From "MEC 93," Proceedings of the 1993 MyoElectric Controls/Powered Prosthetics Symposium
Fredericton, New Brunswick, Canada: August, 1993. Copyright University of New Brunswick.

REDUCING THE HOUSTON FLEXIBLE WRIST TO PRACTICE

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THE ORIGINAL HOUSTON WRIST

In another paper Rosa Jacobs will describe the Houston Flexible Wrist and its successful use on a number of children and adults. Reported here is the method followed for generating a production version of this wrist and the several products that are now available. Figure 1 shows a cross sectional view of a typical wrist fit to a user in the Houston trials. The ball element is more accurately described as a knob since there was no attempt to achieve true ball and socket fit. Rather contact between the knob and the edge of the hole in the lamination element tended toward a line contact. Both elements were aluminum and the contact generated considerable wear and friction.

The most important element in the wrist after the ball and socket is the compression pad assembly. As the hand moves with respect to the forearm, the pads are both compressed and stretched. There is a considerable absorption of energy since they are made of Poron® foam; however, they do bring the wrist back to neutral whenever a deflecting torque is removed. Though not shown in the drawing the glove worn with the typical hand is also part of the system tending to straighten the wrist back to neutral when it is bent.

DESIGN CRITERIA FOR THE PRODUCTION WRIST

After a study of the wrists used in Houston and after extensive discussions with the fitting team, the following criteria were written down.

1. Simple to produce. Versions must be made for about a dozen sizes of wrist from four manufacturers. At least one, VASI, has indicated an interest in making the wrist the standard wrist if further clinical trials prove this innovation to be of sufficient value.

2. Able to deflect 30° in any direction. The prototype units could deflect about 15°. User feedback indicated that this was not enough. Jacobs has documented a number of activities where 30° would be desirable. Thus the goal for maximum deflection was set at 30°.

3. Able to rotate around long axis. Users are able to preposition most prosthetic hands in rotation. Thus the rotation friction must be adjustable. However, rotation must be limited to about one turn to prevent the user from twisting wires off.

4. Adjustable restoring torque. The user or the prosthetist should be able to adjust the density or compression of the pads that provide restoration to neutral and rotational friction.

5. Compatible with cosmetic gloves. The bending must not unduly stretch the typical cosmetic glove or cause it to tear or deteriorate.

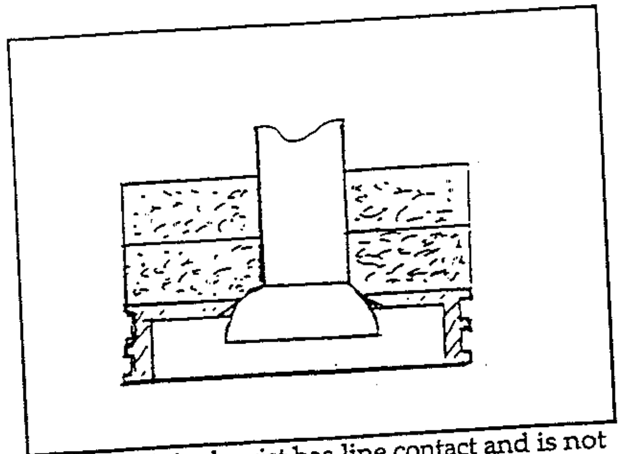

Fig 1. Original wrist has line contact and is not designed to accommodate each manufacturer's hand.

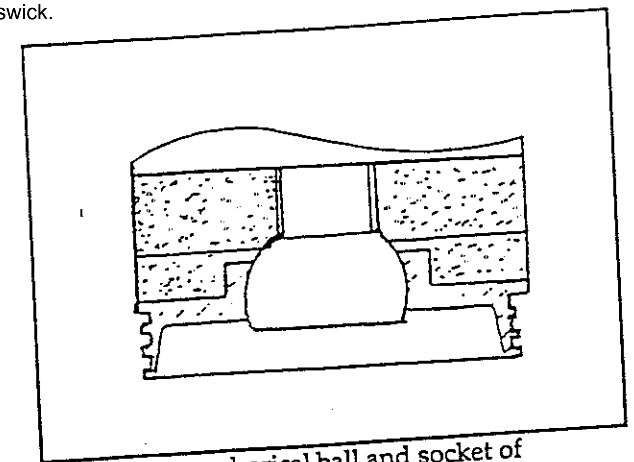

Fig 2. True spherical ball and socket of hardcoated aluminum eliminated wear in preproduction wrist.

6. Easy to install. The prosthetist must be able to add the hand to the installed wrist collar with a minimum of difficulty.

7. Attach in a standard way. Commercial wrist units all attach in a more or less standard way. The unit should accept a thermoformed or laminated outer socket and be amenable to being glued in place. Purchasers must be able to buy this element separately when building a new prosthesis due to growth.

8. Long wear life. The wrist should be able to outlast the hand it is attached to.

PREPRODUCTION PROTOTYPES ADD NEW FEATURES

Figure 2 shows a cross section view of the first production prototype for an Otto Bock 6-3/4 hand. The following points should be noted:

1. The pivot is a true ball and socket with spherical surface.

2. The socket element also functions as a lamination or attachment element.

3. The ball and the socket are made of aluminum alloy with .001 inch (25 micrometer) thick hardcoat.

4. The maximum deflection is 26°.

CONSIDERATIONS BECOMING APPARENT DURING THE FINAL DESIGN.

During the design process new considerations come to light. The following were added to the list during the design stage or after studying the first prototypes.

1. Use of gold-anodized aluminum. Parts of the first prototypes were hard anodized. The dark green showed through light colored gloves. Thus a new spec required all surfaces in contact with the glove to be gold anodized aluminum which appears through the glove the same as the color used in the plastic fingers and hand cover.

2. The pads must be tan Poron®. The original pads were the blue Poron® supplied to pedorthotists for shoe liners. Tests showed this to be the best foam but the color could not show through the glove. Here tan was the best off-the-shelf color available.

3. Three thin pads are better than one thick. It is costly to shape the inside of a large pad but easy to cookie cut several thin pads with varying inside and outside diameters.

4. The pads must be glued together. Much of the restoring force of the pads is lost if they do not work together. It turned out that the manufacturer will supply pads with adhesive backing and a peel-off release strip which avoids hand cementing with a contact cement.

5. The ball should be made of Delrin AF. The ball will have a very long wear life against anodized aluminum if made of this material which is loaded with 15% PTFE.

6. The stem element must be hollow to carry wires to the hand. This constraint is a real nuisance because the hole must be big enough to pass a connector in most cases. For the larger hands where it was practical to use a 3/4 in. ball and either a 1/2-20 or M12-1.5 thread this diameter was .316 inches to pass a Steeper connector. For the smaller VASI hands everything needed to be smaller— 1/2 inch for the ball, 5/16 for the thread and 3/16 for the hole. Here even the thread pitch needed to be made finer in order to keep enough metal in the stem— 5/16-32 was the size chosen.

THE DESIGN TAKES SHAPE

Constraints on the socket. What is the worst thing that could happen with a ball and socket wrist? Clearly having the ball pop out of the socket would be disastrous. Thus the engineer wants to know the minimum safe wrap around. First, one must look at tolerance on the fit and possible wear. But surely the important thing to look at is the amount of interference as a percentage. A 10% figure was chosen. Thus if the diameter of the ball is .500 inch, the diameter of the entrance hole would be .450 or 10% less. If a smaller percentage is chosen the hoop stress in the edge of the socket becomes excessive.

Maximum bend angle. In similar manner one looks at the ball and stem diameters. If the ratio of thread to screw gets too large there is no ball left, but the hollow stem and the need for some metal in the stem keeps the stem relatively large. Finally, one needs to select sizes that enable the manufacturer to use standard taps for the thread. For the larger hands the ratio turned out to be 1/2 to 3/4 or 66%, and for the smaller hands 1/2 to 5/16 or 62%. Figure 3 shows how the 10% socket constraint and the 3/4 - 1/2 constraints determine what angle is left over to create the bend angle.

How does the prosthetist install the wrist? The prototype was easy to install in a dummy wrist. A screwdriver slot in the ball could be reached from inside the socket. However, in the field one needs to adjust the pad compression or even remove the wrist with the socket in place. A number of "tricks" have been tried and it looks like an answer is at hand as the first small production run is begun. The installer needs to be able to alternately hold the ball on the stem while rotating the hand in one direction and then hold the ball to the socket while rotating the other way. The ball is held to the stem with a "interference" thread tap that leaves a little interference at the root of the thread. To overcome this friction the ball needs to be held very firmly when it is to be locked. This is done by sliding a rod along the top of the lamination collar into a hole in the socket and finally into one of three holes in the ball (Fig. 3). Although not shown, the mechanism to prevent excessive pro-supination is a simple nylon cord between the lamination collar and the hand with enough slack for a half turn in either direction.

Final considerations. A heavy child is hanging on a jungle gym. Someone whacks the prosthesis from the side. Will the stem be strong enough? This very question led to two changes. The thread selection 32 to the inch instead of 24 or 16 gained .010 inch of wall thickness. An extra 20% strength was gained by simply changing from the draftsman's favorite alloy 6061-T6 to the stronger 2024-T4.

CONCLUSION

This article has been presented so that the rest of the treatment team will see just how the engineers and manufacturing people make their contribution. A very simple mechanism was chosen for the sample and yet it is apparent that a large number of decisions and compromises had to be made to deliver a reasonable product. And the process is not over. We have learned that one will always need to go back after a year or so and listen to the clinicians. Surely there will need to be further refinements that our colleagues will ask for.

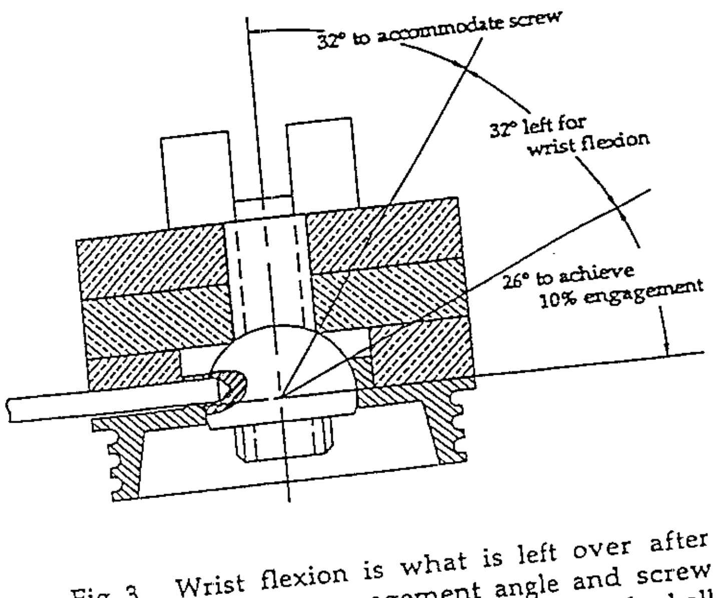

Fig 3. Wrist flexion is what is left over after subtracting engagement angle and screw angle. The rod on the left positions the ball while the hand is rotated during installation.

Fig 4. Maximum deflection of the Steeper myoh version of the Houston FlexiWrist.