

# Normal Shape-Normal Alignment (NSNA) Above-Knee Prosthesis

by Ivan A. Long, C.P.

On March 13, 1974, I saw the first x-ray of an amputee standing with his prosthesis, equal weight on both feet, heels 2" apart and toes 3" apart. (See Figure 1. Notice the two zippers on the boots.) After seeing the amputated femur in such abduction, I realized that the quadrilateral socket and standard alignment procedures were not adequate for an above-knee limb. In December 1975, *Orthotics and Prosthetics*, the journal of the American Orthotic and Prosthetic Association, published my article, "Allowing Normal Adduction of Femur in Above-Knee Amputations."

On February 2 and 3, 1981, I presented a demonstration and the booklet "Fabricating the 'Long's Line' Above-Knee Prosthesis" at Sabolich, Inc. in Oklahoma City. Shortly thereafter, news of a CAT-CAM socket available through Sabolich was announced.

For the last 11 years, I have been fabricating only above-knee limbs and all have "Long's Line." The following article is presented so that prosthetists can provide the above-knee amputee with a limb that has a comfortable socket and alignment that allows him to walk in a normal fashion without drawing attention. Recently, it has been decided to call this work "Normal Shape-Normal Alignment" (NSNA) above knee prosthesis.

## WHAT IS WRONG WITH OUR PRESENT A/K PROSTHESES?

Most above-knee amputees walk with a wide base and a lurch to the amputated side. Only 100 percent concentration can change that pattern. We looked at 100 x-rays of above-knee amputees standing in their prostheses and found

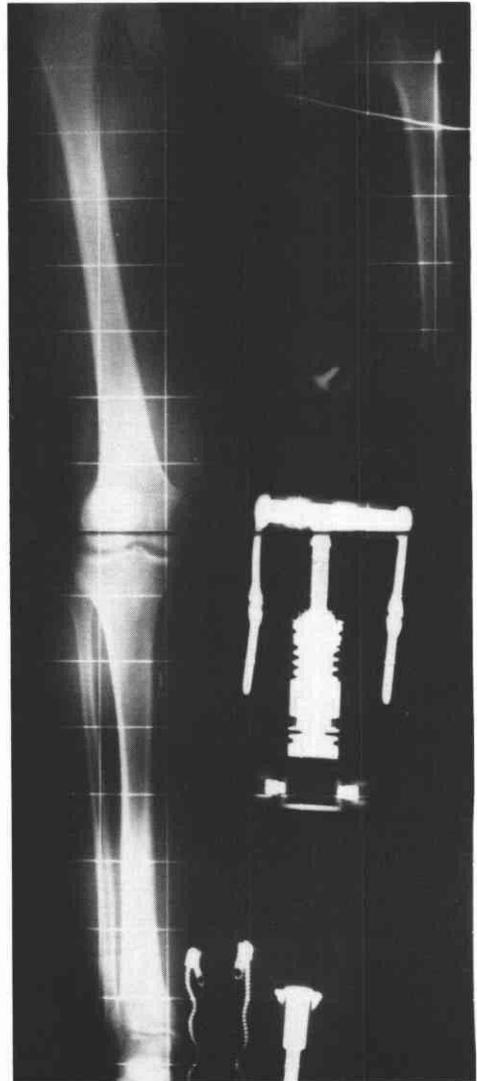


Figure 1. X-ray of standing patient showing relative abduction of amputated femur as compared to normal side.

92 out of 100 to have a difference in angle of the femur. In 91 to 92, the difference was towards abduction. (In this article, the angle of the sound femur is considered normal and movement away from the midline will be called abduction.) Most amputees would have to cross their legs to put the amputated femur in normal position while wearing the standard quadrilateral socket made all over the United States.

Abduction was caused by the quadrilateral socket being entirely too large in the M-L dimension and too tight in the A-P. The ischium sits on top of the seat at best and a couple of inches above it in most fittings. The x-rays show the lateral wall to be several inches away from the femur except at the most distal point. When the femur exerts force against the lateral wall in weight bearing, the quadrilateral socket moves laterally immediately, because the ischium has no effect on stopping this shift. With the more narrow socket and increased A-P, the ischium is inside the socket, preventing lateral shifting of the socket during weight bearing.

To insure proper angle of the femur, the distal femur is brought directly under the head of the femur. This allows hip musculature to work in a normal fashion. The narrow socket with a well shaped lateral wall will support this angle, and the ischium will secure the socket from shifting laterally, which destroys femoral support.

Balance is dramatically improved when the foot is placed directly under the head of the femur rather than under the ischium. The amputee will immediately bring his feet closer together when he starts to walk, as opposed to a widened position when the foot is placed under the ischium.

Long's Line is a straight line from the head of the femur (located approximately at the center of a narrow socket), through the distal femur, and down to the center of the heel. This line is not always vertical because it constantly shifts when changing from a standing position to a walking position.

In order to support the femur, it is necessary to narrow the M-L dimension of the socket. The resulting greater A-P allows muscular function which is not possible with the crowded effect of a narrow A-P. Table I is used as a guide in establishing the width of the finished positive model. The figures were taken from approximately 500 sockets made in this facility, and many of these sockets have now been worn eight years. Very few, if any, sockets have been replaced because of shrinkage. Many sockets

Circumference just below ischium	Goal M-L
9"	-2.5
10"	-2.7
11"	-2.9
12"	-3.1
13"	-3.3
14"	-3.5
15"	-3.7
16"	-3.9
17"	-4.1
18"	-4.3
19"	-4.5
20"	-4.7
21"	-4.9
22"	-5.1
23"	-5.3
24"	-5.5
25"	-5.7

Table I.

have been replaced as muscles return to normal and the thigh takes on its original shape and size increases. Most of the increase in size will take place in the A-P dimension, with very little change in M-L. Increasing the M-L dimension by anything more than 1/4" will result in a lateral gap at the top of the socket.

## TECHNIQUE

Thigh is measured as to length and circumference as high as possible and every two inches.

Taking a cast: Take two pieces of 6" wide cotton stockinette, 32" long. Cut 17" into each piece and sew together to make undergarment for casting (Figure 2). Measure length of thigh and sew one leg of garment to fit thigh. Cut small holes in front and back of top of garment and insert cord to tie up over amputee's shoulder to help hold garment securely in place. With a snug fitting undergarment on the patient, and with the seam as near center as possible, the prosthetist will work from the side and completely circle the pelvis above the trochanter with a single wrap of 4" non-elastic plaster bandage. Pull it snug, for this wrap is to prevent downward slippage of the cast as more wraps of plaster are applied around the thigh. Work quickly so your finger can be placed around the ischium to mark its location and proper depth of cast before the plaster sets. This spot will be

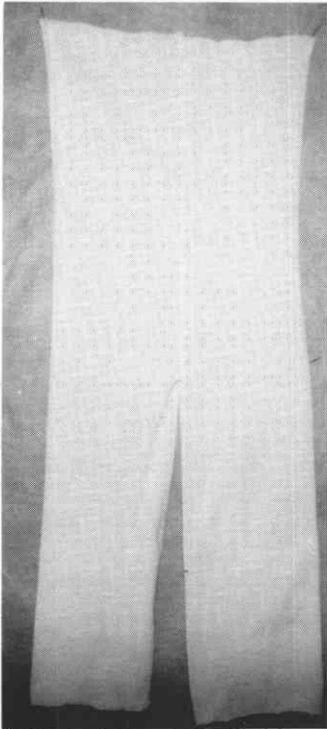


Figure 2. Casting garment.

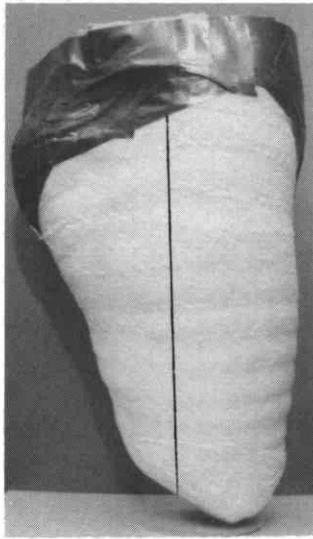


Figure 3. Lateral view of cast ready to pour.

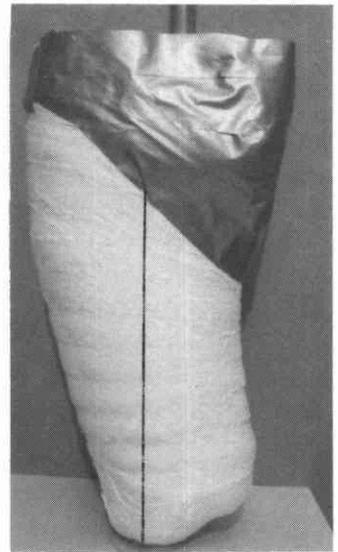


Figure 4. Anterior view of cast.

used to measure length to floor, pelvis level. The hand should be held to indicate the medial and posterior surfaces of ischium. Do not push forward of ischium. Ask the amputee to bring his knees together as tightly as possible and to extend his thigh to tighten the hamstrings. Hold this position until the plaster sets. Now place a vertical mark on lateral surface, with muscles tightened in extension (Figure 3).

Tear the single wrap of plaster than encircles the pelvis. The cast will drop away. Immediately check depth of cast and location of ischium.

Prepare cast for filling by adding duct tape around top to make top level. Pipe must be parallel with lateral mark, and tipped to medial to approximate Long's Line angle (Figure 4).

Now pour the cast full of plaster and let it set.

When the plaster bandage and stockinette are peeled away, we now have a grossly oversized model (Figures 5 and 6) that must be reduced in size. Practically all the reduction will take place on the lateral wall.

Referring to Table I, the socket M-L will be 4.5" for a 19", 0 circumference level measurement of the amputee.

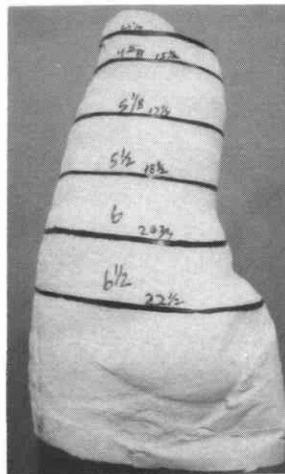


Figure 5. Posterior view of unaltered model.

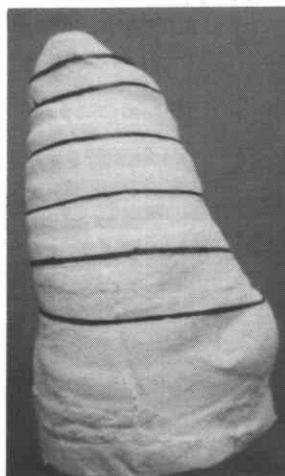


Figure 6. Lateral view of unaltered model.

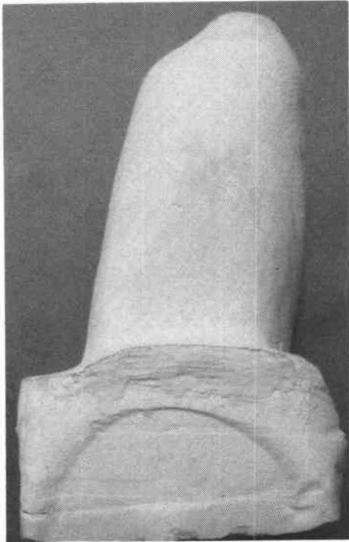


Figure 7. Medial view of modified model.

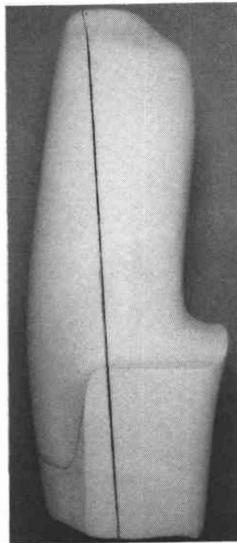


Figure 8. Posterior view of modified model.

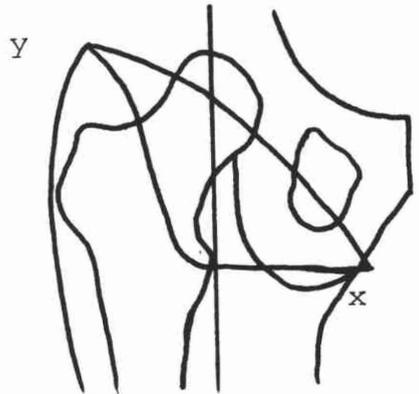


Figure 9. Anterior view showing relationship of medial brim (point X) to ischium and of lateral wall (point Y) to greater trochanter.

## SOCKET MODIFICATION

1. Lateral wall is to be shaped to give support over a wide area, and particularly the lateral posterior aspect of socket.
2. The medial wall will be lower than seat level, and the cast will be the guide as to how low (Figure 7).
3. Depth of the socket will be the same as measured length of the thigh.
4. The seat will be at right angle to Long's Line.
5. Long's Line is drawn from center of M-L (see chart) to center of distal femur (Figure 8). (Distal femur will be very close to lateral surface, probably covered only by skin.)
6. Top 1" of medial wall will flare outward at 45° (Figure 9, point Y).
7. Lateral wall is higher than usual. Do go above the trochanter (Figure 9, point Y).
8. Seat need not be wide, but sharp edges must be avoided (Figure 10). The ischium will bear on flare of socket, both medial and posterior.
9. Do not worry about the socket touching the greater trochanter. Take the cast down as though the trochanter does not exist. Practically all sockets gap in this area. In order to achieve the desired M-L, many casts will be reduced 2" or more (Figure 11, Table II).

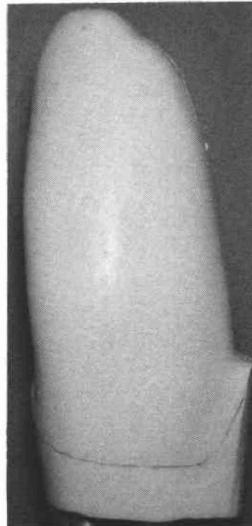
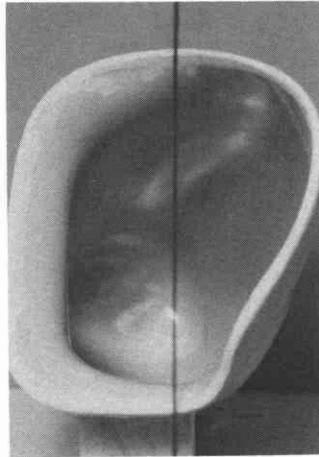
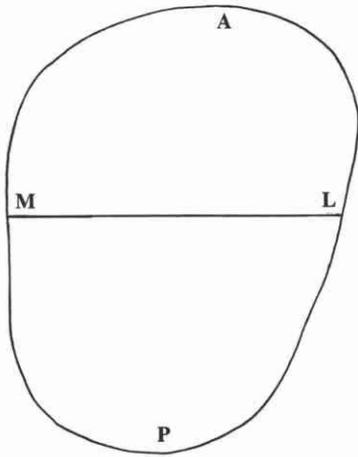


Figure 10. Lateral view.

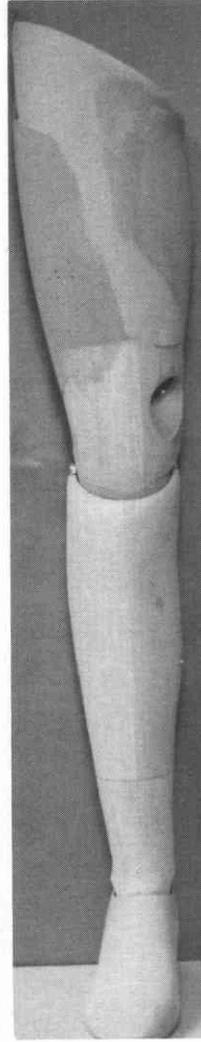
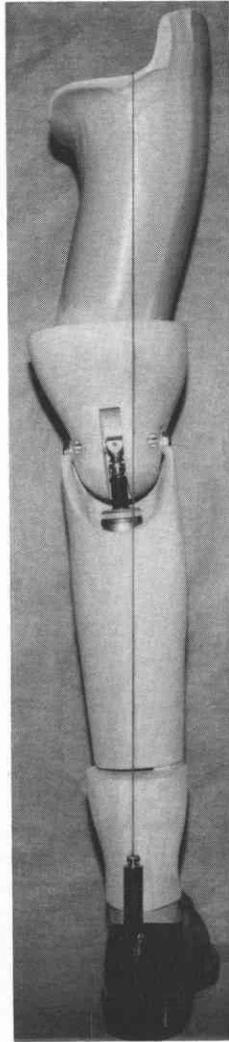
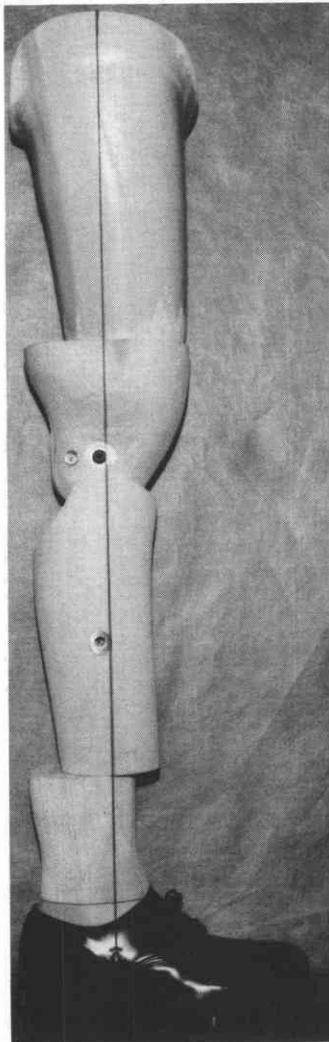
### Example of Shaping the Positive Mold for a Particular Patient:

Amputee Circumference Measurements	Unaltered Plaster Mold	Finished Plaster Mold
0"–19"	22 <sup>1</sup> / <sub>2</sub> "	18 <sup>1</sup> / <sub>4</sub> "
2"–18 <sup>3</sup> / <sub>4</sub> "	20 <sup>3</sup> / <sub>4</sub> "	17 <sup>1</sup> / <sub>2</sub> "
4"–17 <sup>1</sup> / <sub>2</sub> "	18 <sup>1</sup> / <sub>2</sub> "	17"
6"–16 <sup>1</sup> / <sub>4</sub> "	17 <sup>1</sup> / <sub>4</sub> "	16"
8"–14 <sup>1</sup> / <sub>4</sub> "	15 <sup>1</sup> / <sub>2</sub> "	14 <sup>1</sup> / <sub>4</sub> "
9"–13"	13 <sup>1</sup> / <sub>4</sub> "	13"

Table II.



**Figure 11.** Proximal view of socket and socket pattern for thigh measuring 19". Actual measurement of the pattern is 18".



**Figure 12.** (left) Lateral view of bench aligned prosthesis.

**Figure 13.** (center) Posterior view of bench aligned prosthesis.

**Figure 14.** (right) Anterior view of prosthesis following completion of shaping.

10. Many sockets require fill added distally on medial side, only because I failed to remove enough material in this area when modifying the model.
11. Laminate socket using two layers of 1 oz. dacron felt plus extra felt around top.
12. Remove socket from cast and trim excess plastic.
13. Mark the center of the lateral wall at seat level for TKA. TKA should be parallel to lateral cast mark lines (Figure 12).
14. Mark Long's Line on posterior of socket (Center of M-L through distal femur) (Figure 13).
15. When using a standard wood set-up, knee bolt should be 4° higher on lateral side when Long's Line is vertical. Long's Line will thus not be in center, but towards lateral side.
16. Mount socket on set-up so that lines are straight (Figures 12 and 13) and medial wall checks out for height.
17. Install valve and walk amputee.

**DO NOT** change the alignment. Allow the amputee to take a few steps and watch the foot come in to a narrow base normal gait pattern. Notice level knee bolt while walking.

**DO** expect the amputee to have much more difficulty in readjusting to his old prosthesis. He will need to widen his base and may experience vertigo at first due to lack of support and extreme inward location of the foot.

To finish shaping of the thigh, material is added to the knee block to widen the knee block in front of medial joint. This must not limit full extension (Figure 14).

#### **AUTHOR**

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