The Northwestern University Supracondylar Suspension Technique for Below-Elbow Amputations[1]

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The use of myoelectric control for the below-elbow amputee has eliminated the need for the harness for power transmission. Therefore, the major function of the harness in relation to a myoelectrically controlled prosthesis is suspension; and, with the use of self-suspending socket, such as the NYU Muenster-type socket described by Kay et al. (3), it is possible to eliminate the harness completely.

It has been found that the NYU Muenster-type socket has disadvantages which can affect the overall use and function of a myoelectrically controlled prosthesis because of its high anterior and posterior trimlines. The design is applicalbe to only rather short below-elbow amputations and provides a somewhat limited range of motion at the elbow, as pointed out by Gorton (2) and Friedman (1).

A supracondylar suspension technique for below-elbow amputations has been developed as part of NU Myoelectric Below-Elbow Prosthetic System and was designed to provide more below-elbow amputees with the advantage of self-suspension, regardless of the length of their amputations. This socket, utilizing supracondylar suspension, will accommodate all lengths of below-elbow amputations and will provide an improved range of motion at the elbow.

Data collected on a total of twelve amputees fitted at the NU Prosthetic Research Laboratory over a period of 2 1/2 years are given in Table 1. Three of the amputees have been refitted since their initial definitive sockets because of atrophy or a change from one myoelectric system

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TABLE 1. CASE HISTORIES AND BIOMECHANICAL DATA

#	PATIENT	AGE	SEX	CAUSE OF AMPUTATION	RIGHT OR LEFT	STUMP LENGTH	PRESENT OCCUPATION	DATE FITTED	STUMP LENGTH	EXTENTION*	FLEXION*	RANGE OF MOTION*
1	R.T.	24	M	Traumatic	Right	9 1/2	Office work	1-22-70	9 1/2	12°	127°	115°
2	D.M.	21	M	Traumatic	Right	7	Student	1-23-70	7	24°	105°	81°
3	D.S.	25	M	Embolus	Left	5 3/4	Farmer	3-17-70	5 3/4	12°	120°	108°
4	N.B.	14	M	Congenital	Left	5 1/8	Student	4-27-70	5 1/8	7°	110°	103°
5	T.S.	20	M	Traumatic	Right	6 3/4	Student	9-25-70	6 3/4	13°	120°	107°
6	P.W.	21	F	Congenital	Left	4 1/2	Housewife	10-26-70	4 1/5	10°	111°	101°
7	W.L.	26	M	Traumatic	Left	7 5/8	Laborer	10-31-70	7 5/8	13°	123°	110°
8	W.D.	54	M	Traumatic	Right	7 3/8	Photographer	11-17-70	7 3/8	11°	125°	114°
9	M.R.	18	F	Congenital	Right	4	Student	12-14-70	4	11°	111°	100°
10	B.R.	37	F	Tumor	Right	5	Housewife	4-12-71	5	17°	119°	102°
11	W.V.	39	M	Traumatic	Left	4 3/8	Office work	5-26-71	4 3/8	15°	120°	105°
12	R.S.	24	M	Traumatic	Right	4 3/4	Student	8-23-71	4 3/4	14°	115°	101°

*With prosthesis on

**Patient has limited range of motion without prosthesis.

to another. One amputee, a juvenile, has been fitted four times because of longitudinal bone growth. His approximate time between fittings was 6 months.

The Veterans Administration is presently conducting a field study on externally powered components which include the supracondylar suspension technique on the below-elbow patients fitted in the study. Some 60 prosthetists involved in the study attended a special course which included instruction in this

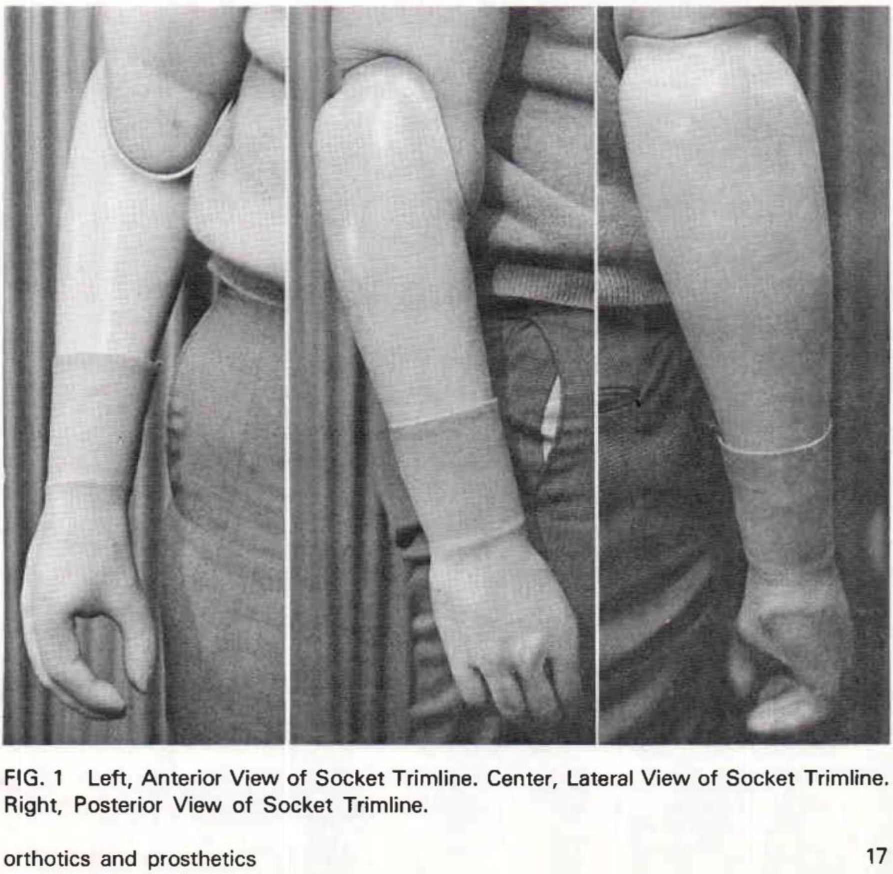

FIG. 1 Left, Anterior View of Socket Trimline. Center, Lateral View of Socket Trimline. Right, Posterior View of Socket Trimline.

fitting technique. A total of 26 such fittings have been completed since the field study began in April of 1971, and many of the prosthetists have applied this technique to conventional fittings as well as externally powered fittings.

The NU Myoelectric Below-Elbow Prosthetic System that utilizes this suspension technique, is shown in Figure 1. Note the contours of the socket trimline in the anterior, lateral, and posterior views.

Figure 2 illustrates the range of elbow flexion which can be obtained on most below-elbow amputees because of the low anterior trimline.

FIG. 2 Range of Elbow Flexion Possible.

CASTING PROCEDURE

The most important step in fitting a socket of the type being considered is to record accurate anatomical data. In addition to the data normally recorded, it is necessary to measure the medial-lateral distance between the humeral condyles. This is best done with a double-headed combination square or the VAPC caliper. The measurement should be snug, being sure that it is taken at the apex of the condyles. The length measurement of the amputated limb should be taken from the posterior edge of the olecranon to the end of the longest cut bone, when the elbow is flexed to 90°. This measurement not only is important for determining the length of the prosthesis, but it is necessary in determining how low the anterior trimline can be in relation to the length of the amputation limb. All other measurements are recorded in the conventional manner.

Two layers of #56 Tubegauz are applied to the amputation limb and suspended with a figure-of-eight elastic webbing strap. Tubegauz is preferred for the cast sock because it maintains contours well and provides adequate definitiion of the bony prominences of the olecranon process and humeral condyles. It is very *important* that the olecranon process and humeral condyles be outlined accurately with indelible pencil in order to provide accurate references for modifying the positive mold.

The elbow must be flexed 45° when the cast is taken to insure a proper contour of the posterior aspect of the upper arm, superior to the humeral condyles. This is necessary in order to maintain an optimum range of extension when modifying the positive mold.

It has been found that a more smoothly contoured cast can be obtained if elastic plaster bandage is used for the initial wrap. It is reinforced with regular plaster bandage after it has set. The plaster wrap should extend no less than one inch superior to the olecranon process and humeral condyles. No attempt should be made to distort the cast in any manner while it is setting because this will disrupt the general contours of the amputation limb and displace the outlined areas of the olecranon process and humeral condyles which are very important references needed for modifying the positive mold. Once the cast is removed, it should be checked to see that the outlined areas were not displaced and the areas should be remarked to insure good transfer to the positive mold.

CAST MODIFICATIONS AND BIOMECHANICAL PRINCIPLES

Before one attempts to modify a positive mold for a socket of this type, he should fully understand the biomechanical principles involved and how they are related to the suspension, flexion, and extension features of the socket. Suspension, the most important feature, must be considered at all times during the modification of the positive mold. Also, it is necessary to point out that the modifications described in this report do not account for the thickness of a prosthetic sock. Therefore, it is necessary to adjust the measurements to accommodate for the thickness of the prosthetic sock, if the amputee is to wear one.

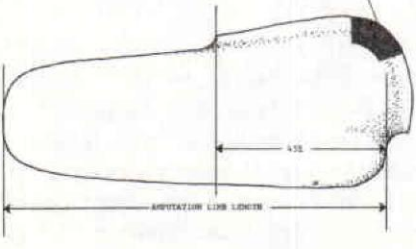

FIG. 3 Lateral View of Socket and Trimline.

In Figure 3 the shaded area at the anterior-proximal corner of the socket trimline is the point at which the humeral condyles enter the socket. The distance between the two corners at the trimline must be 1/8 inch smaller than the measured M-L dimension at the condyles so that the condlyes can pass through with only a slight expansion of the socket. The measurement should be divided in such a manner that each side of the trimline cups over the condyles 1/16 inch. If the M-L dimension is too small, the condyles will not pass into the socket; if it is too large, the suspension will be inadequate in this area. The suspension also is affected by the flexibility of the resin in the definitive socket. The best results have been obtained with a 60% rigid and a 40% flexible mixture of acrylic resin; if polyester resin is used, the mixture should be 70% rigid and 30% flexible.

In some cases the proximal M-L measurement of the positive mold will be too small even before it is modified. Generally this occurs with an upper limb that is thin or atrophied, causing the medial condyle to be more prominent than usual. When this is the case, the positive mold must be built up on the medial side and plaster removed on the lateral side to insure that each side cups over the condyles 1/16 inch.

When the amputation limb is longer than 5 inches, the distance between the lowest point of the anterior trimline and the olecranon process, also illustrated in Figure 3, should be approximately 45% of the total length. This percentage is necessary for long below-elbow amputations in order to allow entrance into the socket without impinging on the anterior-distal trimline. Also, this will provide adequate room for tissue bunching in the cubital fold during flexion and allow the optimum range of elbow flexion. If the amputation limb is less than 5 inches in length, it is necessary to establish an anterior-distal trimline which will provide an adequate anterior weight-bearing area.

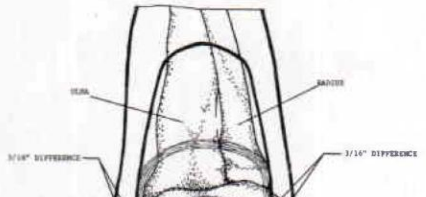

FIG. 4 Anterior-Superior View with Elbow Flexed to 90°.

Figure 4 illustrates the relationship between the socket trimline and the skeletal structure of the elbow. This is an anterior-superior view of a transverse section through the upper arm and humerus with the elbow flexed to 90%. Of particular interest is the ralationship of the anterior trimline to the humeral condyles. The anterior trimline, superior to the humeral condyles, should be at least 3/8 inch smaller than the measured M-L dimension at the humeral condyles in order to provide adequate suspension in a flexed position. This measurement allowance also should be divided equally so that the trimline cups over the condyles 3/16 inch on each side. This is very important during extreme flexion because the forces being exerted against the socket by tissue bunching in the antecubital fold are acting so as to push the socket off.

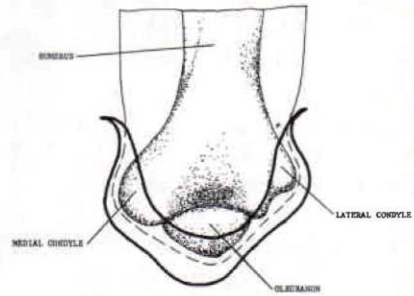

FIG. 5 Posterior View with Elbow Flexed to 90°.

Figure 5 is a posterior view of the elbow flexed to 90%, again illustrating the relationship of the anterior trimline to the humeral condyles. Notice how the socket cups over the humeral condyles and how the proximal trimline is flared outward to prevent irritation of the tissues in that area. Generous flaring of the entire trimline will increase the overall comfort.

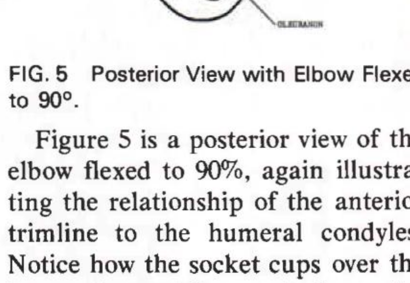

FIG. 6 Transverse View Just Superior to the Epicondyles.

Figure 6 is a transverse view just superior to the epicondyles, illustrating the relationship of the posterior-superior trimline to the humeral condyles and the olecranon process with the forearm in full extension. In order to allow a maximum range of extension, it is necessary that the posterior trimlines be well rounded to accept the contour of the upper arm, proximal to the humeral condyles. As mentioned in the section on the casting technique, this contour is best obtained by taking the cast with the elbow flexed 45°.

In order to maintain good suspension in the fully extended position, the posterior trimline must cup over the olecranon process at least 1/2 inch. The reason for modifying the area over the olecranon process more than the areas over the condyles is to take advantage of the excellent pressure-bearing area provided by the triceps tendon. This is the major pressure-bearing and suspension area when carrying or lifting heavy objects. In some instances, it is necessary to modify the positive mold more than the prescribed 1/2 inch in order to insure that the condyles are not subjected to excessive pressure. One should be cautious of overmodifying in this area because it will have a direct effect on the range of extension in the definitive socket. The amount of modification in this area is best evaluated during the check-socket fitting by applying a force to the socket which simulates the forces acting on the prosthesis when the amputee is lifting or carrying an object.

Figure 7 illustrates the forces which affect the amputation limb when lifting or carrying and object with the prosthesis. These forces create a torque which causes pressure on the anterior-distal aspect of the radius and pressure on the olecranon process and triceps tendon. This is a desirable reaction because it enhances suspension and comfort by insuring that the posterior-proximal trimline is cupped over the olecranon process and

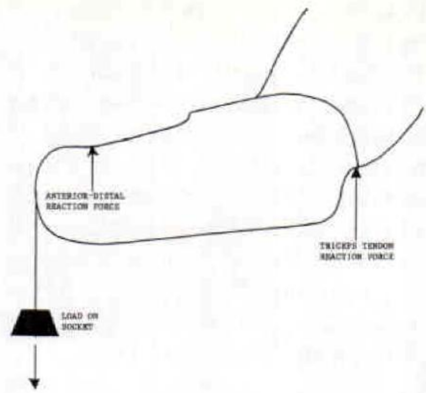

FIG. 7 Reaction Forces Created by a Load on the Socket.

creating pressure on the triceps tendon instead of the humeral condyles.

The reliefs for the humeral condyles and olecranon process should not be added to the positive model until the entire trimline is well established. The reliefs for the humeral condyles should be at least 1/8 inch thick and extend to the border of the outlined areas before tapering into the positive mold. The relief for the olecranon process also should be at least 1/8 inch thick and positioned toward the proximal edge of the olecranon as illustrated in Figure 8.

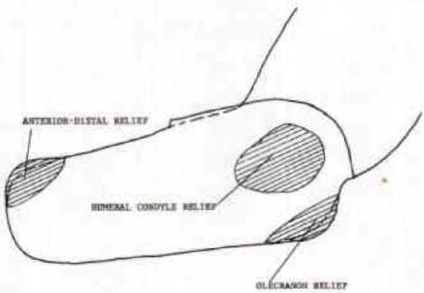

FIG. 8 Socket Relief Areas.

CHECK-SOCKET FITTING PROCEDURE

To properly evaluate the suspension of the socket, it is necessary to do a check-socket fitting before fabricating the definitive socket. A synthetic balata, such as Polysar X-414[3], has proven to be an excellent material for check sockets because it can be easily molded and can be re-formed readily when a remodification of the cast is necessary.

A Polysar tube with a 2-inch inside diameter and a 1/4-inch wall thickness is generally adequate for the average amputation limb. The length of the tube should be 1 1/2 inches longer than the overall length.

The synthetic rubber tube is heated and then pushed over the modified positive mold on which a generous application of vaseline has been made. Once the tube is well over the proximal trimline, it should be molded into the contours of the trimline.

To remove the check socket from the positive mold, it is necessary to cut a slit on the anterior surface. This will permit the medial and lateral wings of the socket to expand while pulling it off the positive mold. After the socket is removed, the slit should be closed and held together with pressure-sensitive tape, and all excess material should be cut away to the proximal trimline.

The synthetic rubber has a higher coefficient of friction than polyester or acrylic; therefore, it is necessary to powder the check socket with talc before the amputee attempts to don the socket.

The inability of the humeral condyles to pass into the entrance of the socket is generally caused by a proximal M-L dimension that is too small or an anterior trimline that is too high or too narrow, causing tissues to bunch up against the anterior trimline. The positive model should be remodified and the check socket reheated and re-formed. Although the synthetic rubber can be reheated in localized areas and remodified, this is not recommended because it is difficult to heat a local area without distorting other areas of the socket.

Once the humeral condyles are seated well in the socket, the suspension is checked. This is best done by applying a force to the socket which simulates the weight of the prosthesis distal to the end of the amputation limb. If the socket displaces easily without resistance from the amputee, the suspension is inadequate. This is an indication that the proximal M-L dimension in the anterior-proximal corners is too wide. The socket should displace with a fair amount of force without the amputee offering resistance, but if the amputee offers resistance, the socket should not come off. In most instances the forces acting on the socket tend to enhance the suspension by keeping the posterior wall over the olecranon process at all times.

POSSIBLE POST-FITTING PROBLEMS

The humeral condyles tend to be rather tender during the first few days after the initial fitting. Tenderness may also develop in the tissues of the antecubital fold. This tenderness should diminish as the tissue and bones build up a tolerance to the socket. It is therefore advisable to build up this tolerance gradually and not overuse the prosthesis during the first week or so after the initial fitting.

[3] Polymer Corporation Ltd., Sarnia, Ontario, Canada.

Experience has shown that an amputee may initially have some difficulty in donning the prosthesis. This problem disappears quickly as he gains experience in putting it on.

ACKNOWLEDGEMENTS

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