A Calf Corset Weightbearing Ankle-Foot Orthosis Design

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Introduction
Designing and providing an ankle-foot orthosis (AFO) that allows the client to walk comfortably and safely without bearing weight through the skeletal elements of the lower leg and foot has proven to be a daunting challenge. The patella tendon weight-bearing (PTB) ankle-foot orthosis is often prescribed for unweighting the lower tibia, ankle and foot despite fairly wide recognition that it achieves only partial unweighting. This orthosis design dates back at least to the early 1960s (1, 2, 3, 4, 5). Some articles report very good clinical results but note that extraordinary care in fabrication and follow-up is necessary (6). The orthosis presents such a challenge due to the anterior-posterior (A-P) pressures and circumferential constraint in the proximal brim area.

It is worthwhile to note that a PTB AFO presents significantly different challenges than a PTB prosthesis. First, the "pre-flexion" commonly fabricated into a BK prosthesis increases the projected undercut of the patellar tendon and tibial flare areas. Pre-flexed alignment is a much less practical option in an orthosis and requires a tighter A-P dimension. The second, and perhaps the more important, difference is the pumping action derived from every step taken with a BK socket. That aid to circulation does not exist in the AFO counterpart of the PTB prosthesis. Finally, tightness of the PTB AFO brim while sitting cannot be relieved by a slight distal displacement as occurs with a BK socket.

Design
Our earliest design efforts involved trying to augment patella tendon weightbearing (which we knew to be marginal) with calf weightbearing. As time went on we found calf weightbearing so effective, and patella tendon weightbearing so problematic, we dropped the latter and concentrated on optimizing the former. We created a design that uses a calf corset to transfer weight to the AFO. The corset circumferentially encompasses the inverted cone-shaped lower leg up to the level of the apex of the gastrocnemius/soleus muscle belly (see Figures 1 and 2). At that point the posterior coverage ends, but anteriorly, the orthosis extends up to or near the patellar tendon. In virtually all nonpara-
lytic cases, the calf muscles (especially the plantar flexor muscle group) present sufficient projected undercut area to achieve 100 percent unweighting. To achieve this, however, requires certain design features, which will be noted shortly.

We first used this design for people with fractures of the distal tibia, talus or calcaneous. Those fractures were often transcondylar; some were surgically fixed internally. The design also is useful for treating talar Osteochondritis Dissecans. More recently we have used it to follow reconstructive orthopedic surgery after crushing injuries to the mid- and hindfoot. Some of our colleagues have used this design to unweight neuropathic (Charcot) ankle and foot joints and heel ulcers (7, 8).

Let us back up a bit and consider some of the treatment factors and variables so we may best understand the orthotic design requirements and rationale. First, we must appreciate that since the taper of the inverted, cone shape (and the corresponding projected undercut area) is not large, we must achieve an almost perfect match between the contours and alignment of the corset and the anatomy it is to fit against. Next, we must be aware that edema, atrophy and other factors can and do cause variations, over time, in the size and shape of the lower leg. Changes in size and shape usually are not symmetrical so they contribute small but important alignment variations.

We have found the following design features essential for true weight transfer for a period of months when the size and shape of the lower leg has varied.
1) The calf corset must be of a moldable and self-reconforming material.

2) The calf corset must be suspended within the orthosis frame in a way that allows the medial-lateral (M-L) diameter, as well as the A-P diameter, to reduce or pull-in as the cuff is laced tight.

3) The calf corset must be suspended in such a way to allow some self-aligning within the frame of the orthosis.

The reconforming requirements lead us to use a full-leather, lacet corset. Leather has been neglected by some practitioners, but it offers good contourability, permeability and tensile strength, making it a perfect material for leg corsetry. It can accommodate complex and time-variable contours without compromising structural stability or fit as would fabric or plastic.

The calf corset is suspended within the AFO structure at four points. The proximal suspension points are simply riveted to the plastic shell structure near the top of the polypropylene shell's medial and lateral extensions. The plastic shell at those points may spring inward or outward as needed to follow size changes. The other suspension points are attached at about mid-corse with metal “leaf” springs. The leaf springs let the corset pull away from the structure and/or move anteriorly and posteriorly as necessary to correct any alignment imperfections. You can see how this suspension scheme transfers loads from the conformable corset to a rather rigid weight-bearing structure without letting the latter's rigidity impose constraints that hurt the corset's fit.

The corset and shell of the orthosis extend to the proximal tibia anteriorly but only to the crest of the calf muscle belly posteriorly. The posterior trimline is proximal to minimize forces and pressures generated against the tibia by floor reaction forces between foot-flat and toe-off. Those forces can be quite large in cases where orthotic ankle motion is totally or partially blocked. Modifying the client's shoe to give a “rocker” or roll-over effect is an option for reducing the magnitude of these anterior floor reaction forces and the high stresses they induce across the ankle joint and stirrup. The posterior trimline is as shown (see Figure 3) to allow the client to loosen the corset by merely pushing the orthosis a centimeter distal on his or her leg when seated. This very low posterior trimline is an important measure of comfort. The low posterior trimline in no way detracts from the function of the orthosis.

When we first began to see how effective the calf corset was, we decided to measure and record the amount of weight transferred. That was soon abandoned as we discovered that by simple adjustment of the calf corset height, we could eliminate weight-bearing contact between foot and foot plate. A calf corset weightbearing AFO fabricated for the primary author confirmed that total weight transfer could be accomplished and maintained comfortably throughout a day-long wearing period.

**Conclusion**

Decisions about limiting ankle motion are very important. For fractures we recommend that the ankle joint be fixed. Those clients should be taught to walk without any forceful calf muscle activity because the calf muscles themselves can exert very large forces on the bony elements—even in the leg when seated. This very low posterior trimline is an important measure of comfort. The low posterior trimline in no way detracts from the function of the orthosis.

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absence of weightbearing. We recommend the same for clients with Osteochondritis Dissecans, neuropathic (Charcot) joints or metatarsal ulcers. Ankle joint range-of-motion may, in most cases, be increased by increments before discontinuing the orthosis (i.e., fracture treatment).

When calf muscles are severely atrophied, such as in spina bifida, they do not present enough inverted cone taper for this type of suspension. We have used a similar approach in one such case by attempting to achieve suspension by using the tibial flare area just distal to the knee joint. Although we were successful, it was so challenging we would list severe calf atrophy as a contraindication to the use of the calf corset weight-bearing design. We would also urge caution in using this design for patients with significant peripheral-vascular disease and for patients with significant sensation loss in the calf area.

It seems very unlikely that the concept of calf-corset weightbearing is new. It is such a direct, simple and intuitive approach, many others must have fabricated very similar designs in the recent and distant past.

References

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