

CASTING TO MAKE A FRAME SOCKET FOR USE WITH FSR PRESSURE PADS

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ABSTRACT

A technique is described to cast for a frame socket to be used with Force Sensing Resistors (FSR's). The technique produces the largest number of control sites and ensures that at each site all forces on the FSRs are normal not shear. Key elements of the technique are prior identification of the control sites, casting the 'immobile frame' first and the use of multiple splints to locate up to five sites with respect to the immobile frame.

BACKGROUND

A number of frame sockets have been analyzed after failures of the Touch Pad™ Force Sensing Resistors (FSRs). FSR's are particularly useful because they produce a signal proportional to the application of pressure. A prime cause of failure is the application of shear forces to the pads, but moisture can also be a problem. During analysis it became evident that better methods were needed for taking the cast so that it would be easy to find the optimal location and orientation of the pads to prevent shear. Key elements of this casting technique are prior identification of pad sites, casting the 'immobile' frame first, and separate castings for forward, back and up. To understand the technique one must first review what a frame socket needs to do.

Design Elements: Frame for a Touch-Pad-Controlled Prosthesis

- 1. Suspension.** The frame must support the weight of the prosthesis comfortably all day. This means distributing weight over the largest area possible without jeopardizing other design goals.
- 2. Torque control.** The prosthetic arm is a large weight, two or more inches (50 or more mm) from the nearest part of the body. This represents a considerable torque to be counter-balanced by the frame and its straps. In addition, the prosthesis will generate considerable additional torque when the arm is set into a position of shoulder flexion or abduction or the elbow is flexed. To counterbalance torque, both force and moment arm are required. Area far from the arm attachment point creates the greatest moment. For comfort, the force should be spread over a wide area.
- 3. Ventilation.** Loss of a limb is loss of a body part with a high surface to volume ratio. This considerably reduces the amputees ability to dissipate heat. A frame should cover as little total area as possible while still providing area selectively for torque control and suspension.
- 4. Provision of many control sites.** For a myoelectric fitting only two sites are normally needed. For a Touch-Pad-controlled prosthesis, the more sites the easier the operation. The goal for the shoulder disarticulation prosthesis is five sites and for the short humeral neck prosthesis six. However, even three good sites will permit excellent control. To activate a number of push sites that "feel" like they are located in distinctly different positions in space requires that the tip of the shoulder be free to move. The frame design must not restrict this motion.
- 5. Stable mount for prosthesis.** Normally a shoulder joint will be mounted to a flat area about 2.5" (65mm) in diameter. Struts must join the rest of the frame with sufficient strength and stiffness so this mount is stable. The forces here can be surprisingly large. For a large adult, the frame must support a load of 50 ft-lb (68 N-m) in extension and 25 ft-lb (34 N-m) in adduction. The load with just a prosthetic hand and an elbow joint is more modest, about 1.5 ft-lb (2.1 N-m).

1. **Straight up.** Simply elevate the shoulder about 1/2" (12mm).
2. **Forward and up.** Move forward about 1/4" (6mm) and up 1/2" (12mm). Force is at about 45°.
3. **Straight forward.** Move straight forward about 3/4" (20mm).
4. **Backward and up.** Move up 1/4" (6mm) and back 1/2" (12mm).
5. **Straight backward.** Move backward about 3/4" (20mm).

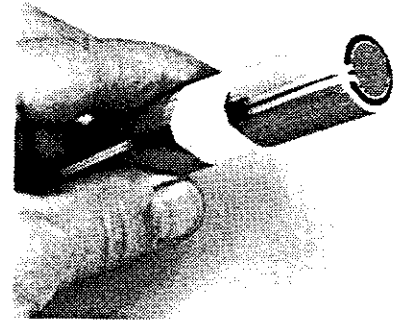


Figure 1. Touch Pad on the end of a wooden dowel

Table 1. Five Good Shoulder Control Sites

TESTING AND EVALUATION

No one would take a cast for a myoelectric prosthesis without first determining optimal sites for the electrodes. It is just as important to determine both the location and orientation of push sites ahead of time. This test will require an FSR Touch Pad mounted on a hard, flat disk about the size of a quarter dollar. The disk in turn should be on the end of a handle. A simple mount can be made by cutting a short length off a discarded broom handle. Mount the pad on the end with the connector along the handle as shown in Figure 1. The output of the Touch Pad is ideally led to Liberty's Two-Bar-Display Tester or another meter. Alternatively one can use a second pad and a prosthetic hand for testing especially if the hand has variable speed response. The tester uses the second pad to close the hand after the subject opens it. If the disk is at the end of a cylinder, you can easily hold it against the amputee while feeling the degree of push and noting the orientation of the pad. For each site you will need to note how far the pad needs to push into soft tissue before it meets bone or cartilage resistant enough to generate a good signal. Also note the orientation of the handle holding the pad. Mark the optimal location so it will show on the cast.

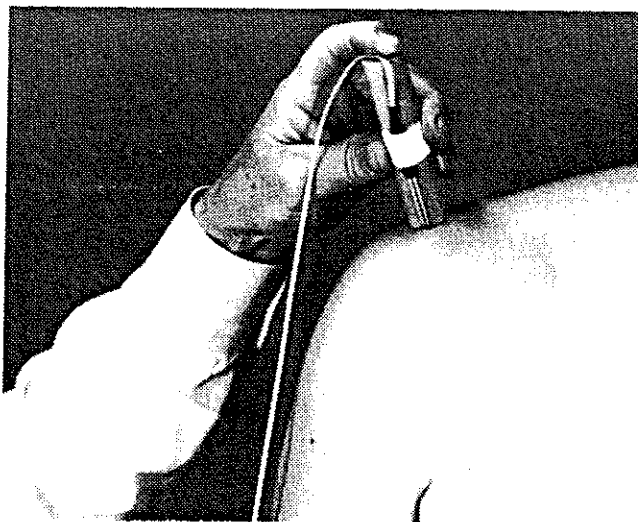


Figure 2. The subject is pushing 'straight up', but note the correct angle.

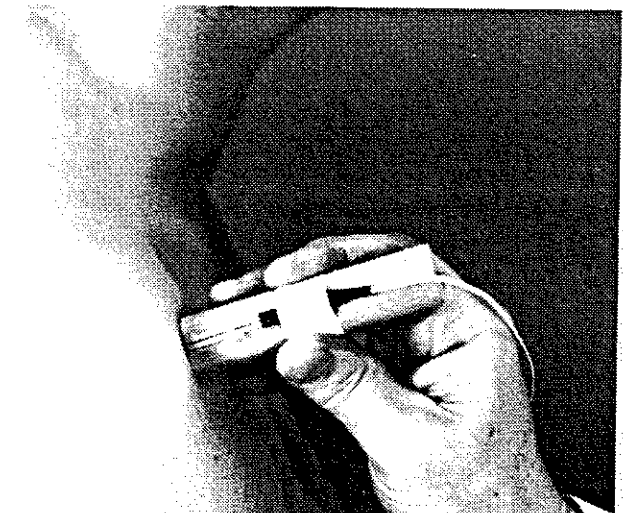


Figure 2. The subject is pushing 'straight forward.'

Establishing the Location of Five Good Sites

Table 1 lists the five good sites that are most likely to be found. Unless great care is taken they are not independent. For instance, it is quite easy to have *straight up* activate *forward and up* or *backward and up*.

- 1. Straight up.** For the straight up site simply have the subject push straight up against the test pad. Move the pad about to find the site requiring the least force. Mark this site on the skin and record how deeply the test pad needed to penetrate and the best orientation of the pad. See what happens to the best orientation as the shoulder is raised. You need to know this because the up site is activated by raising the tip of the shoulder about 1/2 inch (12 mm). Note how far the subject can raise the shoulder and also a somewhat smaller convenient lift.
- 2. The forward sites.** The goal is to obtain two independent sites. One will use motion straight forward and the other will require the subject to raise the shoulder before moving forward. And the two sites must not interfere. Start by pushing with the touch pad probe while the subject pushes straight forward. See how far forward the subject can move and still activate this location. Now have the subject's shoulder in a raised position. Again look for a forward push site, but make the site as high as possible. This site can be activated by pressure straight forward or up or anywhere in between; however, it should require little or no forward *motion*. Keep in mind that use of this site should not activate the straight up site or the forward site. Try to find a location that orients the probe about 45° forward of vertical.
- 3. The rearward sites.** Establish these sites the same way as the forward sites. You are probably going to find that the lateral end of the spine of the scapula will be the activator of choice.
- 4. Comments on the sites.** There will be a lot of difference between a skinny subject and one with a lot of padding. Think about how the site responds to pressure. With a boney site, the pad may push in only a millimeter or two, while a fleshy site may result in a lot of penetration. Mark each site and note how much penetration is required. You will need this to take the cast. Also note the orientation of the pad.

Identifying the Immobile Anatomy

Move your own shoulder up and down, forward and backward. The acromion will experience the most excursion with respect to the rest of the body and the attachment of the clavicle to the sternum the least. Points intermediate along the clavicle will move more or less according to their position. Thus, to establish a nonmoving frame, the suspension should be close to the neck. All parts of the rib cage where you can feel the ribs will also be relatively immobile. For taking the cast this immobile area must be identified. All areas where the boney structure lies near the surface also need identification especially the clavicle, the acromion and the spine of the scapula. Note how the clavicle moves as the five pad sites are pushed. To minimize motion of the frame relieve to accommodate this motion.

TAKING THE CAST

Cover the subject with tightly pulled stockinette all over the side to be cast. Be sure that the covering reaches below the ribs and close to the center line and neck. Mark all boney areas and prominences and mark the five chosen sites with distinctive circles. Outline the immobile area. Be sure that sufficient casting material is ready. Lay out strips of plaster wrap for the splints ahead of time. Have a wooden dowel about the same size as the dowel you used for the touch Pad testing. You can push with this on the chosen sites during casting and thereby make cast modification easier.

The Immobile Cast

Prepare several long multilayer splints and have them ready. Then place one splint close to the neck and down the front and back. Join this with a splint covering the lower rib cage. Then fill in the remaining immobile areas. Be sure to pick up the detail around the clavicle. Smooth this cast. Add layers and ropey stiffeners as required so you will have both strength and stiffness. Be sure that the subject can move the tip of the shoulder up and down, forward and back while the cast hardens. If this motion deforms any area much, that area is not 'immobile'.

The Forward Site

Prepare a thick but short splint and place it with the top edge level with the top of the unraised shoulder. Have the subject push full forward and then ease off slightly while you push in on the forward site with the same pressure and orientation you used during the forward test. This piece of the cast should come all the way to the centerline but should come no higher than required to pick up the forward site. It must not prevent the subject from raising the shoulder in the next stage. When this piece sets, the subject should relax into the neutral position. There should be a gap between the site and the subject. Remember there is a tendency for the subject to relax during hardening. Prevent this or there will be no gap where you need it.

The Rearward Site

Use the same technique as above to cast the rearward site. Keep in mind that the ideal rearward site activates well but has a gap when the subject returns to neutral.

The Upper Sites

Have the subject reach straight up. This action should not alter the gaps at the forward and rearward sites. Your observations now will help in possible modifications of those two sites. Have the subject with the shoulder elevated move as far forward and back as possible without pushing the already established sites. You are now finding the range of motion for activating *forward-and-up* and *rearward-and-up*. You may want to repeat the testing of these two positions before adding the forward-and-up splint and the rearward-and-up. Be sure the patient has some upward motion left in the center so straight up will not be activated along with either of the other two sites. Place a piece of quarter-inch-thick (6mm) foam over the center of the shoulder so you can capture the straight up position and the rearward and up at the same time with one splint. Just be sure to push down where the straight up site will be in the neutral position. This will be a little forward of the position while picking up the *up and rearward* site.

Final check

Before removing the now rigid frame casting have the subject bend forward slightly. Note where this normal postural motion will cause undue pressure and constraint. You will modify the cast or cut away the frame to relieve this pressure. Have the subject reach for the five control sites. Can they be felt distinctly due to the depressions formed by the probe while each section of the cast was hardening. If not, consider building these areas up now in the cast. (In the finished frame these areas must be absolutely flat and orientated correctly.) Then replace the cast and use it like a check socket. When you have done as much with the cast as possible, pour the positive cast. Make any modifications that seem to be required and then pull a check socket out of a clear rigid plastic like Centri's Cenplex.

THE CHECK SOCKET

The check socket will give you a chance to remove the portions of the socket that do not resist torque or support load. Attach a chest strap as you will in the final fitting and add some weight to the attachment point for the arm. If you have followed the procedure correctly you should be able to install Touch Pads on the five flat mounting points and the subject should be able to generate a range of signals at each site.