Prosthetics and Orthotics International, 1979, 3, 137–139

Alignment of the above-knee prosthesis*

J. FOORT

Department of Surgery, Division of Orthopaedics, University of British Columbia, Vancouver.

Alignment will be discussed in terms of what happens as a result of specified changes in the relative positions of the prosthetic components.

As a person walks on his prosthesis the conditions which predominate at various stages can be identified:

(a) the conditions of no-load, or *swing phase,*
(b) the conditions under which there is full loading or *stance phase,*
(c) the capacity to control the prosthesis easily or *voluntary control*
(d) the conditions under which little or no control can be exerted.

Alignment will be considered with these conditions in mind in the hope that visualization of what is happening as you work toward *optimizing comfort, saving energy and normalizing the appearance of gait* will be made easier.

As you watch the amputee walk, everything happens at great speed, and there is need for some sort of anchorpoints for your observations. You depend on motions—*motions en masse, motions between the prosthesis and the wearer, motions between the prosthetic parts.* You may however, develop the habit of feeling the effects of what you see as *forces.* As I watch a person walk with the view to changing his alignment I imagine *how the prosthesis or its parts would bend if they could, and how they would want to move to modify this tendency if they could.* From this I get clues as to what changes to make.

I have boiled it down to just a few things which I consider for change:

1. Length of the prosthesis.
2. Foot position—front, back, inward, outward.
3. Foot angle—toe up, toe down, toe in, toe out.

The stump is considered as the datum or reference system to which the position of parts is referred.

As for knee pivot position, (4) I think of this only in terms of the internal or external angulation of the axis from right angles to the line of progression. The forward or backward position has influence, but the prosthetist can easily pre-set this position with respect to the stump and leave refinement of stability to the positioning and angulation of the foot. Similarly, inversion and eversion relate more to cosmesis than function and can be neglected except in that sense.

Let us consider the effects of the changes we can make to the length, position and angle of the various parts; and as we do so, let us use the motions for clues while we sense these as forces necessary to give us the information we need for making a particular change.

1. Length of the prosthesis

The length of the prosthesis is affected not only by its axial elongation or shortening, but also by the inclination of the segments relative to one another. Thus, plantarflexing the foot makes the prosthesis seem longer at the end of the stride and shorter at the beginning of the stride. There is also a small effect which comes from inclining the shank toward the back or toward the front. Then, as changes are made in other segments of the prosthesis there may have to be a compensating change in the axial length of the prosthesis. But to be specific: *if the prosthesis is too long, the amputee will (a) rise up on the foot of the normal side in swing phase of the prosthesis or*

All correspondence to be addressed to Mr. J. Foort, Department of Surgery, Division of Orthopaedics, University of British Columbia, 2740 Heather Street, Vancouver, B.C. Canada, V5Z3J4.

*Based on a paper presented at the ISPO International Course on Above-knee Prosthetics, Rungsted, November, 1978.

the prosthetic toe will scuff. (b) the pelvis will drop on the normal swinging leg side during stance phase on the prosthesis along with which there may be high forces in the crotch which cause pain, or (c) the amputee will space his feet to effectively shorten the prosthesis for stance phase and (d) swing the prosthesis through with it held out by hip abduction to help clear the foot and set it in the wide based position for the next weight bearing period.

If I shorten the prosthesis the amputee will (a) have increased voluntary control, (b) will usually shorten his stride, (c) will narrow his walking base, and (d) will lean laterally over the prosthesis to balance.

The best length depends on how long the stump is and how much voluntary control the amputee can and will exert over the prosthesis. A rule of thumb is that for a very long stump, equal length between the normal and prosthetic sides will be used unless there are other considerations which require it to be shortened (such as considerable activity on rough terrain). For progressively shorter stumps, the prosthesis is made shorter. The endpoint for shortening is determined by a balance between comfort, energy costs and cosmesis, factors which relate to amputee preference.

2. Foot position

As the prosthetic foot is displaced forward, the stride on the prosthetic side will be of INCREASED LENGTH. Conversely, *as the prosthetic foot is displaced toward the rear, the stride on the prosthetic side will be of DECREASED LENGTH.* Nor does it matter whether the foot position is altered by changing the inclination of the shank, as when a tilt is made in an alignment unit at the knee, or the foot position is changed by a translatory motion, as when a sliding mechanism is used in an alignment unit at the knee, even at the foot for that matter. It is the displacement of the foot relative to the stump that counts.

If the foot is displaced medially there are a variety of possibilities; *(a) the amputee may adduct the hip and walk with a narrow base.* Watch for gapping at the brim of the socket laterally and sense the low force situation there and how the forces would be high in the crotch and at the lateral side of the stump distally. He may catch himself early on the sound leg to "get away" from the crotch and distal pressures or *(b) he will abduct the hip, moving the foot laterally for relief and increased voluntary control; in this case he will lean over the prosthesis to gain balance or (c) he may stay erect, imparting a strong lateral push to his body with the sound leg as he enters weight bearing on the prosthesis.*

A variety of possibilities also exist if the foot is displaced laterally. The amputee will *(a) compensate by moving the foot toward the midline to decrease the walking base or (b) he will leave the foot displaced laterally and lean over the prosthesis to achieve balance. He may (c) leave the foot laterally positioned and merely stay erect, giving his body a lateral impulse with the sound leg as he enters the weight bearing phase on the prosthesis.*

You will notice that there is a degree of voluntary control over conditions which result from medial or lateral displacement of the foot. How the amputee responds to such changes in foot position depends to an important degree on the length and strength of his stump, or more importantly, on the capacity of the stump to tolerate the forces and to generate the forces for control of the prosthesis through hip muscle actions and shifts in the centre of gravity.

3. Foot angle

Toe down *imposes a tendency to SHORTEN the stride on the NORMAL side.* Toe up *has the opposite effect, LENGTHENING the stride on the NORMAL side.* You may have noticed among geriatric or weak amputees the tendency to step up to the level of the prosthesis with the normal leg so that the feet are together and then to step out again with the prosthesis. This asymmetry is his response to the forces being felt against the stump as the front lever of the foot creates an increased moment against the stump.

As you can see, the actions of the front and back levers of the foot are affecting the *timing* of the stride. You can easily sense this intuitively. Imagine the force-point moving from heel to toe as the prosthetic foot supports the amputee with the prosthesis at different angles of inclination as it passes from heel contact to toe support. Sense the "bending" effect this would have. And you must consider what is happening at the top end of the prosthesis too! As it happens, there is a corresponding force-shift from the *front* brim of the socket at heel contact when the inguinal crease area is a major weight bearing area to the *back* brim of the socket as weight is borne through the toe of the prosthesis. *This synchronous tilting backward and forward of the line of action of forces through the prosthesis between heel contact and toe support has the effect of keeping forces acting on the knee pivot nearly constant when alignment is optimum, or at least within a good range for voluntary control over the knee.* Thus, when the foot angle as viewed from the side is correct, even when the line of action of forces falls *behind* the knee axis, stability is maintained. This is because during that period—when the short hind lever is in effect—both feet are in contact with the ground *(double support)* and hip extension on the prosthetic side can add a stabilizing force to the knee until, at the later stage when double support has ceased, the ground reaction point has moved sufficiently forward on the foot to set the line of action somewhat in front of the knee axis. You may have noticed how plantarflexing the prosthetic foot improves knee joint stability for amputees who fail to pull back on the hip to add the needed stabilizing force at the knee. In the German system of alignment, the amputee essentially toe-walks all the time, and the foot is displaced back to compensate. Foot angle and foot position as viewed from the side are significant factors in the comfort, energy consumption and cosmetic effect of the prosthesis.

I have often used toe-in to provide a quick check of whether or not the amputee needed more *medial placement* of the foot, and used toe-out for the reverse. From this you can easily deduce the significance of toe-in and toe-out on prosthetic function. However, in the extreme, the effects are opposite at heel-contact to what they are at toe-support as you can easily visualize. This sort of positioning is fixed by cosmetic requirements as a rule, and this is adequate when everything else is done well.

Summary

1. *A long prosthesis forces drop of the pelvis on the normal side, can cause crotch pressure and distal femoral pressure leading to discomfort, can reduce voluntary control, may force the amputee to walk with an abducted stump hip for stance phase and to swing the leg outward for toe clearance in swing phase or to compensate by rising up on the sound foot to clear the prosthetic foot.*

2. *A short prosthesis may shorten stride, increase listing over the prosthesis in stance phase, enhance prospects for a narrow walking base and increase the ease of balancing over the prosthesis in stance phase.*

3. *Moving the foot forward relative to the stump increases prosthetic stride length.*

4. *Moving the foot posteriorly relative to the stump does the reverse.*

5. *Displacing the foot medially has variable effects which may include walking with a narrow base, moving the foot laterally by hip abduction of the stump for relief of pain and increased voluntary control. Stump length and strength is a strong mediator in what choice the amputee makes as he tries to get comfort, save energy and maintain a cosmetic gait.*

6. *Displacing the foot laterally may lead to the amputee adducting the stump to reduce the width of the walking base, or force him to lean over the prosthesis during stance phase on it, or lift his body over the prosthesis by means of a strong lateral impulse from the sound leg as the prosthesis becomes weight-bearing with the torso erect.*

7. *Increasing downward inclination of the prosthetic toe shortens stride on the normal side.*

8. *Tilting the toe upward on the prosthetic side lengthens stride on the normal side.*

9. *Knee axis stability is increased for a larger percentage of the stance phase on the prosthesis when the prosthetic toe is inclined downward or when the prosthetic foot is moved forward with respect to the stump.*

10. *Toe-in and toe-out have comparable effects to moving the foot inward or outward except that the effects are lessened or reversed at heel contact, tending toward the effects indicated as the step advances.*

12. *Inversion-eversion changes are basically for cosmetic effects.*