

A new model of plastic ankle foot orthosis (FAFO (II)) against spastic foot and genu recurvatum

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Abstract

A plastic ankle foot orthosis (AFO) was developed, referred to as functional ankle foot orthosis Type 2 (FAFO (II)), which can deal with genu recurvatum and the severe spastic foot in walking. Clinical trials were successful for all varus and drop feet, and for most cases of genu recurvatum. Electromyogram studies showed that the FAFO (II) reduced the spasticity of gastrocnemius and hamstring muscles and activated the quadricep muscles. Gait analysis revealed a reduction of the knee angles in the stance phase on the affected side when using the FAFO (II). Mechanical stress tests showed excellent durability of the orthosis and demonstrated its effectiveness for controlling spasticity in comparison with other types of plastic AFOs.

Introduction

Although the usefulness is recognised of plastic ankle foot orthoses (AFOs), which are developed to suit the Japanese life style (taking off shoes in the house and putting them on out of doors), they manage severe spastic drop foot

(Shamp, 1989) and genu recurvatum with difficulty.

A newly designed plastic AFO, is proposed, termed the FAFO (II), which is made of 3 mm thick polypropylene. This orthosis is designed to deal with spastic drop foot and genu recurvatum, and its effectiveness is studied using gait analysis and electromyogram studies.

Materials and methods

Fabrication

The major characteristics of the FAFO (II) are shown in Figure 1. The plaster cast for the FAFO (II) is taken in five degrees of ankle dorsiflexion. Figure 2 shows the method for determining the amount of heel lift. The patient

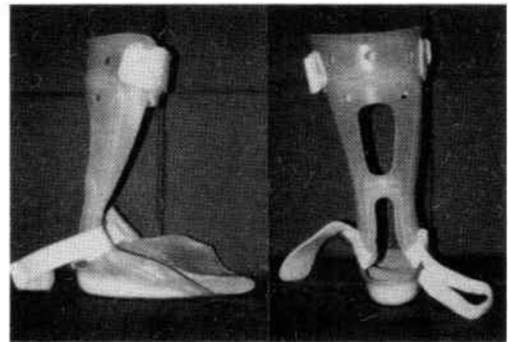


Fig. 1. Anterior and lateral views of FAFO (II).

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Fig. 2. Measuring of the amount of heel lift.

stands in the parallel bars in a relaxed condition and takes a step forward with the sound limb. In this position, the distance of the heel of the affected side above the floor is measured to determine the amount of heel lift required. The trim line of the ankle part of the FAFO (II) is determined by measuring the strength of spasticity (Fig. 3). The minimum force to inhibit genu recurvatum is estimated using a spring scale, with the affected heel lifted by the pre-determined amount. Curves of the dorsiflexion moment of the FAFO (II) previously obtained by measurement (Fig. 4) are used to select the appropriate line (Fig. 5). Each curve represents the characteristics corresponding to a trim line identified according to the distance from the back of the sole piece to the anterior border of the posterior fenestration. Trim lines from 5 to



Fig. 3. Measuring lower limb spasticity.

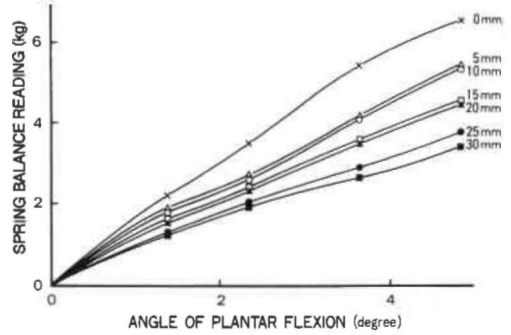


Fig. 4. Dorsiflexion moment in relation to plantar flexion for different trim lines.

30mm by 5mm intervals are illustrated in Figure 5. The positive model is modified by an additional anterior inclination of five degrees of the upper calf part so that the orthosis will push the calf anteriorly and correct the recurvatum position. An ankle strap inhibits the posterior parts from opening during plantar flexion and holds the ankle joint in the orthosis, without inhibiting dorsiflexion. The corrugation of the posterior and lateral parts of the orthosis resists the plantar flexion moment of the spastic foot. The FAFO (II) has a bridge in the posterior

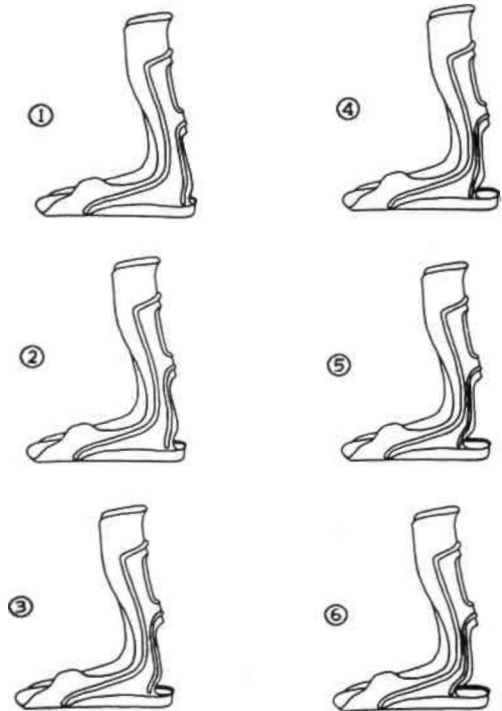


Fig. 5. The trim lines of the posterior ankle area of the FAFO (II).

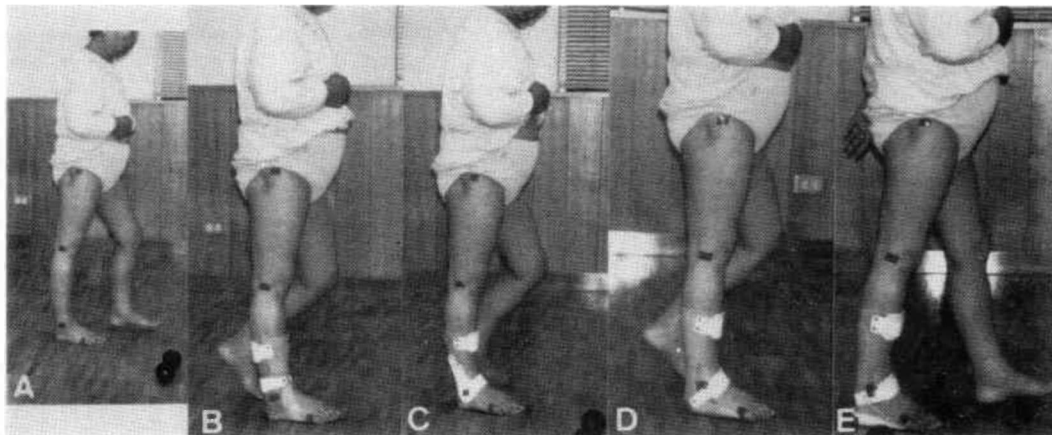


Fig. 6. Case 1 (74 years old, right hemiplegic woman), bare foot in (A) and wearing Yunoko (B), hemispiral (C), shoehorn (D) and FAFO (II) (E).

fenestration which stiffens it and reduces the rotational movement of the orthosis at the ankle and resists ankle plantar flexion. The heel lift in the orthosis reduces the spasticity of the calf muscle. Holding the first metatarsal bone corrects the varus foot in the swing phase.

Clinical trials

Thirty-nine patients, consisting of 26 males and 13 females whose average age was 58 years (4 to 75), attended the orthotics clinic from October 1988 to December 1989. All patients had severe spasticity in their lower limbs according to Shamp's rating (Shamp, 1989). They were considered appropriate for the FAFO (II). No other type of AFO was prescribed during this study.

Diagnoses of the patients were as follows; 34 cerebral vascular attacks (CVA), 4 spinal diseases, and one other. A total of 41 feet were fitted with the FAFO (II). The major symptoms of these patients were 23 genu recurvatum (in stance phase), 28 varus feet and 39 drop feet (in swing phase).

Three CVA patients who suffered from hemiplegia and displayed genu recurvatum in the stance phase and varus and drop foot in the swing phase were selected and each fitted with four different types of plastic AFOs. Figure 6 shows one case (74 year old right hemiplegic woman) fitted with the chosen devices — (A) bare foot, (B) Yunoko (Asayama, 1989), (C) hemispiral (Lehneis, 1974), (D) shoehorn (Sarno, 1971), and (E) the FAFO (II). Their gait was analysed and electromyograms made

of their quadriceps, gastrocnemius, tibialis anterior and hamstring muscles to estimate spasticity and muscle activity during walking, under the conditions of wearing the various AFOs and also without any device fitted.

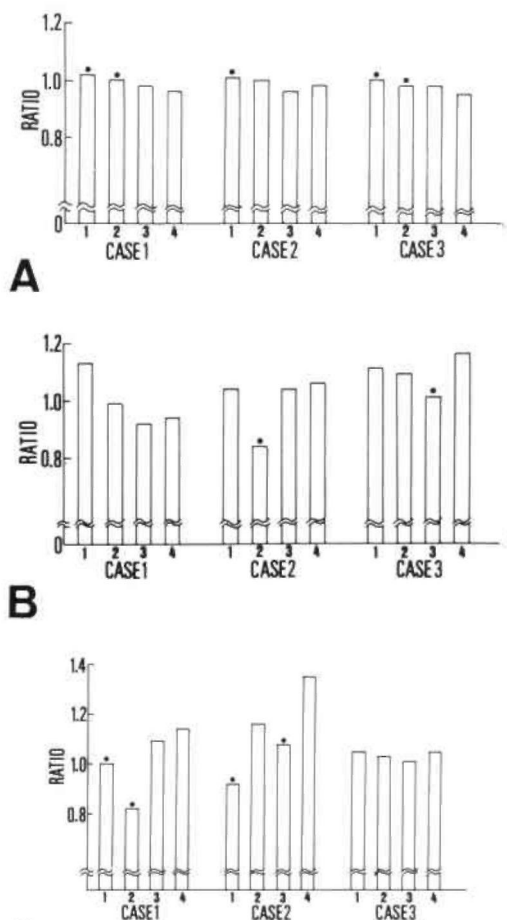
The gait of each patient at a comfortable speed was recorded by video camera and analysed by a computerised motion analyser (Sony, Japan). The knee angle in the stance phase, gait speed and stride length of the sound side were calculated.

To test the durability of the orthosis a bending fatigue test was performed. The concentration of the stress on the orthosis was checked by brittle lacquer test.

Results

As a general observation it was seen that for the 39 patients wearing the FAFO (II), varus and drop foot were corrected in all cases. Genu recurvatum correction was effective in 21 of the 23 patients who displayed the condition.

The gait of the 3 CVA patients was analysed bare footed and when wearing the four different plastic AFOs described above. Figure 6 gives a subjective impression that the FAFO (II) displayed the best correction of genu recurvatum (Fig. 6E). Figure 7 shows the ratio of the knee angle at mid-stance (Fig. 7A), the gait speed (Fig. 7B) and the stride length of the sound side (Fig. 7C), when wearing the various AFOs, to the values obtained in bare foot walking. The values are given separately for each case and are identified as (1) Yunoko orthosis (2) hemispiral orthosis, (3) shoehorn



C Fig. 7. The ratio of the knee angle (A), the gait speed (B) and the stride length of the sound side (C) in comparison to values obtained in bare foot walking. Measurements are displayed for Yunoko (1), hemispiral (2), shoehorn (3) and FAFO (II) (4).

orthosis and (4) the FAFO (II) orthosis. An asterisk (*) indicates that results are statistically significant $p < 0.05$. The FAFO (II) produced the greatest reduction in knee angle in two of the three cases (cases 1 and 3) while the other orthoses did not have much effect. In two of the patients (cases 2 and 3) a higher gait speed was measured when wearing the FAFO (II) and in all cases this orthosis produced the greatest increase in stride length. These results appear to indicate greater stability or confidence when wearing the FAFO (II) than the other orthoses fitted.

The illustrative case in Figure 6 had suffered from right hemiplegia for 5 years. Figure 8 shows the ratio of her integrated

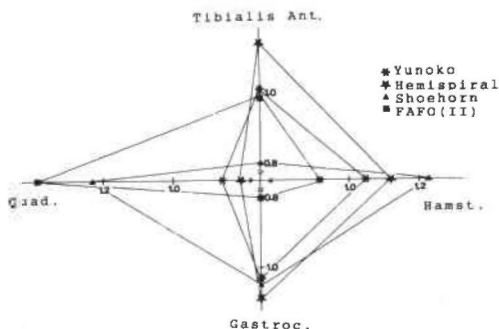


Fig. 8. The ratios of the integrated electromyogram of the same patient when wearing four different AFOs.

electromyogram when wearing each of the devices to the values obtained in bare foot walking. The greatest reduction in activity of hamstrings and gastrocnemius was displayed when wearing the FAFO (II) and this was accompanied by the greatest increase in quadriceps activity. These measurements suggest that the FAFO (II) reduced the spasticity of gastrocnemius and hamstrings while activating the quadriceps muscles.

Figures 9 shows a brittle lacquer test of the FAFO (II). Stress concentration is observed in the ankle joint area. Fatigue testing (Fig. 10) was carried out on the FAFO (II). the ankle

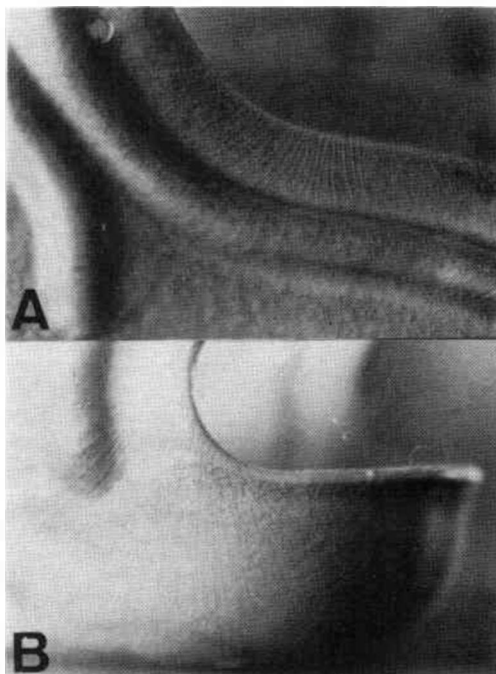


Fig. 9. The brittle lacquer test of the FAFO (II) showing stress concentrations.

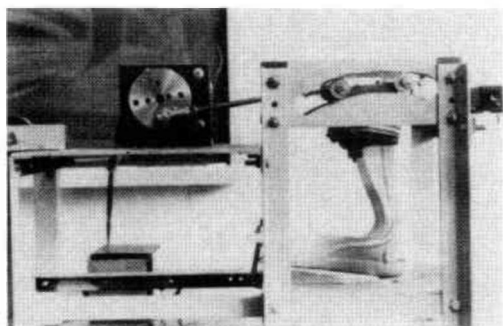


Fig. 10. The fatigue test of the FAFO (II).

was dorsiflexed to 13° at 143 cycles per minute. Three millimetre long cracks occurred in the calcaneal area of the orthosis after 5.05×10^6 cycles.

Discussion

The FAFO (II) is theoretically designed to deal with severe spastic foot and genu recurvatum. The fabrication of the orthosis is based on this design and not an empirical model. The FAFO (II) was analysed during clinical trials and mechanical studies. The orthosis was designed for relatively severe spastic patients who could not be corrected by conventional plastic AFOs. In this study it is established that the orthosis satisfied this aim mostly by reducing spasticity and stabilising the affected lower limbs. However, two patients with genu recurvatum could not be corrected. These two patients had some problems. One of them had a long-standing genu recurvatum thus the habitual pathological gait could not be corrected by the orthosis. The other had insufficient heel lift to reduce calf muscle spasticity. Prior to this present orthosis, some tone reducing orthoses have been reported (Sussman, 1979; Zachazewski, 1982; Bronkhorst, 1987). However, comprehensive studies have not been performed on these orthoses.

The side effect of the heel lift provided by the orthosis should be studied in respect of the need

for corresponding limb length correction of the sound side to improve the gait pattern. In the Japanese life style, the heel raised shoe of the sound side must be removed so the limb length discrepancy will be emphasised. However the increased stability of the affected limb provided by the orthosis improves walking ability in the house without correcting limb length discrepancy.

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