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Ankle Foot Orthosis: A review

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Abstract

Orthoses is an outer external tool or device which used to assist or restrict body parts movement by aligning, protecting and support. Ankle foot orthosis (AFO) is one of the widely utilized oethosis for patient has foot drop, or other problems in foot and ankle. There are many types of AFO according to the materials that form it including metal, plastic and carbon AFO. The plastic AFO is the most prevailing AFO style, including a small calf exterior and a narrow ankle trim line behind the malleoli. While carbon type have become more popular type in the previous decade. It is an incredibly light in weight and strong material. In addition, there are many recent trends in AFO. First, The AF Servo's back is constructed of plastic, while the front is constructed of fabric, with the trimline extending beyond the lateral malleolus and it is pre-assembled in a range of sizes and can be worn instantly by twisting the dial to speed the manufacturing process. Second, TurboMed is a dynamic AFO that can be worn on the outside of a variety of different types of shoes, including sneakers, shoes, and sandals. The 3D printed AFO is a one-of-a-kind orthosis created by additive manufacturing, a process that layers materials to create a solid shape which is manufactured using 3D printers. Finally, Kenaf composites are made of natural fibers and meet the minimum mechanical property standards for AFOs.

Keyword: Orthosis and ankle foot orthosis.

Introduction

Orthoses is an outer external tool or device which used to assist or restrict body parts movement by aligning, protecting and support. It able to improve the function of the movable parts like limbs of the human body and correct or prevent deformity. Orthosis is considered as “a medical device that externally applied to improve or restore structural and functional characteristics of nervous and musculoskeletal systems”. The lower limbs orthosis is a medical device attached or applied to the lower segment of the body in order to enhance the function via providing support by stabilizing gait, correcting flexible deformities, preventing progression of fixed deformity and controlling motion (1-3). Orthotics have been utilized by patient from wide range and varying communities involving frail elders, many athletes and others (4). There are various kinds of orthoses involving foot orthotics, ankle foot orthoses, knee-ankle foot orthosis, and Hip-Knee-Ankle-Foot Orthosis (5).

Ankle foot orthosis (1) is a brace or orthosis that places around the ankle and part of the foot. AFO is applied externally which used to control the motion and position of the ankle, correct deformities or compensate for weakness (6). It is represented in Figure 1. AFO is design to support and protect ankle and foot or enhance walking. These orthoses usually start below the knee and extending behind the ankle then under the foot. They are used to help align or support the ankle and foot. In addition, they can be utilized to prevent the contractures of muscle in the calf. AFO comes in different designs in order to meet the required need for each condition and has benefit in a wide range of cases like stroke, cerebral palsy, trauma, spinal cord injury, nerve damage, foot drop and others (6, 7). This work aims to review the AFO, its materials and the recent advances related to it (8).

Figure 1. Ankle-foot orthosis [6].

AFO types

The most AFO types are required as braces for patient with various lower extremity problems can be as follow:

1. Metal bars: is usually utilized in specific scenario such as neuropathic feet, post-polio, etc. as shown in Figure 2a.
2. Total contact: is made of material provides intimate fit, total contact with leg and sleek. The better patient comfort and compliance are get from using this type of light weight with 150-200 g, this sort explained in Figure 2b.
3. Floor reaction, uses force via foot plat toe aspect to prevent subsequent knee collapse and forward tibial progression, Figure 2c.
4. Unweighting, uses prosthetic principles that may be total surface bearing (TSB), patella tendon bearing (PTB) or specific weight bearing, Figure 2d.
5. Immobilizing, is usually used with deficiency of lower extremity when ankle immobilization is required, Figure 2e.

These types of ankle foot orthoses are used for the following problems of the patient, such as foot bone fractures, diabetic foot, distal tibia/fibula fracture and tendocalcaneus rupture. The above mentioned AFO types may be manufactured as non-articulated and articulated [9, 10].

AFOs can be classified according to the substance they are made of:

Metal AFO, (Figure 2a) which consist of an ankle joint, foot attachment or shoe as well as 2 metal uprights with a band on calf join proximally. This type indicated for different pathologies involving the foot with edema, the insensate foot or if there is adjustability in the devices desired. Metal AFO also classified into:

- Single channel ankle joints that provide a plantarflexion stop and assistant to dorsiflextion.
- Bi-channel ankle joints that provide foot assistant for both the plantarflexion and dorsiflexion direction of the foot.

Plastic AFO, (Figure 2b) is the most widely used AFO type. AFOs made of plastic, are the most frequent type. They are primarily constructed of a thermoplastic material, polypropylene (PP), with Velcro straps for tightening. They can be made from a patient's cast or molding. The first way may be appropriate for short term usage, whereas the another is preferable for long-term usage, since it allows for customization of the plastic type, color, and thickness. Trimlines (rigidity degree), foot plate design and degrees of dorsiflexion, are all characteristics of a plastic AFO. The posterior leaf spring (PLS) design is the primary distinguishing feature of plastic AFOs.

This is the most prevailing AFO style, including a small calf exterior and a narrow ankle trim line behind the malleoli. This type is commonly positioned for 5-7 degrees of dorsiflexion and features a quit low-profile 3/4 length of footplate. By inhibiting ankle plantarflexion at heel impact and in the swing phase, the PLS compensates for flaccid foot drop [11]. Additionally, plastic AFOs can feature a hinged ankle joint, as illustrated in Fig (2c), which allows for limited plantarflexion and some dorsiflexion. Nevertheless, hinged AFOs have a smaller range of adjustment than metal AFO type. The footplate design may be 3/4 length, stopping just before the metatarsal heads to facilitate shoe entry, or full length with cushioning, that is often reserved for the most spastic or susceptible foot [12].

Additionally, there are numerous kinds of plastic AFOs that are developed for certain disorders.

Carbon AFOs (Fig. 2d) have become more popular type in the previous decade. It is an incredibly light in weight and strong material, but it is not adaptable and not suit the limb correctly. Its design is optimal for foot drop [13].

Figure 2. Types of AFO [9].

AFO materials

AFOs are composed of cotton or braces, plastic foams, leather, and rubber materials, whereas functional AFOs are composed of rigid, semi-rigid, or flexible graphite or plastic materials. They are typically slim and readily fit into the majority of shoe styles [14]. An AFO may be constructed from a variety of materials, including carbon fiber (CF) reinforced materials that hang on the front of the lower leg, extending all the way to the ankle and inhibiting planar flexion. It can be worn beneath standard shoes and clothing and creates a natural walking pattern [15]. Additionally, the orthosis secures the orthosis to the leg by the use of fasteners. It is constructed from a combination of robust flexible and inflexible reinforcing parts. The flexible element is used to cover the major foot sole portion of the shoe, while the reinforcement element is used to cover a narrow section of the entire frame [16].

The frame is preferably made of thin flexible fiber glass that is reinforced with plastic resin. The reinforcing element is built of stiff CF that is reinforced with plastic resin. The strong flexible element is preferably made of aramid fibers that have been reinforced with plastic resin [17]. The OFO can be built using thermoplastic materials. After warming the thermoplastic sheets in the oven to the correct temperature, they can be simply made and designed in the mold [18, 19].

Recent trends in AFO

1. Servo AF

The AF Servo's back is constructed of plastic, while the front is constructed of fabric, with the trimline extending beyond the lateral malleolus, as depicted in Figure 3a. It is pre-assembled in a range of sizes and can be worn instantly by twisting the dial to speed the manufacturing process. The BOA fit system is a simple and intuitive fitting mechanism that enables the user to easily adjust it for an optimal fit using the simple operational dial. Patients can easily fit their feet into shoes since it gently conforms to the shape of their specific bodies. Additionally, because it prevents loosening, it may avert additional injury. AF Servo is recommended for individuals with mild foot drop who are unable to manually elevate their foot [18].

2. TurboMed

TurboMed is a dynamic AFO that can be worn on the outside of a variety of different types of shoes, including sneakers, shoes, and sandals. TurboMed's mechanical architecture refuels dorsiflexion power instantaneously in reaction to the stride during walking. TurboMed's exoskeleton design enables it to be readily removed from the majority of ready-made shoes without coming into touch with the flesh of the foot or ankle, hence avoiding pressure on bone protrusions or wounds (Figure 3b). Additionally, it is not left- or right-handed and is available in a range of sizes (160–340 cm) [20]. It is made of a tough plastic that can be thermoformed to fit the user's foot width or degree of drooping, and its reasonable adaptability to uneven or sloping ground permits sports such as climbing. TurboMed may benefit individuals who have dorsiflexion deficits, foot drop, hemiplegia, or peroneal nerve palsy as a result of stroke, cerebral palsy, or multiple sclerosis. Additional choices may be introduced on a case-by-case basis. An extension stopper can be fitted to the TurboMed body to limit the bending of the heel support and to decrease the range of motion of the TurboMed body in patients with knee hyperextension, calf atrophy, foot slap, and spasticity. If there is evidence of foot inversion, ankle fixation straps may be used to correct the posture [20]. TurboMed, on the other hand, is utilized less commonly due to worries about the applied load's ability to sustain the plastic materials (15). At the moment, there are only a few research studying TurboMed's effects. Additional research is necessary to determine whether walking abilities and body alignment improve, as well as to detect changes in physical damage such as wounds and edema [18].

Ladlow et al. [22] investigated the passive dynamic AFO effect with TurboMed-like properties on more than 20 patients who had received severe from trauma in lower extremity in 2018. Following a median of 34 months of AFO use, the percentage of patients capable of walking and running independently increased by 21% and 53%, respectively. The percentage of patients who reported feeling no discomfort raised from 13% to become 31%. [18].

3. AFO printed in 3D

The 3D printed orthosis is a one-of-a-kind orthosis created by additive manufacturing, a process that layers materials to create a solid shape [23]. The AFO, which is manufactured using 3D printers, may be fine-tuned using software to fit bone protrusions or incisions, enabling the manufacture of orthoses that are almost difficult to fabricate using conventional procedures [24]. When used to thicken or thin a specific area or to create perforations for ventilation, AFO can be shaped in a variety of ways and neatly without leaving surrounding fractures [23, 25]. The strength points of 3D printed AFOs involve rapid manufacture, as other conventional orthoses need a long time to create due to manual assembly of the individual parts; reproducibility with the same quality at any time, as the pieces are easily copied; user customization; and a low price. Additionally, the lightweight design alleviates some of the tension associated with orthosis wear, and the high level of water resistance facilitates cleaning. The material is extremely durable because to its composition of a nylon-based polymer with a high degree of stiffness and impact strength, or thermoplastic polyurethane, a non-toxic and highly flexible thermoplastic filament [26]. The 3D-printed AFO can be used to treat persons who suffer from foot drop, Charcot–Marie–Tooth disease, or plantar fasciitis as a result of a stroke, cerebral palsy, or multiple sclerosis [27]. Xu et al. [27] randomly allocated 60 patients with plantar fasciitis to receive a prefabricated AFO or a customized 3D printed AFO in 2019 and compared the degree of pain eight weeks afterwards. As a result, the mean visual analog scale score decreased significantly in the group wearing prefabricated AFO, from 8.72 3.93 to 5.25 1.22, and in the group wearing 3D printed AFO, from 7.34 3.43 to 3.12 0.51; this indicates that the group wearing prefabricated AFO had significantly greater pain-control effects than the group not wearing prefabricated AFO [18].

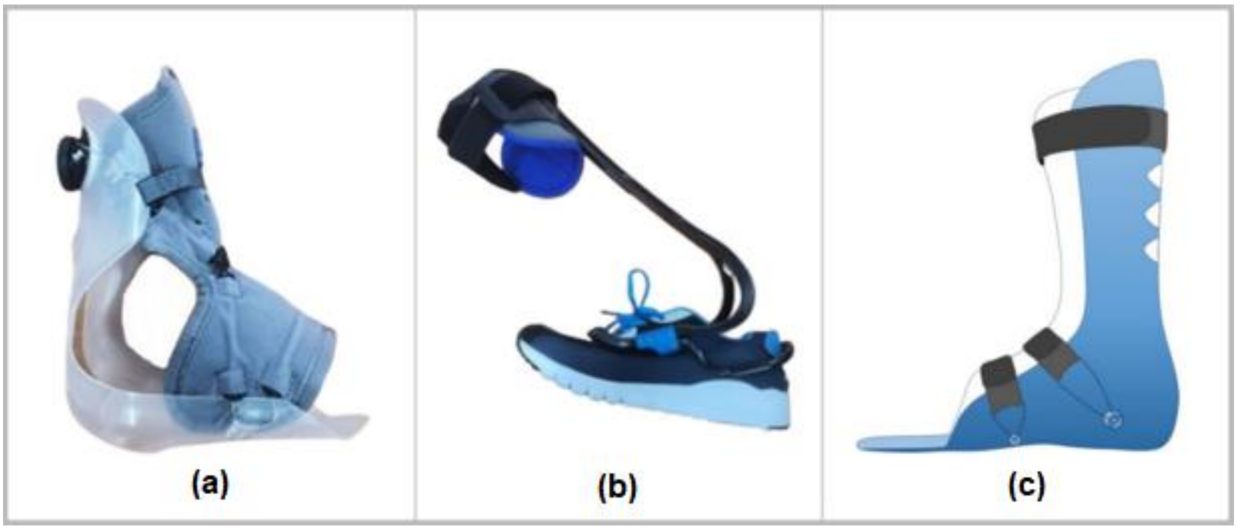

Figure 3. AFOs recent trends, (a) AF Servo, (b) TurboMed and (c) 3D printed AFO [18].

4. Kenaf Composites

Kenaf composites are made of natural fibers and meet the minimum mechanical property standards for AFOs [28]. Kenaf is a woody ground cover that matures in 6–8 months to a height of 5.5 meters; thus, its availability and production costs are irrelevant when used as a composite [29]. Additionally, when used as an orthosis, Kenaf fibers absorb oils and liquids, minimizing skin irritation. Because kenaf cannot withstand the orthosis's limited strength on its own, it is desirable to integrate the reinforcing material (fiber) with the matrix (resin) to extend the life of the orthosis [30]. When AFO are created with Kenaf composites, the material's strength and rigidity are maintained while the cost and weight are reduced, allowing for the production of ecologically friendly and recyclable AFO (22). According to Shahar et al. [28] in 2019, carbon fiber composites are the optimum material for AFOs due to their low weight and high strength when compared to conventional materials such as wood, metal, and leather, as well as plastic and carbon fiber composites. While the cost of plastic orthoses is higher due to the high cost of raw materials, Shahar et al. stated that "Kenaf composites can be used in place of carbon fiber composites or plastics, as well as for additive manufacturing using 3D printing technology"; thus, the use of Kenaf composites is expected to increase in the recent future. However, such analyses are important due to a scarcity of study on the AFO effect made of this composites [18].

Conclusion

There are many types of AFO available. It can be manufactured using various types of materials involving metals, plastic or carbon fiber. This type of orthosis are used for ankle and foot problems such as foot drop. Recently, there is new technics and materials could be used to manufacture AFO like using Kenaf Composites, 3D printer, TurboMed and manufacturing AF Servo. These recently manufactured AFO have shorter production, easier donning, better durability and more sophisticated shape-making ability. However, these new recent types and technics do not preclude the conventional types.

Declaration of competing interest

The authors declare that they have no any known financial or non-financial competing interests in any material discussed in this paper.

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