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Original Article

Study on the design development of a multi joint ankle foot orthosis

Eun-Hong Choi, PT, MS[1)], Seong-Gil Kim, PT, PhD[2)], Young-Jun Shin, PT, MS[3)], Dae-Hwan Lee, PT, PhD[4)], Myoung-Kwon Kim, PT, PhD[5)*]

[1)] *Department of Physical Therapy, College of Rehabilitation Sciences, Daegu University, Republic of Korea*
[2)] *Department of Physical Therapy, Uiduk University, Republic of Korea*
[3)] *Department of Physical Therapy, College of Rehabilitation Sciences, Daegu University, Republic of Korea*
[4)] *G.O. Meditech, Rehabilitation Medicine Device Research Institute, Republic of Korea*
[5)] *Department of Physical Therapy, College of Rehabilitation Sciences, Daegu University: Jillyang, Gyeongsan, Gyeongbuk 712-714, Republic of Korea*

Abstract. [Purpose] The purpose of this study was to investigate the effects of a newly designed multi joint ankle-foot orthosis on the gait and dynamic balance of stroke patients having foot drop. [Participants and Methods] This study was investigated 10 participants who were diagnosed with stroke. Patients were evaluated based on a 10-meter walk test, timed up and go test and Berg balance scale after each participant wore a plastic ankle-foot orthosis and a multi joint ankle-foot orthosis (AFO) that consisted of orthosis joints (having poster-stop joint and Klenzak joint functions). [Results] The 10-meter walk test, timed up and go test and Berg balance scale showed significant differences in the orthosis with the Klenzak joint function. [Conclusion] The appropriate use of Klenzak AFO of the newly designed multi joint AFO is expected to have a positive effect on improving the gait and balancing ability of stroke patients having foot drop.

Key words: Multi joint ankle foot orthosis, Stroke, Gait

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INTRODUCTION

Stroke is defined as a neurological disease caused by a blocked blood supply to the brain or the bursting of a blood vessel of the brain[1)]. Stroke patients suffer sensorimotor impairment including abnormal gait, spasticity, disorder of selective motor control, and muscle weakness[2)]. Among them, abnormal gait and disorders of balance caused by equino-varus foot are continuously displayed in stroke patients. Stroke patients with equino-varus foot show a compensation movement pattern, which is known as a hemiparetic gait[3)].

Hemiparetic gait in patients with equino-varus foot results in slower cadence and shorter stance phase on the affected side[4)]. Therefore, improving gait speed and gait pattern with continuous equino-varus foot treatment is widely perceived as the most important goal in stroke rehabilitation[5)]. To achieve rehabilitation goals, the most common way to improve walking in stroke patients is to wear an ankle foot orthosis (AFO)[6, 7)].

Ankle foot orthoses provides medial-lateral stability in stance by limiting ankle and subtalar movement while facilitating toe clearance in the swing phase[8)]. Tyson et al. reported that AFO could increase energy cost of walking, ankle and knee kinematics, as well as kinetics in stroke patients[9)]. Ferreira et al. improved gait velocity and cadence by applying AFO in

*Corresponding author. Myoung-Kwon Kim (E-mail: skybird-98@hanmail.net)

Table 1. Comparison of gait and balance ability according to AFO type

	C-AFO	K-AFO	P-AFO	F	p
10MWT (m/s)	0.28 ± 0.07	0.31 ± 0.09	0.27 ± 0.07	29.3	0.0*
TUG (sec)	37.3 ± 8.9	34.5 ± 7.5	37.6 ± 8.2	21.2	0.0*
BBS (scores)	19.1 ± 2.8	19.9 ± 3.2	19.2 ± 3.0	6.1	0.0*

*p<0.05 significance difference in compared to AFO.
AFO: Ankle foot orthosis; C-AFO: Conventional AFO; K-AFO: Klenzak mode of multiple joint AFO; P-AFO: Posterior Stop of multiple joint AFO; 10MWT: 10-meter walk test; TUG: Time up and go test; BBS: Berg balance scale.

stroke patients, proving the effectiveness of AFO[10].

However, existing AFOs have some disadvantages. When wearing an ankle-foot orthosis, Equino-varus foot can be corrected. However, when an ankle-foot orthosis is worn for a long period of time, the range of motion of the foot is restricted. Traditional ankle-foot orthoses are produced by a positive gypsum mold of the patient's feet and use a plastic ankles link as a matter of technical limitations and price. Plastic links have very small elasticity, making it difficult to provide strong support to both the dorsiflexion and plantar flexion. Although customized by patients, it is difficult to achieve functional effects because it is not customized for the symptoms. It is also difficult for patients with severe stiffness or spasticity to wear correctly as it is made of a shape that covers the heel area.

To solve these problems, carbon fiber orthosises are being produced; however, they are so expensive that their application to patients is limited and associated with their ability to connect to the link to carbon-fiber features. Therefore, the purpose of this study is to investigate the effects of the newly designed multi joint AFO, which consists of orthosis joints (having posterior-stop joint and Klenzak joint functions) and a rehabilitation assistant device including a sensing system for gait and balance training on the gait of stroke patients with equino-varus foot.

PARTICIPANTS AND METHODS

Ten participants that met the inclusion criteria were recruited from Y university hospital after providing informed, written consent. Written informed consent according to the ethical standards of the Declaration of Helsinki was provided by all participants prior to participation, and all agreed to participate in this study.

Participants included eight males and two females, while stroke types included four hemorrhagic and six infarction. The mean age of the participants was 57.67 ± 11.18 years, their height was 169.30 ± 8.15 cm, and their weight was 68.40 ± 9.80 kg. In addition, the MMSE-K score was 27.44 ± 1.42 and months since onset was 10.24 ± 2.42.

The enrollment criteria applied were as follows: 1) index stroke >6 months prior in women or men with foot drop (equino-varus deformity), 2) Brunnstrom's stage of motor recovery for the affected lower limb range of 3–5, 3) a Mini-Mental State Examination score greater than 24/30[11], 4) independent gait ability to walk at least 15 m without assistance, 5) no disability in visual, auditory, or vestibular organs, 6) no history of orthopedic diseases, such as contracture, fracture, or arthritis in lower limbs.

The 10 meter walk test (10 MWT), timed up and go test (TUG) and Burg balance scale were conducted after each participant wore a conventional AFO and a multi joint AFO (having posterior stop joint and Klenzak joint). All measurements were taken three times by two physical therapists, and their mean values were used. All measurements were expressed as means ± SD.

Statistical analyses were conducted using SPSS (SPSS Inc. Released 2009. PASW Statistics for Windows, Version 24.0. Chicago: SPSS Inc.). General characteristics were analyzed by descriptive statistics and the results were reported as means and standard deviations. One-way repeated ANOVA was used for the group analysis, and the LSD test was employed to correct for multiple comparisons. Null hypotheses of no difference were rejected if p-values were less than 0.05.

RESULTS

In this study, 10MWT, TUG, and Berg balance scales were compared when C-AFO (conventional AFO), K-AFO (Klenzak mode of multiple JT AFO) and P-AFO (Posterior Stop of multiple JT AFO) were used. In the 10MWT, K-AFO was significantly faster than C-AFO and P-AFO ($p<0.05$). In the TUG, K-AFO was significantly faster than the other two orthoses (Table 1). In the Berg balance scale, the K-AFO scores were significantly higher than the other two orthoses ($p<0.05$) (Table 1).

DISCUSSION

This study was conducted to compare the conventional AFO and the newly designed AFO (multi-joint AFO) that assist the foot drop patients in stroke patients. In the comparison between groups, the group wearing Klenzak AFO showed a

significant increase in 10MWT, TUG and Berg balance scale compared to the conventional AFO group and the posterior stop AFO group. In a study by Gök et al.[12], a comparison of walking ability using plastic AFO and metallic AFO was conducted based on 12 hemiplegic patients. The metallic AFO improved the stability of the ankle and improved heel strike and push off during walking. The results revealed that the metallic AFO was more effective at increasing the dorsiflexion of the ankle. It is believed that the Klenzak AFO improved the ankle dorsiflexion by more effectively controlling the ankle dorsiflexion of the participant than the two other AFO by stably supporting the ankle joint by attaching both metallic multi joints to the existing ankle. The Klenzak AFO uses a spring to assist in ankle dorsiflexion; therefore, the effect of the AFO on the oil damper was investigated. According to this study, the walking ability of the patient was improved by controlled the bending resistance according to the condition of the hemiplegic patient using the spring[13]. This functional and dynamic AFO has been reported to be more appropriate for the condition of the patient and to improve the outcome of walking[14].

The limitations of this study are that the number of participants is too small to show different results depending on the participants; therefore, it is difficult to apply these results to all stroke patients.

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Conflict of interest

None.

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