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The use of orthoses to return young patients to impact activities following complex foot and ankle injuries

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The decision to salvage or amputate a mangled lower limb following trauma is not an easy one (Figure 1). In 1987 Hansen declared in his editorial, that Limb Salvage (LS) surgery following Gustilo and Anderson (GA) Type 3C tibial fractures leaves patients, 'divorced, demoralised and destitute'[1]. Despite extensive research throughout the nineties, by the turn of the millennium, there was no consensus in the literature of the best treatment for the mangled lower extremity. Consequently, there was a need for an evidence base to elucidate which management option, amputation or LS, would provide the best outcome for patients.

The Lower Extremity Assessment Project (LEAP) was a North American based, multi-centre prospective longitudinal study, aiming to answer the question of whether amputees or LS patients had better outcomes following High Energy Lower Extremity Trauma (HELET)[2]. At 2- and 7-year follow-up, LEAP found no statistically significant difference in the Sickness Impact Profile (SIP), (the primary outcome measure), between the primary-, secondary-amputation, and LS groups, but all outcomes were worse than population norms[3,4]. >>

Figure 1: Radiograph following a deck-slap injury showing a mangled foot.

Figure 2: Solid Ankle Foot Orthosis (AFO).

Figure 3: Posterior Leaf Spring (PLS) orthosis.

LEAP finished recruiting over 20 years ago and since then advances have been made in prosthetic design and rehabilitation pathways. Consequently, Patient Reported Outcome Measures (PROMs) and functional outcomes for some amputees, particularly young previously active individuals, are superior to LS patients[5]. It is, however, desirable to prevent amputation where possible due to the potential for long term health complications[6]. The observed technological advances in prosthetic design lend themselves to orthotic design to augment function following LS without the need for amputation. If orthotics can be improved to allow young active individuals to return to impact activities, PROMs for LS patients may be brought in line with amputees, or even potentially match population norms.

Pathology

To understand which orthotic options are likely to improve outcomes for LS patients, it is important to understand the functional deficits these patients experience. Clearly, LS encompasses a wide variety of injuries, diagnoses, and therefore deficits. Deformity, weakness of plantar and/or dorsiflexors, and mechanical pain, as well as functional deficits consequent on arthrodesis and nerve injury, are present in LS patients following HELET. Functional outcomes are further reduced by resultant slower gait, asymmetry due to pain or functional deficit, and energy inefficiency.

Post LS surgery, despite efforts intraoperatively to minimise abnormalities, gait has been noted to change with the severity of the gait deviations predictive of a poorer outcome. Slower preferred walking speed, a lengthened stride time, a deterioration of balance control, and concomitant involvement of the knee joint are all associated with longer LS recovery times.

Orthotic use in those with a salvaged limb

To allow individuals following LS to undertake activities, orthotic devices may be prescribed. Some patients may require several different orthoses to enable a spectrum of activities. Although there are a number of orthoses on the market they can be divided into broad categories. Ankle Foot Orthoses (AFO) are either passive or functional (using motors to enable movement). Passive AFOs fall into two further broad categories: static or dynamic. Static orthoses prevent any motion at the ankle joint and dynamic orthoses allow some motion in the sagittal plane.

Solid AFOs (Figure 2) Are usually made from thermoplastics which are thin and light. They hold the ankle static throughout gait and are of use for patients with dorsiflexor weakness. This level of support however comes at the cost of compromise of the rockers of gait. An example is the Posterior Shell Orthosis. This type of orthosis may be of use during daily activities, but the material and restrictive design means it cannot be worn for impact activities.

An alternative is the patella tendon bearing AFO (PTB-AFO). The **PTB-AFO** is a static AFO that offloads the ankle joint by preferentially placing the forces through the patella tendon. This reduces axial loading of the distal limb and hence improves pain at the ankle joint. These orthoses can be very useful for patients with post-traumatic OA to reduce mechanical pain. Again, during daily activities this type of orthosis may be of use, however the lack of flexibility means it is not suitable for patients wishing to return to impact activities.

Turning to dynamic AFOs, the **Posterior Leaf Spring (PLS)** (Figure 3) Is made of a flexible material to allow for some ankle motion. As the name suggests, a leaf spring action occurs when the AFO is deformed during stance. This energy is theoretically stored and returned at pre-swing. Although in theory this may help with forward propulsion, in practice this does not occur[7]. Although the PLS may be one of a spectrum of orthoses offered to patients, again it is not suitable for running or impact activities.

To overcome deficiencies in the PLS, the **Carbon Fibre Orthosis (CFO)** was created to store energy and allow for impact activities. Unfortunately, although the lower and upper parts of the orthosis are made from carbon fibre, they are joined by a thermoplastic strut which breaks during impact activities. >>

Phase of Gait	Name of phase	% of gait cycle	Action	Comment
1	Initial contact	0-2	The PDAFO positions the foot for heel/midfoot contact (depending on walking or running)	This is useful for patients with dorsiflexor weakness
2	Loading response	2-12	The PDAFO allows for the foot to be placed flat and there is a small amount of tibial advancement	This is useful for patients with dorsiflexor weakness
3	Mid-stance	12-31	The PDAFO acts as a 'load sharing' or 'load redirecting' device in a similar way to a patella tendon bearing device. This limits the load passing axially through the ankle joint and either shares or redistributes that load in an anterior direction	This aids with pain relief in the case of ankle arthritis
4	Terminal stance	31-50	The PDAFO acts as an energy storing orthosis (like the CFO) with the structs deforming to store energy	This aids patients with plantar flexor weakness or following fusion
5	Pre-swing	50-60	The PDAFO returns energy to augment function at toe off	This aids patients with plantar flexor weakness or following fusion
6	Swing phase	60-100	The PDAFO holds the foot in a dorsiflexed position to prevent the toe contacting the ground and ensures the foot is appropriately positioned for initial contact	This helps patients with dorsiflexor weakness

Table 1: Mechanism of action of the PDAFO.

The AFO most likely to return individuals to impact activities is a **Passive Dynamic Ankle Foot Orthosis (PDAFO)**. A PDAFO combines the design features of the aforementioned orthoses, whilst being made entirely of carbon fibre. Two of the most prevalent PDAFOs are the Intrepid Dynamic Exoskeletal Orthosis (IDEO) used in the US and the Bespoke Offloading Brace (BOB) used in the UK. These orthoses were designed to improve patient-performance outcomes for young active patients following LS and attempt to prevent delayed/elective amputation.

Passive Dynamic Ankle Foot Orthosis (PDAFO)

The PDAFO is a custom-made orthosis (Figure 4) and works in several different ways (Table 1).

The PDAFO is of use in a heterogeneous population of patients including those with weakness in plantar and dorsiflexion, mechanical pain on loading of the hind and mid foot, nerve injury, and following ankle and/or subtalar fusion. Up to 80% of wearers have been able to return to running[8,9]. Statistically significant improvements have also been demonstrated in measures of agility, strength, and power bringing measures in line with population norms[10-14]. It is important to note that the PDAFO works best when combined with a bespoke rehabilitation programme[15].

The PDAFO does not work for everyone, there is still a 20% amputation rate following use in patient populations previously considering elective amputation[12,16,17]. Despite this, the outcome for amputees following a trial of the PDAFO is not statistically different from those who pursued amputation primarily[15]. Therefore, it is a good option to offer individuals prior to elective amputation.

Figure 4: PDAFO component parts.

The future

Just as a non-disabled person may choose a pair of shoes for a particular activity, patients may require prescription of several orthoses designed for different purposes. The PDAFO is a good option to return previously active individuals to impact activities following complex foot and ankle injuries. Although it works for a heterogenous cohort of individuals, some will abandon it and others will pursue elective amputation, where again there are a range of prosthetic limbs to cover a variety of needs. Although the PDAFO is currently an expensive treatment option, it has the potential to return economically productive individuals to work and therefore should be considered as part of a rehabilitation package. Orthotic technology has progressed rapidly over the past twenty years, but research has not kept pace with that of prosthetic design and more can and should be done to augment function in limb salvage patients to prevent elective amputation. ■

References

References can be found online at www.boa.ac.uk/publications/JTO.