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Orthoses: A Systematic Review

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ABSTRACT

The purpose of this review paper was to investigate some of the existing studies in the open literature that have novel innovations in the field of orthoses. There are some methods to regain the functions of injured or damaged limbs. It is worth mentioning that orthoses are of paramount importance among these methods. Orthoses are used as an external device to improve the structure and function of an organ in the body. In addition, orthoses prevent pain and deformity development in the limb. There are different types and applications of orthoses and their usage areas are quite wide. Moreover, orthoses are fabricated from different materials such as metal, leather, plastic or a combination of different materials, prefabricated or individually, according to the desired organ by the technical orthopedic specialist. This paper comprehensively reviews the studies that brought innovations to the orthoses literature. Consequently, this review paper provides researchers a useful reference on orthosis parameters such as modelling, material, geometry, and size optimization for key biomechanics applications.

Keywords: Orthosis, assistive device, rehabilitation, biomechanics

1 Introduction

Electromyography (EMG) device is very important for muscle analysis in rehabilitation. Thus, orthoses are developed by analyzing muscle function and emitting muscle movements [1]. Orthoses are medical assistive that enable muscles to regain their strength and support their mechanical and physiological structure through rehabilitation [2]. The orthosis can be used in diseases such as, hemiplegia [3], cerebral palsy [4], hyperflexion [5], dorsiflexion [6], plantar flexion [7], hemiparesis [8], diplegia [9], and spinal cord injury [10] to provide movements of limbs that have partially or completely lost their mobility functions. Orthoses are divided into upper extremity [11] and lower extremity [12] according to their intended purposes. Hand and arm orthoses are used in the upper extremity, and leg and foot orthoses in the lower extremities. Orthoses are classified as passive, semi-active and active according to their working principles [13]. Passive orthoses do not have a built-in power supply. They may differ depending on material properties. Polyurethane [14], thermoplastic [15], polymeric materials [16], composite materials [17], silicone structures [18] are passive orthosis materials mainly used in the literature. On the other hand, semi-active are orthoses with computer hardware and mechanisms. Active orthoses are devices that consist of a power supply, sensors, actuators, and control systems. In orthoses; some systems provide power transmission such as springs [19], wires [20], cables [21], tapes, hinge mechanisms [22]. Active hand orthoses are generally used in the treatment of upper extremity patients. In this way, pneumatic [23], electro-hydraulic [24], and linear motor [25] actuators are used to provide force formation in the patient's

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hand and wrist. In recent years, force motion transmission in hand orthoses has been facilitating rehabilitation by acting directly on the fingers with devices. Orthoses used on the lower extremities are generally made of lightweight materials and metals to prevent imbalance in the foot and to regulate the pressure on the sole. In addition, torque generation in Ankle Foot Orthoses (AFO) are provided by servo motor [26], DC motor [27], pneumatic artificial muscles [28].

This study aims to comprehensively investigate the development of modeling and fabrication techniques of upper and lower extremity orthoses in recent years. Therefore, the design and fabrication processes of innovative studies available in the open literature were covered in detail in terms of engineering. The paper is organized as follows. The components and material properties of wrist – hand and ankle – foot orthoses are described in Sections 2 and 3, respectively. Finally, the concluding remarks are reviewed in Section 4.

2 Wrist – Hand Orthoses (WHOs)

In the literature, different actuators and materials have been used in the design of WHOs. In this section, the most preferred actuators by researchers in WHOs design were investigated. In addition, the working principles and performances of the actuators are examined in detail. Moreover, the most preferred materials in the fabrication of WHOs' housing were also considered in this section. Finally, innovative studies of WHOs are summarized in Table 1. Moreover, some examples of structural configurations of WHOs in the literature are given in Figure 1.

2.1 Actuator Types and Operation Parameters for WHOs

There are different types of actuators that provide the necessary force to move the limbs. In the open literature, some of the most preferred actuators were pneumatic, hydraulics, electric motor, linear motor and DC motor. Innovative WHOs studies with these actuators were investigated in Sections 2.1.1 - 2.1.5.

2.1.1 Pneumatic Actuator

Pneumatic sensors are of high importance in the fabricate of different devices and in the science of mechatronics. Literature survey shows that there are many studies about the pneumatic actuated orthoses. Pneumatic sensors have been used to provide high degrees of freedom in the WHOs studies. For example, Low et al. (2015) designed an adjustable Soft Pneumatic Finger device as a result of loss of muscle force in the upper extremity. Thanks to the pneumatic actuator in the newly developed device, compared to other orthoses, the device is designed to be lighter. As a result of the analysis, it was determined that the 56° angle was suitable for the flexion angle [29].

Hong et al. (2020) designed a robotic device made of a pneumatic origami muscle actuator (POMA) as a result of partial post-stroke paralysis. In this study, the pressure applied to the fingers by the actuator was minimized with the help of the air chamber and flexion movement was provided [30].

2.1.2 Hydraulics Actuator

Hydraulics is a mechanical process powered by fluid pressure. In hydraulic-based systems, mechanical motion is produced by closed fluid pumped and moving piston cylinders. Hydraulic sensors were also used in WHOs to provide force transmission. For example, Bos et al. (2018) proposed an electrohydraulic hand orthosis for use in the treatment of Duchenne Muscular Dystrophy (DMD). Consequently, it allowed each finger to move between 30°-65° with fluid pressure [31].

Bos et al. (2019) designed a surface electromyography (sEMG) controlled electrohydraulic orthosis (Symbihand) for patients with DMD. In this study, the movement of the fingers was carried out with an electric hydraulic system. Consequently, the patient's grasping ability improved by approximately 35% [32].

2.1.3 Electric Motor

In the literature, the electric motor has been used in WHOs studies to direct the force motion transmission in order to provide grip and release ability. For example, Ates et al. (2015) designed and analyzed the Script Active Orthosis (SAO) for hyperflexion disease as a result of a stroke. In this study, rehabilitation is provided to the fingers thanks to the electric actuator placed in the new model developed [33].

Dunaway et al. (2017) designed a myoelectric elbow-wrist-hand orthosis (MEWHO) for hemiparesis caused by chronic stroke. In this model, strong active support can be made with a three-jaw chuck. An improvement of up to 75% is observed when the participant uses the device actively for 150-180 days and performs muscle analysis [34].

2.1.4 Linear Motor

The linear motor is an AC asynchronous motor. It works like the general foundations of any other electric motor. These sensors produce motion directly in a straight line. Therefore, it has attracted the attention of WHOs researchers in recent years. For example, Yoo et al. (2018) designed a new myoelectric orthosis device with a 3D printer to treat muscle fatigue due to Spinal Cord Injury (SCI). In this study, the grab ability is provided with the help of a linear motor. As a result of the performed analysis, a 25-27% increase in the grasping ability of patients within 3-5 weeks is observed [35].

Yurkewich et al. (2019) developed a device with a linear actuator for use in the treatment of stroke patients. In this study, artificial tendons embedded in the robot were performed. Consequently, up to 20.4% improvement was achieved in the patients' ability to hold and release [36].

2.1.5 DC Motor

DC motor is a device that converts electrical energy into mechanical energy with the help of a magnet. DC motors have high and variable starting torque and have many applications in industry. In the literature, DC motors are used in the design of WHOs to facilitate the patient's flexion-extension movement. For example, Gasser et al. (2015) designed a device associated with the distal interphalangeal (DIP) joint for patients with hand paresis. In this study, a special geared DC motor was developed to adjust the torque of the Wrist – Hand Orthosis (WHO), and thus, the individualized force transmission was performed. As a result of the analysis, a torque of 2.9 Nm was sufficient for the clutch movement with the help of the DC motor [37]. Meeker et al. (2017) designed a DC motor-based WHO with EMG band support for stroke treatment. In this study, 53.7 N and 58.6 N forces were applied to the fingers with a DC motor [38].

2.2 Force Transmission for WHOs

In the literature, the force performed by the actuators for exercise is transmitted by different mechanisms. The mechanisms differ according to the WHO's application purpose. It is worth mentioning that force transmission mechanisms are of great importance in WHO designs. There are many studies on this subject in the literature. In this section, the working principles of force transmission mechanisms, which are generally used in the design of WHOs in the open literature, are examined in detail.

2.2.1 Springs

The spring is an elastic mechanism used to store mechanical energy. In WHO designs, springs are preferred to transfer the force performed by the actuators. For example, Barry et al. (2012) examined and analyzed the WHO and manual-assisted therapy (MAT) instruments to be used in the treatment of hemiparesis caused by stroke, and analyzed with the participants. The steel springs are extending from the armband to the fingers are the novelty of this study. Consequently, it was achieved that the WHO performed 12% better on average than the MAT [39].

Park et al. (2018) designed tendon-driven hand orthosis due to muscle loss resulting from stroke. In this study, the force was transmitted to the fingers by a torsion spring. Thus, the patients could easily perform the flexion-extension movement [40].

2.2.2 Cables

In many WHO studies, the link between the actuator and the fingers is provided via a cable system. For example, Ates et al. (2014) designed a script passive orthosis (SPO) for stroke patients. In this study, the movement of the fingers is facilitated with the help of elastic ropes used in the newly developed device. As a result of the performed analysis, a positive effect was observed in patients between 86-89% [41].

Ryser et al. (2017) designed a wearable robotic hand orthosis for continuation of rehabilitation at home after stroke. This orthosis was controlled by an embedded myoelectric intention sensing system using the Myo armband. It is worth mentioning that the motors and the hand orthosis were connected with Bowden cables. In addition, the information was saved on the Bluetooth supported micro SD card developed by Arduino. As a result of the performed analyzes after home treatment, the average of the data obtained from two patients resulted in a success rate of 85% [42].

Haarman et al. (2018) designed a Bowden cable-supported hand orthosis for patients with hemiparesis. The finger caps in the newly developed device directly matched with the rotation centers and provided flexion-extension movement with the help of this cable [43].

2.3 Types of WHOs

WHOs are generally divided into semi-active and active types. The range of motion of the WHO is determined by the type of actuator and the passive materials of the housing. In this section, the studies available in the literature on active and semi-active orthoses are reviewed.

2.3.1 Semi-Active WHOs

In semi-active hand orthoses, force transmission is provided by wire, spring, and strip without a built-in power supply. In recent years, semi-active WHOs have attracted the attention of researchers. For example, Ortner et al. (2010) developed a Steady-State Visual Evoked Potentials (SSVEPs)-based orthosis for persons with tetraplegia. In addition, the proposed semi-active WHO allows the patient to use it actively, as it has a Brain-Computer Interface (BCI) feature. Consequently, 45% improvement was achieved in the grasping ability of the patients between 4-7 weeks [44]. Jeon et al. (2012) designed a spring-assisted hand orthosis for patients with hemiparesis. Consequently, the steel springs used in the SaeboFlex orthosis are designed to provide a semi-active bending motion to the patient by applying direct force to the fingers [45].

2.3.2 Active WHOs

In Active WHOs, the required force is provided by the actuators. Recently, these types of orthoses have attracted high attention by researchers. There are many studies on active WHOs in the open literature. For example, King et al. (2011) designed an electroencephalogram (EEG)-based BCI orthosis for the treatment of stroke patients. In the proposed design, the WHO was actively controlled by the EEG system. Consequently, an accuracy of 95% was achieved in grasping ability [46]. Furthermore, Stan et al. (2015) proposed a BCI orthosis for stroke patients. The innovative feature of the proposed wireless wearable orthosis was the recording of patients' rehabilitation data [47].

2.4 Material Properties of WHOs' Housings

Patient comfort and material cost are very important in WHO fabricating. Therefore, lightweight and affordable polymer and aluminum materials are preferred by researchers in the housing fabrication of WHOs. For example, DiCicco et al. (2004) fabricated an EMG assisted WHO for slow muscle contraction in upper extremity patients. In the proposed model, patient rehabilitation is facilitated by the aluminum anchor plate mounted on the back of the hand and the aluminum bands used for each finger [48].

Carpi et al. (2014) fabricated a WHO with dielectric elastomer transducers. The proposed orthosis was able to respond to electrical actuator with electromechanically active polymers. Accordingly, it is ensured that individuals can perform the flexion-extension movement [49].

Saharan et al. (2017) designed a Twisted and Coiled Polymer (TCP) based WHO due to damage to the Proximal Interphalangeal (PIP) joints in upper extremity discomfort. This orthosis was fabricated by the rapid prototyping method. Additionally, DC motor was preferred for force transmission. Moreover, it was completely wearable on the arm and caused an approximately 20% increase in the patient's finger rehabilitation [50].

Park et al. (2018) designed a wearable multimodal sensor and EMG-controlled robotic WHO for the treatment of stroke. In this study, there were linear correlations between the aluminum fingertips fabricated by rapid prototyping method and the EMG bands. Consequently, 80% faster recovery was obtained between the proposed EMG-based WHO and other similar studies [51].

Table 1: *Summaries of studies in the open literature on WHOs*

Ref.	Intended purpose	Force transmission	Degrees of freedom	Actuator type
[29]	Hand rehabilitation	Mechanism	7	Pneumatic
[30]	Stroke	Mechanism	2	Pneumatic
[31]	DMD	Mechanism	1	Hydraulic
[32]	DMD	Mechanism	2	Hydraulic
[33]	Stroke	Cable	20	Electric
[34]	Stroke	Mechanism	2	Electric
[35]	SCI	Cable	2	Linear motor
[36]	Stroke	Cable	2	Linear motor
[37]	Stroke	Mechanism	2	DC motor
[38]	Stroke	Mechanism	2	DC motor
[39]	Stroke	Spring	2	Unused
[40]	Stroke	Cable	Not mentioned	DC motor
[41]	Stroke	Spring	2	Unused
[42]	Stroke	Cable	2	Electric
[43]	Stroke	Spring	2	Unused
[44]	Tetraplegia	Mechanism	2	Unused
[45]	Stroke	Spring	2	Unused
[46]	Stroke	Mechanism	2	Electric
[47]	Stroke	Mechanism	2	Electric
[48]	Hand rehabilitation	Mechanism	2	Pneumatic
[49]	Hand rehabilitation	Mechanism	2	Electric
[50]	Hand rehabilitation	Mechanism	3	DC motor
[51]	Stroke	Cable	2	DC motor

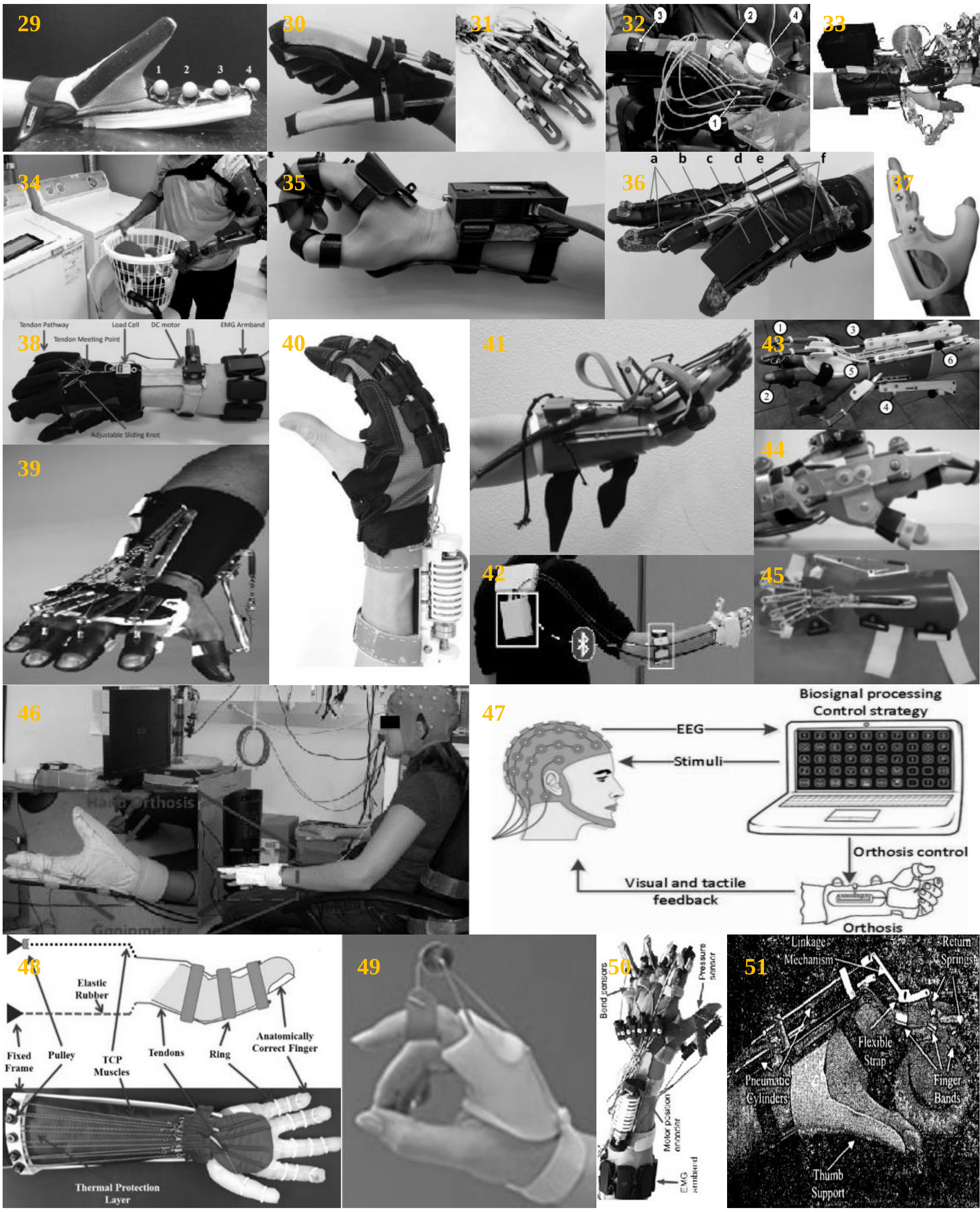

Figure 1: Structure configuration examples of WHOs

3 Ankle – Foot Orthoses (AFOs)

Recently, AFOs are preferred in rehabilitation treatments for foot-drop and restricted movements. In this section, the components of AFOs and their working principle were examined in detail. In addition, the advantages and disadvantages of electro-mechanical components used in the design of AFOs in the open literature were investigated. Finally, innovative studies of AFOs are summarized in Table 2. Moreover, some examples of structural configurations of AFOs in the literature are given in Figure 2.

3.1 Actuator Types and Operation Parameters for AFOs

The actuator converts a form of energy into linear or rotational motion and enables the force application. In AFOs, electro-mechanical actuators that restrict plantar flexion are generally preferred to prevent foot-drop. In the open literature, different actuators have been presented to provide the force required for exercise or treatment in AFOs. In this section, the advantages and disadvantages of the actuators used in the fabrication of AFOs were covered in detail.

3.1.1 Pneumatic Actuator

Pneumatic actuators use compressed air to transfer and control energy. The pneumatic system is dependent to the air compressor. The compressor charges air from the atmosphere and stores it in the high pressure pneumatic tank. In recent years, the development and minimization of pneumatic technology has been in high demand by researchers to perform the required force in orthosis designs. For example, Ferris et al. (2005) developed a pneumatic based orthosis for the human ankle joint. In this study, two artificial pneumatic muscles were used to provide plantar flexion torque. Thus, patients using the recommended AFO were provided with freedom of movement [52].

Chin et al. (2009) fabricated a pneumatic power harvesting ankle-foot orthosis. In the proposed design, a bellow pump was placed on the sole of the foot to prevent foot-drop. Additionally, the bellows component consisted of 169 kPa per step of pressure during ten minutes of walking [53].

Sawicki and Ferris (2009) fabricated a pneumatic artificial muscle based knee ankle-foot orthosis (KAFO) for ankle and knee joints. The housing of the proposed KAFO was fabricated from carbon fiber. Consequently, it was achieved that the torque value in the ankle and knee joints decreased with the movements of the pneumatic muscles [54].

3.1.2 Hydraulics Actuator

Hydraulics is the technology of generating, controlling and transmitting force with fluid under pressure. These actuators are preferred in AFO designs to provide the required force and torque. For example, Yamamoto et al. (2005) developed a hydraulic oil damper-based AFO for the treatment of patients with hemiplegia. In this study, the rotational motion of the ankle was converted into linear motion by means of a cam mechanism [55].

Naito et al. (2009) developed an intelligent ankle-foot orthosis (iAFO) that provides movement torque with a rotating cylinder filled with magnetorheological (MR) fluid for use in a hemiplegic patient. In this study, it was observed that the patient's foot was kept in dorsiflexion during the stance/swing phases and footstep symmetry was improved [56].

3.1.3 Electric Motor

In the open literature, electric motors have been implemented as direct and series driven elements for powered AFOs. For example, Shorter et al. (2011) developed the novel Portable Powered Ankle-Foot Orthosis (PPAFO) for foot flexors which provides the movement with a portable pneumatic power source, sensors on the sole, and electronic motor. Furthermore, it was observed that it helped dorsiflexion with EMG results [57].

Karpe et al. (2021) developed a two-piece AFO for use in physical therapy. An electrical muscle stimulator, electrical wires and electrodes were placed in the foot part of the proposed AFO. Consequently, muscle contractions were controlled with an electrical stimulator. Thus, the dorsiflexion of the patients was improved and their feet were flexible [58].

3.1.4 Servo Motor

The servo motor is a rotary or linear actuator that can be used to precisely control angle or linear motion, velocity and acceleration. These sensors are preferred as the force generation mechanism of AFOs. For example, Suga et al. (1998) designed an intelligent orthosis based on a servo motor. In this study, the motion of the knee joint was controlled with a computerized unit. Consequently, the patients' joints were controlled and regular steps were taken during walking [59].

Kobayashi et al. (2010) developed Articulated Ankle-Foot Orthosis (AAFO). This orthosis was capable of measuring the movement of the center of rotation and the torque. In addition, the proposed orthosis was automated with a hydraulic servo fatigue testing machine and a rack-pinion mechanism was built on top of the orthosis to provide rotational motion. Finally, the orthosis showed angular velocity performance with 1% accuracy [60].

Liu et al. (2018) developed a Wearable Powered Foot Orthosis (WPFO) for use in the treatment of Metatarsophalangeal (MTP) joint loss due to stroke. A servo motor was mounted on the foot part of the proposed orthosis, thus providing movement torque in the joint. Consequently, the forward propulsive force on the joints increased by 8% of body weight [61].

3.2 Force Transmission for AFOs

In the literature, force transmission mechanisms have been used to provide flexion-extension motion in the foot and ankle. In order to determine the working conditions of the force transmission system, the forces and moments that occur during the movement of the foot and ankle should be examined in detail. This section presents some innovative studies examining force transmission parameters.

3.2.1 Springs

In AFOs, a spring mechanism is generally preferred to provide plantar flexion exercises in the foot-ankle joint. For example, Polinkovsky et al. (2012) developed the Insertion Point Eccentricity Control (IPEC) AFO, the torque generated by a spring is transmitted to the ankle by a four bar mechanism. It was determined that the orthosis could provide a torque of 3.88 ± 0.15 Nm for plantar flexion with a spring force of 242 N as a result of the bench test. Consequently, it has been proven that the proposed orthosis can generate the required torque to regulate the movement of the foot during the swing phase [62].

Walbran et al. (2016) preferred to use a carbon fiber composite spring in the 3D printing-based orthosis to control rotation of the ankle. In this study, it was purposed to fabricate a low-cost, flexible and comfortable orthosis for patients. The proposed orthosis allowed the patients flexible use in shoes. Consequently, the desired comfort was provided to the patients [63].

Amerinatanzi et al. (2017) designed the Hinge-based Ankle Foot orthosis (HAFO) with superplastic NiTi springs. It is presented that a 2.5° higher result is obtained in the range of motion of the plantar flexion exercise by using a super-elastic NiTi spring in the hinge mechanism [64].

3.2.2 Hinges

In orthoses, the hinge mechanism prevents the foot from falling into plantar flexion. There are many studies in the literature on this subject. For example, Cullell et al. (2009) designed a hinge-based orthosis for the knee, foot, and ankle joints. In this study, muscle behaviors were simulated and necessary kinematics during walking were provided with a biologically based actuator system [65]. Banga et al. (2020) developed an AFO that can provide movement adjustment with a hinge mechanism in the ankle for use in children with cerebral palsy. The hinge mechanism used had a stress bearing capacity of 365.02 Nm^{-2} [66].

Table 2: *Summaries of studies in the open literature on AFOs*

Ref.	Intended purpose	Force transmission	Degrees of freedom	Actuator type
[52]	Gait rehabilitation	Hinge	1	Pneumatic
[53]	Foot-drop	Hinge	1	Pneumatic
[54]	Gait rehabilitation	Hinge	2	Pneumatic
[55]	Hemiplegia	Hinge	1	Hydraulic
[56]	Hemiplegia	Hinge	1	Servo motor
[57]	Gait rehabilitation	Hinge	1	Pneumatic
[58]	Foot-drop	Hinge	1	Electric
[59]	Gait rehabilitation	Mechanism	1	Servo motor
[60]	Hemiplegia	Mechanism	2	Servo motor
[61]	MTP	Mechanism	1	Servo motor
[62]	SCI	Spring	1	Gear motor
[63]	Foot-drop	Spring	1	Unused
[64]	Foot-drop	Spring	1	Unused
[65]	Gait rehabilitation	Hinge	1	Unused
[66]	Gait rehabilitation	Hinge	1	Unused
[67]	Hemiplegia	Mechanism	1	Pneumatic
[68]	Foot-drop	Unused	1	Unused
[69]	Gait rehabilitation	Spring	1	Unused
[70]	Gait rehabilitation	Spring	1	Hydraulic
[71]	Foot-drop	Spring	2	Electric
[72]	Gait rehabilitation	Spring	Not mentioned	Pneumatic
[73]	Foot-drop	Mechanism	1	Unused
[74]	Gait rehabilitation	Mechanism	1	Unused

3.3 Types of AFOs

AFOs are divided into passive, semi-active and active actuator types due to their structural features. Thus, the actuator type is preferred according to the treatment purpose in AFOs. In this section, the working principles of the actuator types used in AFOs were examined in detail.

3.3.1 Passive AFOs

Passive AFOs are commonly fabricated from thermoplastic materials or lateral passive elements. For example, Hirai et al. (2006) developed a novel AFO with an axis of rotation using a pneumatic passive element. In this study, the rotational movement was provided by transferring the air from the air buffer to the passive element. Consequently, plantar flexion movement of the foot was prevented and free movement was achieved [67]. Kubasad et al. (2020) fabricated passive AFO from high density polyethylene and polypropylene material using rapid prototyping method. Consequently, it was achieved that static and dynamic deformation analyzes decreased by 29.611% [68].

3.3.2 Semi-Active AFOs

Semi-active AFOs provide force generation with rod, cam mechanism, spring and dampers. There are many studies on this subject in the literature. For example, Gil et al. (2018) fabricated a semi-active hybrid unilateral stance control knee AFO. In the proposed orthosis, the pivot joint, user-adjustable rods and the locking mechanism were provided. Consequently, an appropriate physiological gait strategy has been provided [69]. Oba et al. (2019) fabricated a robotic AFO with a variable viscosity link using magnetorheological fluid. Consequently, it has been observed that the semi-active AFO provides freedom of movement in plantar flexion during pushing [70].

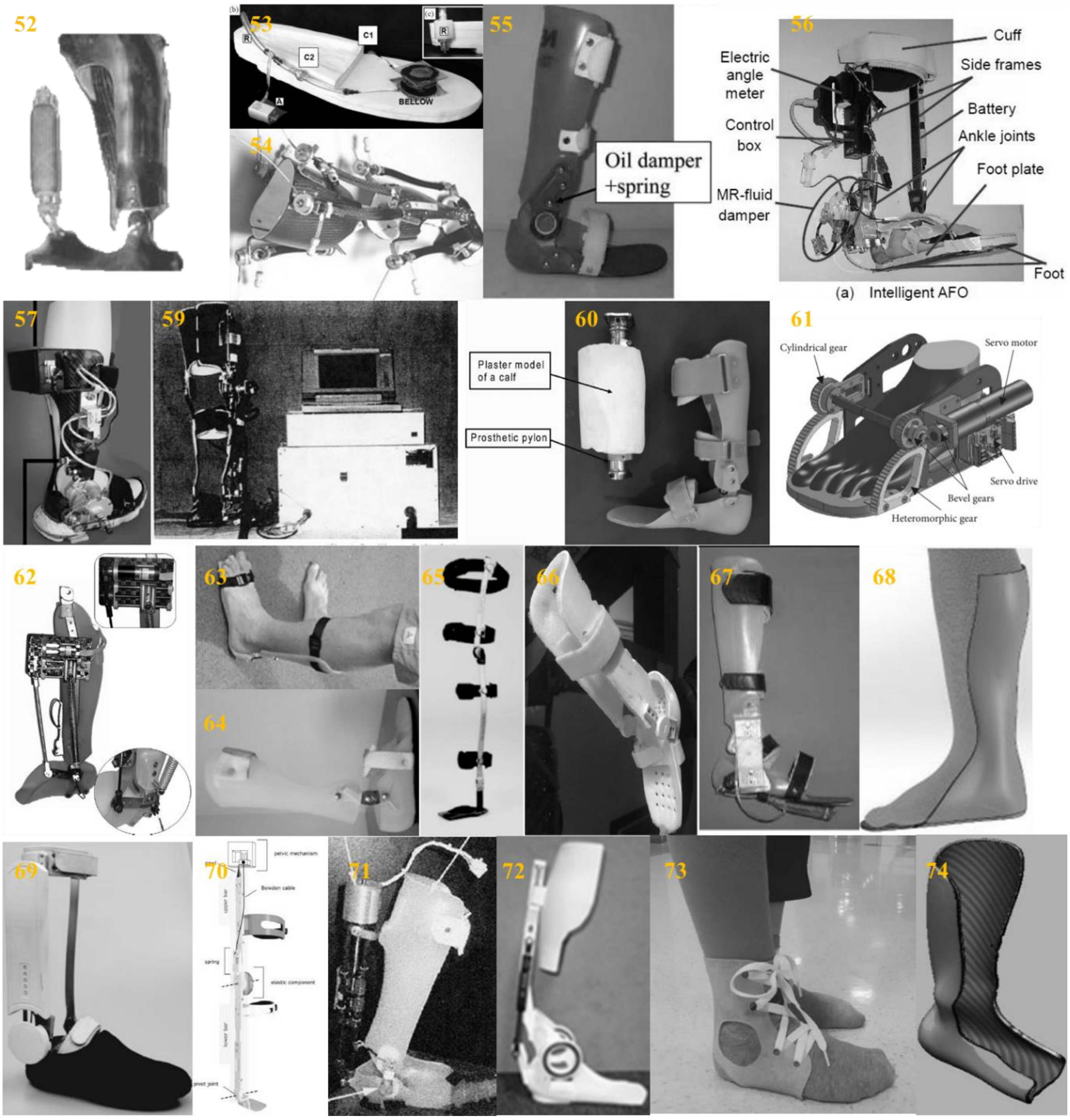

Figure 2: Structure configuration examples of AFOs

3.3.3 Active AFOs

The actuator converts an electrical signal into mechanical motion using a power source. In recent years, AFO researchers have demand to use actuators with the development of electro-mechanical systems. Active AFOs provide the required force with electro-mechanical actuators. In this section, some novel studies on active AFOs are investigated. For example, Blaya et al. (2004) developed a DC motor based Active Ankle-Foot Orthoses (AAFO). The proposed orthosis had variable impedance and the ankle was freely moving. The presented orthosis was capable of dorsiflexion and plantar movements, but the foot could not move to the right and left directions [71]. Telfer et al. (2012) fabricated a Foot Orthosis (FO) to reduce the pressure on the metatarsal head using additive manufacturing (AM) technology. The stiffness of the proposed orthosis was adjustable. In addition, personalized fabrication was possible because additive manufacturing technology was preferred [72].

3.4 Material Properties of AFOs' housings

Thermoplastic materials are inexpensive, light and have high strength properties. Therefore, thermoplastic materials are frequently preferred in AFO fabrication. For example, Cha et al. (2017) scanned the patient's foot with a 3D scanner to fabricate AFO from thermoplastic polyurethane material. Thermoplastic polyurethane material based AFO was flexible and durable. It is worth mentioning that the proposed orthosis was not subject to cracking and plastic deformation after mechanical stress testing [73]. Gautam et al. (2021) fabricated an AFO based on Thermoplastic Polypropylene material. The static analysis was performed to examine the mechanical properties of the proposed AFO. Consequently, it has been obtained that the deformation and safety control value of the provided AFO is moderate [74].

4 Conclusions

Rehabilitation at home is becoming a growing need as cost effective hand – foot rehabilitation is vital for patients with stroke and hemiplegia [75-76]. Orthoses are placed on the body or limb to alter or modify the functional and structural features of the neuromuscular system and skeletal system. Orthoses can be used to control, steer, restrain or immobilize a part of the body, reduce weight bearing and reduce the rehabilitation process of a broken limb. In the past, orthoses were fabricated exclusively for the patient by the orthologist. However, since 1960, innovations in orthoses and prosthetics (artificial limbs) have been influenced by the compatibility of industrial techniques for vacuum forming sheet plastics. Thus, prefabricated orthoses have been available in recent years. The remarkable progress of this science in recent years has been through creativity and innovation. Nevertheless, creativity and innovation factor is one of the most basic factors for orthoses. This paper has been prepared in order to better understand and follow the novel studies on orthoses in recent years.

5 Declarations

5.1 Study Limitations

None.

5.2 Acknowledgements

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5.3 Funding Source

None.

5.4 Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

5.5 Authors' Contributions

Hamid ASADI DERESHGI contributed with the paper writing and revisions.

Huseyin DAL contributed with the paper writing and revisions.

Dilan DEMIR contributed with the paper writing and revisions.

Necip Furkan TURE contributed with the paper writing and revisions.

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