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A Review of Ankle Foot Orthotic Interventions for Patients with Stroke

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Abstract

Lower limb orthotic intervention is considered as an important element in the rehabilitation of the patients with stroke. Hemiplegic gait are widely used by clinicians to describe a pattern of limb movement and body posture for the patients with stroke. This gait pattern is dangerous to the patients as it is an unstable walking pattern and has a high risk of fall. Application of ankle foot orthosis is a generally accepted method among physicians and orthotists for treating the patients with such impaired gait to prevent foot drop in swing phase. It not only facilitates toe clearance to prevent fall but also promotes heel strike in early stance. This article reviews different types of ankle foot orthoses for the rehabilitation of the patients with stroke. Such information would be useful to clinicians and researchers in selecting and developing the most appropriate ankle foot orthosis to their patients with stroke based on individual needs.

CEREBRAL VASCULAR ACCIDENT

Cerebral Vascular Accident (CVA), also known as Stroke (International Classification of Disease 10 - ICD10: 160-169), is the third leading cause of death in Hong Kong after cancer and heart disease. More than three thousands of people died in Hon Kong each year for this condition and the proportion of total registered deaths was 8.88% [1].

Most strokes (88%) are ischemic events, including thrombosis (50%), embolism (30%), and decreased systemic perfusion (8%), while other etiologies include intracerebral hemorrhage (9%) and subarachnoid hemorrhage (3%). In 2008, the estimated direct and indirect cost of stroke was $65.5 billion US dollars in United States of America [2].

GAIT PATTERN OF PATIENTS WITH STROKE

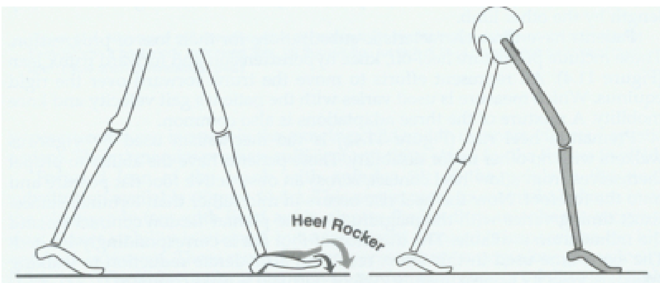
Perry (1985) demonstrated that the range of ankle motion for normal subjects during walking is 10° of dorsiflexion to 15° of plantarflexion [3] but Lamontagne et al. (2002) reported that most of the patients with stroke had reduced dorsiflexion during swing phase of the affected side compared with the control values [4].

Bohannon et al. (1987 & 1991) suggested that achieving normal gait pattern and speed are usually the ultimate goal of rehabilitation for the patients with stroke. Muscle weakness, abnormal tone, sensory and visual deficits as well as decreased joint range are considered to be the important elements that lead to affect gait speed [5, 6].

Hemiplegic gait is widely used by clinicians to describe a pattern of limb movement and body posture for the patients with stroke [7]. The patients often had inadequate shock absorption at heel strike or even worse as absence of heel strike by forefoot contact (Figure 1), inability to generate force for push off to maintain forward propulsion, and inadequate excursion of the paretic limb during swing [8, 9].

Figure 1

Figure 1. Absence of heel strike in the initial contact for patient with stroke (adopted from Perry, 1992).



According to Olney et al. (1996), hemiplegic gait can be classified by a combination of the followings [10]:

- a reduced hip joint angle amplitude in the sagittal plane, caused by a decreased hip flexion at heel strike and a decreased hip extension at toe-off;

- a reduced knee joint angle amplitude caused by increased knee flexion at toe-off and during swing; and
- an increased plantarflexion of the ankle at heel strike & during swing, and decreased plantarflexion at toe-off.

Abnormalities of the joint kinematics often lead to secondary compensations in other body segments. The management targeted to multiple joints rather than signal joint impairment may provide more beneficial results [11]. Therefore, the evaluation of treatment should also consider the overall changes of gait pattern with multiple joints rather than those aimed at single joint.

It was suggested that evaluations of joint and segment kinematics are a valuable resource for clinical practice, since it can precisely measure the angular variations between the segments, clarify and quantify what the human eye, even with great clinical experience, is unable to do [12]. In clinical environment, gait impairments of the patients, including stride length, step length, cadence and velocity, symmetry, can be measured simply with paper walkways [13] and pressure-sensitive mat [14, 15]. The foot and gait problems can also be investigated with dynamic pressure pattern using some portable systems included in-shoe localized pressure sensor [16, 17]. A wireless system with a tri-axial accelerometer has been development for recording the acceleration from the trunk to provide an objective measurement of walking movements as index of treatment outcome for the patients with stroke in rehabilitation [18]. Esquenazi (2002) also pointed out that the applications of joint kinematic and kinetic data provide valuable information of treatment intervention of patients with gait dysfunction [19]. Detail three-dimensional kinematic and kinetic gait profiles of persons with stroke can be identified and investigated with optoelectronic motion analysis system with force plates in laboratory environment [17, 20-24].

ORTHOTIC INTERVENTION FOR PATIENTS WITH STROKE

Polypropylene Ankle Foot Orthosis (AFO) is a common choice among physicians and orthotists for treating patients with impaired gait to prevent foot drop in swing phase. It not only facilitates toe clearance but also promotes heel strike in early stance [25].

A number of studies have demonstrated the positive effect of using AFOs in the patients with stroke leading to hemiplegic gait, but some patients are still reluctant to use rigid AFOs because of limiting ankle joint movement during ambulation. Excessive plantarflexion resistance will cause excessive knee flexion during stance phase [26, 27]. Carmick (1995) also pointed out another disadvantage of the rigid AFO was its limitation of normal movement of the tibia forwards over the weight bearing foot resulting in decreased ankle dorsiflexion and early heel rise in stance [28].

The hinged AFO with plantarflexion stop has been increasingly recommended by clinicians to prevent foot drop. An articulated AFO with planter flexion stop was found to be significantly increased the roll-over shape arc length and arc radius, and also significantly moving the sagittal plane location of the first center of pressure point posterior to the ankle center [29]. Walking with an effective roll-over may facilitate forward progression. Unlike the solid AFO, the hinged AFO allows the tibia to move forward over the weight bearing foot during stance resulting in more normal dorsiflexion motion.

Yamamoto et al. (1993) reported that the most important function of an AFO for patients with hemiplegia is to provide the dorsiflexion assisting moment, in which is normally provided by eccentric contraction of the pre-tibial muscles at the initial stance phase [30, 31]. They proposed that the plantarflexion resistive moment at the initial stance phase should be adjustable for the condition of each patient, in the range from 5 to 20 Nm per 10° of plantarflexion.

EFFECT OF DIFFERENT TYPES OF AFO

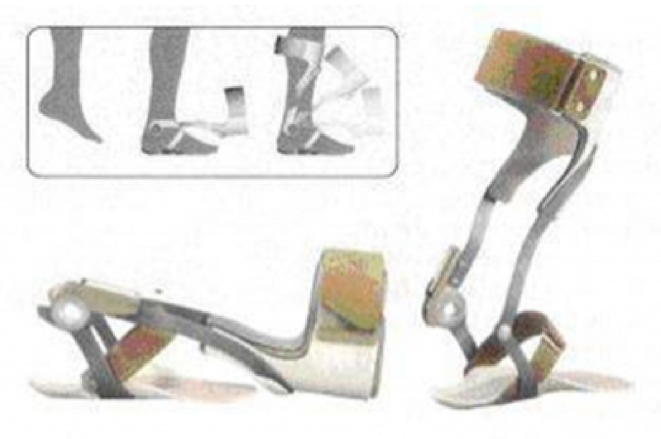
Patients with hemiplegic gait are often aware of excessive backward pressure at toe off, especially going up steps and a slope, or standing up from a chair while using the conventional AFOs [32]. To decrease the excessive backward pressure, a dorsiflexion assist controlled by spring AFO (DACS-AFO) was developed by Yamamoto et al. (1991), who reported that the DACS-AFO can produce a dorsiflexion-assist moment with angle of plantarflexion at heel strike and does not refrain from dorsiflexion at toe off [33].

The Gaitsolution Orthosis (Figure 2) is another similar design from the Kawamura Gishi Co., Ltd., Japan. It targets for the patients suffering from hemiplegia after an apoplectic stroke and needing an ankle-foot orthosis for stabilisation of the ankle. Its functional design allows freedom of motion for the ankle and fast walking. Following the most recent findings [30, 31, 33-35] in the field of walking analysis, the

Gaitsolution does not stiffen the ankle joint but rather provides good motion. The heel impact on the ground is absorbed by a small hydraulic buffer inside the orthotic joint, transforming it into a flowing motion so that the patient is able to keep the balance during walking. At the same time, walking is rendered more efficient. While this method provides the stability required, the abandonment of unnecessary contact surfaces prevents a pressure feeling usually caused by an orthosis.

Figure 2

Figure 2. The Gaitsolution Orthosis (adopted from the Kawamura Gishi Co., Ltd.)



Apart from the Gaitsolution Orthosis, another design is called dream brace / joint. They were first developed by the ORTHO Incorporation, Japan. The concept of Dream Joint is to offer wider angle of plantarflexion & dorsiflexion that can get a free and smooth motion (Figures 3 & 4). A one-way frictional bearing clutch is used in the design. Unlike other mechanical joints, its dial-lock mechanism allows some ankle dorsiflexion and plantarflexion by setting the applied torque to the joint.

Figure 3

Figure 3. Slope walking with rigid AFO (adopted from the ORTHO Inc.)

Figure 4

Figure 4. Slope walking with Dream Brace (adopted from the ORTHO Inc.)

Although AFOs have been demonstrated to be beneficial to stroke gait [36], some physiotherapists still have reservation to use the orthoses. As they believed that orthoses might induce disuse effects during the period of orthotic intervention, which made the existing loss of strength getting worse and possibly delaying recovery [37]. A evaluation study was performed by Tyson's group (2001) [13] who tried to assess the effect of a hinged AFO on functional mobility and gait impairments in people with a severe hemiplegia and patients' view on the use of orthosis. Functional Ambulation Categories was used as a measure of disability. They used paper walkways to measure gait parameters and a questionnaire to determine the user's opinion of the hinged AFO. The results showed significant improvements in functional mobility and in some gait parameters.

On recent review of published literature, not many authors focus their studies on evaluation of the differences between the hinged AFOs with plantarflexion stop and the AFOs like DACS-AFO, Gaitsolution Orthosis or Dream Brace. Hachisuka et al. (1998) tried to evaluate the usefulness of DACS-AFO on five hemiplegic patients in their study [32]. Although the DACS-AFO had demonstrated excellent biomechanical characteristics, patients did not accept this AFO because of its weight, noise and appearance. The authors concluded that AFO should be further improved to make it more suitable for patients' daily usage.

Another study was performed by Yokoyama et al. (2005) [38]. They developed an AFO with oil damper unit, which provides resistance to ankle plantarflexion. They used gait analysis system to compare the kinematic effects on gait of two patients with hemiplegia at two situations - AFO with plantarflexion stop and AFO with an oil damper. The results showed that patients had sufficient plantarflexion of the ankle and mild flexion of the knee during initial stance phase when they worn the AFOs with oil damper. The author suggested that comprehensive evaluations on kinetic, kinematic and temporal-spatial parameters of these AFO were required.

Yamamoto et al. (2005) performed a study on AFO with an oil damper – the GaitSolution Orthosis [34]. They tried to investigate the effect of this AFO on gait of three patients with hemiplegia by three-dimensional motion analysis system. It was found that the adequate resistive moment of the GaitSolution Orthosis would help to compensate for insufficient activity of the dorsiflexors. The rigid AFO with plantarflexion stop causing the shank moved forward excessively and rapidly at the time from heel strike to foot flat. This resulted in instability of knee joint. By the use of the GaitSolution Orthosis, gait pattern with minimized hyperextension or instability of the knee joint and smooth progression of the body during stance phase were noted. The authors concluded that the GaitSolution Orthosis is a useful device for gait training because it prevents rapid plantar flexion but allows gradual plantarflexion in stance phase. Subjective information of the comfortability of the patients in using the GaitSolution Orthosis was also evaluated with a questionnaire. It was reported that patients felt comfortable in using GaitSolution Orthosis mainly depending on trunk posture and hip joint outward rotation especially in the recovery phase [35].

CONCLUSION

This article reviews different types of ankle foot orthoses for preventing drop foot gait of the patients with stroke. These orthoses included rigid, semi-rigid, plantar flexion resist and dorsiflexion assist types. The selection of orthosis should be based on the physical condition, activity level and living environment of the patients. A more appropriate ankle foot orthosis could allow the patients with stroke to better adapt to their daily activities and reintegration to the society.

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