7. LOWER EXTREMITY ORTHOSES

7.1.1. Foot Orthoses (FOs)

Foot orthoses (FOs) are the most common type of lower limb orthosis. FOs are used to realign the foot, change the distribution of pressure in the foot, and reduce pain. In addition, they can correct for problems at more proximal joints (e.g., leg length discrepancy, weak quadriceps, and osteoarthritis of the knee). An FO can consist of an insert that fits inside the shoe, an internal shoe modification, an external modification to the heel or sole of the shoe, or combinations of the previous (Figure).

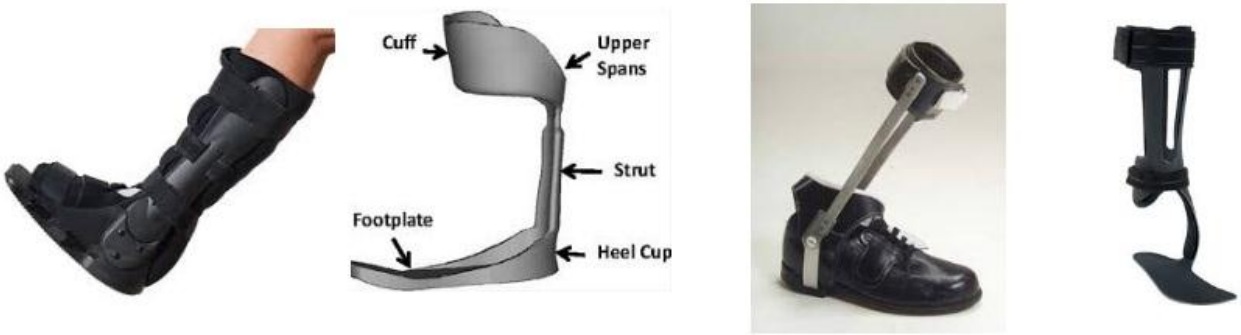
Shoes may be considered FOs when prescribed for therapeutic reasons. A shoe with an enlarged toe box can be used to relieve pressure on claw, hammer toes, and bunions. Inserts inside the shoe are used to reduce pressure on load-bearing areas. Internal shoe modifications can provide the same benefits as inserts but cannot be transferred to another shoe. An important anatomical consideration in the use of foot orthoses is the goal of keeping the subtalar joint in a neutral position. The subtalar joint is the joint between the calcaneus and talus. It allows for the motions of inversion and eversion as well as supination and pronation at the ankle. Abnormalities in the alignment of this joint can limit proper functioning of the foot, including gait abnormalities, and lead to pain and degeneration in all joints of the lower limb. Maintaining neutral subtalar joint alignment is the primary goal of FOs.

In OA of the knee, even though the site of pathology is at the knee, orthotic treatment can be accomplished with FOs. In typical knee OA, the medial knee joint is more significantly affected. When the medial knee joint decreases in size, the knee tends to deform such that the lower leg and foot are medially displaced (a condition known as genu varum, or "bowlegged"). A lateral heel wedge can be used to compensate for this condition and keep the leg in a normal alignment, thereby alleviating pain and preventing further degeneration. Plantar fasciitis is a condition of very small tears in the fibers of the plantar fascia at its site of insertion on the bottom of the calcaneus. This creates inflammation at this site, which results in heel pain. The condition can be caused by excessive mechanical forces placed on the plantar fascia, for example, in an excessively pronated foot, tight Achilles tendon, or high arches. This condition can be treated with an orthotic device that distributes the weight to minimize pressure on the painful area. A device as simple as a heel pad (or heel wedge) can be used for this purpose.

7.1.2 Ankle–Foot Orthoses

AFOs contain a component that crosses the ankle joint. Their primary function is to control the amount of dorsiflexion and plantarflexion that the ankle can move through. However, all AFOs have a component that connects to the foot, and can therefore be useful in controlling movement at the subtalar joint as well as providing medial–lateral ankle support. As with FOs, AFOs can be useful not only in conditions that affect the foot and ankle but in conditions of more proximal joints as well. For example, an AFO can be useful in the treatment of quadriceps weakness, a condition of instability at the knee. Unlike FOs, AFOs cross a joint and have attachments both above and below the joint. Therefore, more components are required and the device as a whole is somewhat more complex. It is useful in the discussion of AFOs to divide them into two broad categories: metal and plastic. Metal AFOs have largely been replaced by plastic AFOs

The metal AFO is made up of at least four components: (1) the calf band, which attaches the device to the leg, (2) the metal uprights, (3) the ankle joint, and (4) the attachment to the shoe (Figure).



The calf band is made of metal only in its posterior half. The anterior half is a Velcro band. The function is to attach the AFO to the leg and to prevent posterior movement of leg relative to the ankle. The metal uprights connect the calf band to the ankle joint and shoe attachment, and can provide some medial–lateral support. The ankle joint is made up of several components that will be discussed further in the following text. The attachment to the shoe may be a solid or a split stirrup. A solid stirrup is permanently attached to the shoe, whereas a split stirrup (or calipers) allows the uprights to be removed from the sole plate that attaches to the bottom of the shoe. The metal ankle joint is made up of two channels, one anterior and one posterior. Depending on the clinical application, pins or springs can be inserted into each channel.

A pin is placed in a channel to prevent motion. A pin in the anterior channel will prevent dorsiflexion of the ankle, and it is known as an "anterior stop" or "dorsiflexion stop." A pin in the posterior channel will prevent plantarflexion of the ankle, and it is known as a "posterior stop" or "plantar stop." A spring placed in a channel will assist with motion at the ankle. A spring in the posterior channel will help the ankle dorsiflex, for example, in a patient with weakness of their dorsiflexion muscles that results in foot drop during ambulation, causing frequent falling. Springs are not typically used in the anterior channel because the amount of force needed to provide

for functional plantarflexion would be too great to be accomplished with a spring. As mentioned earlier, plastic AFOs have virtually replaced metal AFOs in clinical use. AFOs made from plastic are less expensive, more cosmetic, lighter, and provide better foot support when compared to metal AFOs. Cosmesis is improved because the plastic AFO can be worn inside the patient's shoes. They can be prefabricated (off-the-shelf) or custom molded to the specific dimensions of the patients and the specifications of the physician.

Plastic AFOs can be divided into two categories: solid or hinged. A solid AFO is made from a single piece of plastic, and it has no extra ankle component (Figure). Even though there is no ankle joint, some motion is allowed at the ankle due to the inherent flexibility of the material. The angle between the foot and the leg will be determined by the clinical needs of the patient. For example, in a patient with dorsiflexion weakness, the angle should be set to 90◦ to allow for toe clearance during ambulation. A hinged or articulated plastic AFO has two plastic components connected by a metal ankle joint. They are used when some ankle motion is wanted, and complete restriction of movement is not necessary. The metal ankle joints are identical to those used in metal AFOs, and have the same components and functions.

The stability of the ankle joint in a plastic AFO is determined by three factors. (1) the trim line, which describes the line of the most anterior extension of the part of the AFO that is posterior to the ankle (the posterior leaf); if the trim line is moved anteriorly, the ankle becomes more stable; (2) the thickness of the plastic; a thicker plastic will provide more stability; and (3) corrugations in the posterior leaf, whose presence makes the ankle more stable

7.1.3 Knee Orthoses

A knee orthosis (KO) is an external device that crosses the knee in order to provide support, correct deformity, or prevent injury to the knee itself. Because the knee is the only joint involved, their use is limited to conditions that affect only the knee. Although they are used for a wide variety of applications, the use of KOs is a subject of some controversy. Although there are a few indications for KOS that are well supported by scientific evidence, the amount of knee orthoses prescribed far outnumbers those for which there is consensus regarding their utility. It is widely accepted that KOs are useful patients with genu recurvatum (hyperextension of the knee). By applying the three-point system of orthosis design, a Swedish knee cage can keep the knee from hyperextending (Figure).

One brace is placed posterior to the knee joint at the level of the knee. The other two bands are placed anterior to the knee joint, one above and one below the level of the knee. With the use of a knee joint that allows full knee flexion while limiting extension beyond neutral, the patient can be protected from genu recurvatum.

Many providers and patients have advocated the use of KOs for prophylaxis against knee injury or in the rehabilitation from a knee injury. These braces are often prescribed to be worn during athletic activity. Despite their widespread use, there is little scientific evidence to support their efficacy, and the use of these devices is controversial. In some cases, the devices may be detrimental to the patient by increasing the amount of energy required for walking or running, or by providing the wearer with a false sense of security.

A single-axis knee joint may be placed in line with the natural knee joint or may be offset in the anterior–posterior plane. A knee joint that is offset posteriorly can help stabilize the knee. If the knee is offset posteriorly, the ground reaction force that is applied to the lower limb from the ground will be directed in front of the knee. This will have the effect of promoting knee extension. By promoting knee extension, knee buckling can be prevented, thus making the knee more stable. A knee lock is a component of an orthotic knee joint that locks the knee in a given position.

7.1.4. HKAFOs and Reciprocating Gait Orthoses

Hip–knee–ankle–foot orthoses (HKAFOs) are very similar to KAFOs, but contain a component that attaches to the patient's trunk. The most common type of HKAFO is a reciprocating gait orthosis (RGO). An RGO is a bilateral HKAFO with both limbs connected. It is composed of a series of cables and pulleys. The purpose of the equipment is to provide for unilateral hip flexion simultaneously with contralateral hip extension. When a patient wearing a RGO lifts one limb off the ground, the cables and pulleys provide hip flexion of that limb, thereby advancing the limb, or accomplishing a step. Next, the other limb is lifted from the ground, and that limb is advanced to complete one full stride. RGOs are used in conjunction with upper limb crutches to assist in ambulation for patients who may otherwise not be able to ambulate. Much like KAFOs, RGOs are typically used in paraplegic patients. RGOs are usually prescribed to children aged 3 to 6 years. Similar to ambulation with KAFOs, ambulation with RGOs is slow, inefficient, and energy consuming. Almost all patients will choose to use a wheelchair as a primary means of ambulation, but RGOs can provide an excellent resource for exercise and may allow the patient to experience the world "at eye level."

7.2. Upper Extremity Orthoses

Upper extremity orthoses are mainly prescribed in order to provide support, prevent deformities; maintain function; and/or restore function of upper limb. Depending on the intended purpose, these orthoses are either static, providing complete immobilization, or dynamic, allowing only functional motion while restricting others. Typical conditions under which upper extremity orthoses are prescribed are fractures, nerve injuries (median, ulnar, or radial), brachial plexus injuries, burns, inflammatory joint conditions (rheumatoid arthritis), degenerative joint conditions (osteoarthritis), postsurgical management of tendon injuries, spasticity (postcerebrovascular accident or cerebral palsy), and repetitive stress/strain disorders (carpal tunnel syndrome). The prescription guidelines for all orthoses are very specific, which depends on each patient's medical condition and functional requirements. Also, orthosis wearing schedules and follow-up are crucial factors in maximizing the effectiveness of orthosis and potentially eliminating or reducing adverse effects that may result from its inappropriate use.

7.2.1. Finger Orthoses

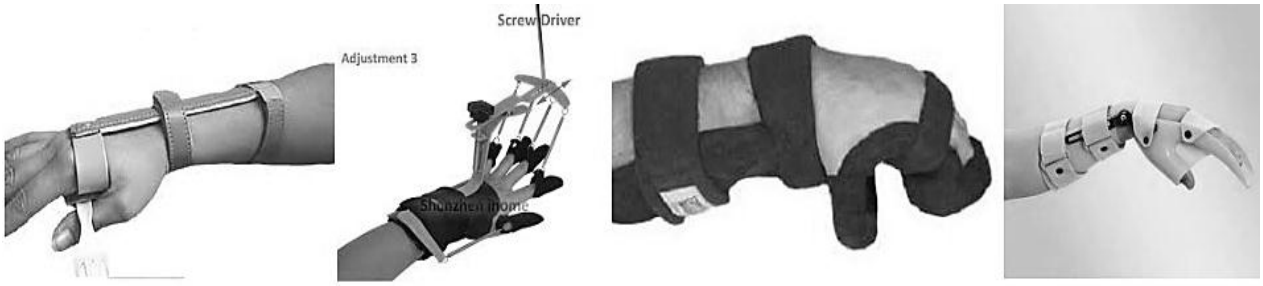
The first category in finger orthosis comprises the immobilization orthoses, which are typically used to restrict motion at the metacarpophalangeal joint (MP), proximal interphalangeal joint (PIP), and distal interphalangeal joint (DIP) individually. The dynamic finger orthoses are used for mobilization of PIP and/or DIP joints. Two types of orthoses are prescribed for individuals with rheumatoid arthritis for prevention of deformities of boutonniere and swan-neck. Boutonniere deformity results in flexion of PIP and hyperextension of DIP, whereas swan-neck results in hyperextension of PIP with flexion of DIP joints. The orthosis prescribed for boutonniere deformity prevent flexion at the PIP joint and extension at DIP. The orthosis prescribed for correction of swan-neck deformity prevents hyperextension at PIP and flexion at DIP joints. The two aforementioned orthoses are important as they prevent occurrence and/or aggravation of deformities while not restricting functional use of the hand in other activities.

7.2.2. Hand Orthoses

The immobilization orthoses in this category limit motion at the MP, PIP, and DIP all together. These orthoses are also prescribed for prevention of MP joints ulnar deviation, which is commonly seen in individuals with arthritis. Two types of mobilization hand orthoses mainly used are: PIP flexion mobilization orthoses and PIP extension mobilization orthoses. These dynamic orthoses are effectively used in flexor tendon contracture and postsurgical management of extensor tendon.

7.2.3. Wrist–Hand Orthoses

Wrist immobilization orthoses (WHO) that are typically used to prevent motions of wrist extension and wrist flexion are the dorsal wrist immobilization orthosis and volar wrist immobilization orthosis. An ulnar wrist immobilization orthosis is used to prevent excessive ulnar deviation and the radial wrist, and thumb immobilization orthosis is used to prevent radial deviation while performing activities. The aforementioned orthoses are useful in conditions such as rheumatoid arthritis and deQuervain's condition, which result because of acute inflammation of the abductor pollicis longus tendon. Emphasis, while immobilizing the wrist joint, is placed on maintaining the hand in a functional position of 25 to 30◦ wrist extension. WHO that allow mobilization of the wrist and other joints in the hand are the wrist extension MP flexion mobilization orthosis and the wrist flexion MP extension mobilization orthosis.



The purpose of this orthosis is to develop natural grasp and release pattern after both central nervous dysfunction such as a stroke and peripheral nerve injuries such as radial nerve palsy. Other forms of mobilization WHO consist of MP flexion and MP extension mobilization orthoses, which are commonly used in postsurgical rehabilitation after finger flexor and extensor tendon injuries. WHO are used in decreasing muscle tone in the hand after a stroke or other types of disorders involving upper motor neurons. Antispasticity WHO commonly prescribed are: hard cone and thumb/fingers spreader. Despite extensive clinical prescription, the evidence for the effectiveness of these orthoses in controlling spasticity is limited.

7.2.4. Elbow Orthoses

Two types of immobilization elbow orthoses (Eos) are available: posterior elbow immobilization orthosis and anterior elbow immobilization orthosis. The anterior elbow immobilization orthosis is commonly prescribed after burns in order to prevent elbow flexion contractures. A nonarticular circumferential elbow orthosis is used frequently in acute-stage intervention for a condition known as lateral epicondylitis or tennis elbow. A mobilization orthosis for elbow joint is prescribed after elbow extensors contracture to provide slow, progressive flexion motion for lengthening elbow flexors.

7.2.5. Shoulder Orthoses

Shoulder abduction orthosis is used for immobilization of the shoulder joint in an abducted position and for prevention of an adduction/internal rotation deformity, which is very common after brachial plexus injury or after burn. Humeral orthosis, which is a nonarticular orthosis and is also referred to as a functional brace, refutes the old concept of strict immobilization after fracture, using casting or other techniques.

This orthosis, which is circumferential, is prescribed after a fracture of the shaft of the humerus and is effective in enhancing the healing process while simultaneously reducing complications due to prolonged immobilization. The concept used in designing this orthosis is that partial loading on the bone after fracture enhances activities of osteoblasts, which are the primary factor in bone healing. After hemiplegia/hemiparesis resulting from a stroke, use of shoulder orthoses, also referred to as *hemiplegic sling*, has been indicated as an effective intervention for further prevention of shoulder joint dislocation or subluxation. This orthosis passively holds the shaft of the humerus in the glenoid fossa, preventing dislocation by compensating for lack of voluntary control of muscles and laxity of ligaments around the shoulder joint. However, evidence for their effectiveness as an intervention after stroke is lacking. Also, use of this form of orthosis is recommended to combine with other rehabilitation techniques, such as therapeutic exercises and activities, in order to prevent future nonuse or neglect of the affected extremity.

7.2.6. Shoulder–Elbow–Wrist–Hand Orthoses

The most common form of shoulder–elbow–wrist–hand orthoses (SEWHO) is one given to patients after brachial plexus injury. This orthosis keeps the upper extremity in abduction, externally rotated at the shoulder joint, extended and pronated at the elbow, and extended at the wrist joint, thus preventing occurrence of further deformity.



7.2.7. Advances in Upper Extremity Orthoses

Advances in upper extremity orthoses has been indicated in several domains. Use of functional electrical stimulation (FES) adjunct with an upper extremity orthosis is one such emerging intervention. Other forms of upper extremity orthoses are those that utilize external power sources for either providing continuous motion, such as continuous passive motion (CPM) orthosis, or to provide assistance during upper limb motion. One such form of powered upper extremity orthosis was designed and tested for providing continuous assisted or resisted motion of shoulder, elbow, and forearm joints altogether or individually. This externally powered orthosis called a motorized upper limb orthotic system (MULOS) was reported to be effective in prevention of upper extremity joint contractures, assisting in daily functional tasks, and improving strength of upper extremity muscles.