-in-one silicone myoelectric prosthesis had great results, it was the most time consuming and expensive method of fabrication.
Silicone and Plastic Lamination Combinations (Hybrid):

1st Hybrid Design
- liner was made with embedded electrodes
- stockinette was embedded to attach initial lamination
- within the initial lamination, electrode wire channels were formed
- wax was used to build up a space for battery
- 2nd lamination w/ 4 star washers over distal end for attachment of wrist plate
- wax was melted out through a large hole (large enough for battery to fit through)
- electrode wires fed through initial lamination

Technical problems:
- very difficult to slide battery in due to the inflexibility of the resin
- due to repeated heating to try to get the battery in, the top layer of lamination was not flat and very messy.
- Very difficult to put in the screws to attach to the hand through the wrist plate
- Screws used to attach wrist plate to lamination had to be very small and located where access was difficult

2nd Hybrid Design
- internal battery, enclosed charge plug with zipper opening
- embedded electrodes
- dummies were made for battery and charge plug (charge plug placed proximally)
- electrode wire channels were incorporated in the silicone liner with exit hole at the distal end of liner.
- 1st lamination embedded in silicone
- 4 star washers were embedded in the lamination for attachment of the outer shell
- wrist unit was attached via 2nd lamination

Fabrication drawbacks:
- hard to get silicone liner off the cast
- hard to remove the plaster dummy (battery)

3rd Hybrid Design
- 1st lamination is attached to the silicone
- removable battery and wrist are mounted to second lamination
- this process is the same as a regular myo and definitely is the least labor intensive with equal cosmesis to the other methods described.
Donning and Doffing

In order to provide a durable and simple suction system, valves have not been installed in the distal sockets. A simple and effective method of releasing air upon insertion of the limb has been developed where a thick nylon cord is draped down the socket wall and allowed to curl around the distal end of the socket. This creates an air channel allowing for evacuation of air from the socket as the limb displaces the air. Once the limb is fully inserted the cord is easily pulled out and an air-tight suction suspension achieved. To remove the prosthesis many of the patients have been able to slide a finger into the socket and then force the air pocket created by the finger to the distal end thereby breaking the suction seal. Some newer amputees who have more sensitive limbs are unable to tolerate the pulling associated with this first method and have preferred to slide a thin corset stay into the arm thereby creating an air channel to the end of the socket allowing easy removal.

Results

To date, all of the fittings using custom silicone socket technology have been successful. There have been no rejections, no skin issues, and only minor adjustments required. The socket adjustments have been required due to shrinkage of the residual limb. In the cases where the residual limb reduced in size, the patients complained of discomfort and/or pain, red to purple skin color upon removal of the prosthesis and swelling. These problems would be expected in a total suction socket whenever residual limb volume reduces. The problem has been corrected by adding a TEC spot (a urethane disc produced by Otto Bock) in the area of swelling.

The longest follow-up is two years. Material durability has proven to be acceptable for all patients fitted, with no significant damage reported.

Battery systems that can be placed inside of the hand geometry are needed to optimize the appearance of these prostheses. Also a charging plug that can be placed at the proximal trim line that would allow charging without rolling down the glove or cutting a hole in it would be very beneficial.
Figure captions:

Figure 1 – use of internal battery positioned between two wrist plates using the transcarpal hand achieves appropriate length for this wrist disarticulation amputee. (This method was recommended by Liberating Technologies, Holliston, Maine).

Figure 2 - the completed all silicone prosthesis.

Figure 3 - a hybrid silicone/plastic laminate construction using internal battery with transcarpal hand.

Figure 4 shows the completed prosthesis on this young man with congenital absence of his hand.

Figure 5 - a hybrid constructions with internal battery. A zipper allows access to the pocket housing the battery. Note the proximal position of the charge plug for easy access without rolling down the glove.

Figure 6 - the unrestricted elbow range of motion using custom silicone designs.

Figure 7 - a hybrid construction for wrist disarticulation with removable battery.

Figure 8 - a finished silicone socket with laminated struts providing hand stability. The patient has a wrist disarticulation amputation. The hand is a Sensor Speed with wrist disarticulation wrist and removable LiIon battery. All components are provided by Otto Bock.

Figure 9 - a clear silicone test socket fitting and electrode site selection. Here the electrodes are being calibrated for proper control of an Otto Bock DMC transcarpal hand using the MyoBoy tester.

Figure 10 - the excellent cosmetic result that can be obtained using custom silicone techniques. In this case acrylic nails have been attached to the PVC production glove to improve appearance.

Reference: