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Clinical evaluation of a knee-ankle-foot-orthosis for hemiplegic patients

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Abstract

A knee-ankle-foot-orthosis has been developed that incorporates a genucentric knee joint and a similarly designed ankle joint. Its design is discussed and a clinical evaluation of its use on twenty five hemiplegic patients is presented.

Introduction

At present, various orthoses for hemiplegics are designed to correct deformities and allow effective ambulation. A knee-ankle-foot-orthosis (KAFO) has been newly developed with a genucentric knee joint (Foster & Milani, 1979) and a similarly designed ankle joint connected to an arch foot support with a specially designed heel trim. Over the past three years, more than thirty patients have been prescribed these orthoses with very satisfactory results.

Materials and design

The orthosis is a long leg shelled type, made of a flexible plastic laminate, "Subortholen". The thigh part of the orthosis consists of an anterior wall and posterior cloth cuff. It is connected with the lower leg shell by the polycentric (genucentric) knee joint which is made by overlapping the anterior thigh shell and the lower leg shell (Fig. 1).

This allows a range of movement from 10 to 130 controlled by a small plastic stopper attached to the upper edge of the lower leg shell (Fig. 2).

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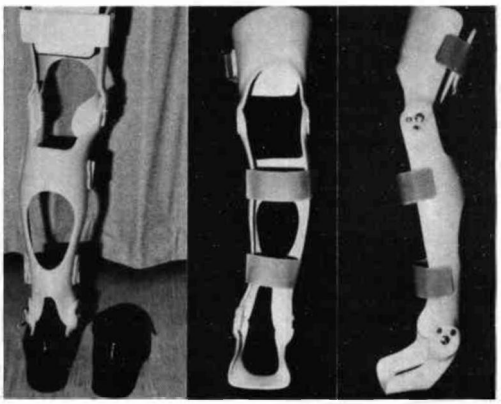

Fig. 1. The knee-ankle-foot-orthosis.

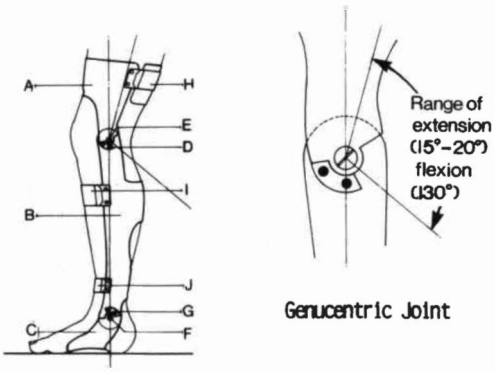

Fig. 2. (A) Anterior thigh shell
(B) Lower leg shell
(C) Arch support
(D) Plastic stopper
(E) Genucentric knee joint
(F) Polycentric ankle joint
(G) Plastic stopper
(H) Posterior cuff
(I) Upper anterior cuff
(J) Lower anterior cuff

When the knee joint of a subject is unstable, the knee joint of the orthosis can be firmly locked by means of the small bars attached posteriorly.

The orthosis is light in weight, weighing about 500 gm. The ankle joint of the brace is also a polycentric joint made in the same way as the knee joint. The ankle joint allows a range of movement from 0 to 30 in dorsiflexion. Holding the knee joint in a slightly flexed position in the orthosis, a hemiplegic can swing his affected leg forward easily. If the knee joint of a subject is unstable it can be fixed in the extended position by locking the small bars (Fig. 3); these can be unlocked after gait training, when the subject becomes able to achieve smooth ambulation with a free knee joint.

The heel trim of the orthosis is shaped so that the subject's heel does not slip out of the orthosis. The foot part of the orthosis consists of the arch support connected to the ankle joint; it does not cover the forefoot. By this device, the subject can carry out the toe-off phase of ambulation more easily (Fig. 4). This orthosis has moderate flexibility and consequently it can prevent confinement or immobilization of the affected leg in the brace. The patient can put on or remove the orthosis easily and insert it into a shoe.

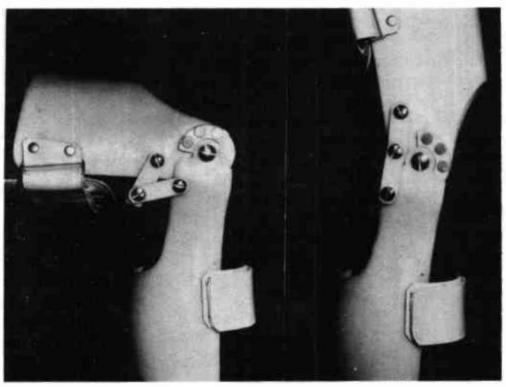

Fig. 3. Knee joint locking mechanism.

Results

The orthosis has been fitted to thirty six hemiplegic patients over the past three years, October 1978 to March 1981. These subjects were graded as stage 3–3·5 in Brunnstrom's functional classification of hemiplegia. (Brunnstrom, 1966). Twenty five of the thirty six cases were observed to investigate the results of the fittings (Table 1).

Fig. 4. Effective heel strike and toe off.

All twenty five cases were able to ambulate smoothly after fitting and all have continued to wear the orthosis without rejection. The length of time it has been fitted was 14·6 months on average, the longest period being thirty five months and the shortest one month.

Cases 6 and 23 could remove the orthosis after 12–15 months, and can now carry out independent ambulation. Another two cases, cases 4 and 25, prefer to wear the orthosis, however they seem to be able to ambulate independently without them.

Three cases were fitted with a KAFO after being fitted with an AFO due to instability of the knee joint (case 8), muscle weakness (case 11), and severe foot deformity (case 22). All could ambulate effectively in the KAFO.

Case 8 can now walk in the KAFO for long distances, 6 kilometres daily, Case 5 is now working as a member of the municipal assembly, the knee joint of the KAFO in his case was locked at the onset of application.

Case 14 with psychological disturbances, and cases 15 and 24 with weakened leg muscles can walk in the KAFO under supervision. The following investigations were performed.

Table 1. Hemiplegics supplied with KAFO

Case number	Sex	Age	Attack of stroke	Onset of bracing	Brunnstrom's classification		Duration of bracing (months)	Present stage		Comments
					UE	LE		UE	LE	
1	M	71	Jun. '78	Oct. '78	3	Pre 3	35	3·5	3·5	(1) A recurrence of stroke in Feb. 1981.
2	M	54	Jun. '78	Oct. '78	2	Pre 3	35	3	3	(4) Marked preference for KAFO.
3	F	57	Mar. '79	Apr. '79	2	Pre 3	29	3	3	(5) Engaged as a member of the municipal assembly at present. Application of KAFO with locked knee joints at the onset.
4	M	64	Mar. '78	Jul. '79	3	3	26	3	3·5	(6) Removal of KAFO at present after application for about 1 year.
5	M	65	Apr. '79	Sep. '79	2	2	24	3	3	(8) Maintenance of ability to ambulate for a long distance about, 6 km daily, without breakage of KAFO.
6	F	55	Jul. '78	Jun. '79	3	Pre 3	12	4	3·5	(9) Maintenance of ability to ambulate for a distance about 2–3 km daily in home.
7	F	67	Jul. '76	Oct. '79	3	3	23	3	3	(11) Exchange for KAFO due to instability of the knee joint in AFO. Preference for KAFO.
8	M	53	Feb. '72	Jun. '79	3	3	27	3	3	(12) Acquirement of stability of the knee joint in KAFO.
9	M	62	Jun. '80	Aug. '80	2	Pre 3	13	3	3	(14) Acquirement of the ability to ambulate under observation, psychological disturbance and distinct synergy movement.
10	M	27	Mar. '80	Sep. '80	3	3	12	4	3·5	(15) Acquirement of the ability to ambulate fairly quickly in spite of muscle weakness at hip and knee joints.
11	M	53	Dec. '79	Nov. '80	3	3	10	3	3	(16) Acquirement of the ability to ambulate in spite of flaccid and weakened muscles at hip and knee joints.
12	F	62	Oct. '80	Dec. '80	2	Pre 3	9	3	3·5	(19) In addition to a stable and not so slow ambulation, exchange for AFO in the near future, due to obtaining stable knee joint in KAFO.
13	F	70	Feb. '79	Apr. '79	2	Pre 3	29	3	3	(20) Continuous performance of gait training in KAFO at present.
14	F	62	Dec. '80	Apr. '81	1	Pre 3	5	2	3	(21) Exchange for KAFO due to incomplete correction of severe foot deformity in AFO, fair improvement of foot deformity in KAFO.
15	M	58	Feb. '81	Apr. '81	1	2	5	3	3	(22) Removal of KAFO after application for 15 months maintenance of the ability of independent ambulation at home at present.
16	M	42	Nov. '80	Apr. '81	1	2	5	3	3	(24) Maintenance of the ability to ambulate under observation in spite of marked muscle weakness and low graded functional stage.
17	F	45	Dec. '80	Feb. '81	2	Pre 3	7	3	3	(25) Exchange for AFO after application of KAFO for 6 month's stable ambulation.
18	F	61	Feb. '81	Apr. '81	2	Pre 3	5	3	3·5	
19	M	40	Feb. '81	May. '81	2	3	4	3	3·5	
20	M	51	Mar. '81	Aug. '81	1	2	1	2	3	
21	M	67	Feb. '81	Apr. '81	1	2	5	2	3	
22	M	51	Mar. '81	Jul. '81	3	3	2	3	3	
23	M	48	Oct. '78	Jun. '80	3	3	15	4	3·5	
24	F	65	Aug. '77	Feb. '80	2	Pre 3	19	2	3	
25	M	58	Dec. '80	Jan. '81	3	3	8	4	4	
Average		56	UE = Upper Extremity LE = Lower Extremity				14·6			

Cases – functional stage between 3-3·5 based on Brunnstrom's classification

	KAFO (Group A)		AFO (Group B)	
Sex	Male	Female	Male	Female
Numbers	16	9	33	17
Average age in years	56		59	
Total number	25		50	
Average time after stroke	20 months		40 months	

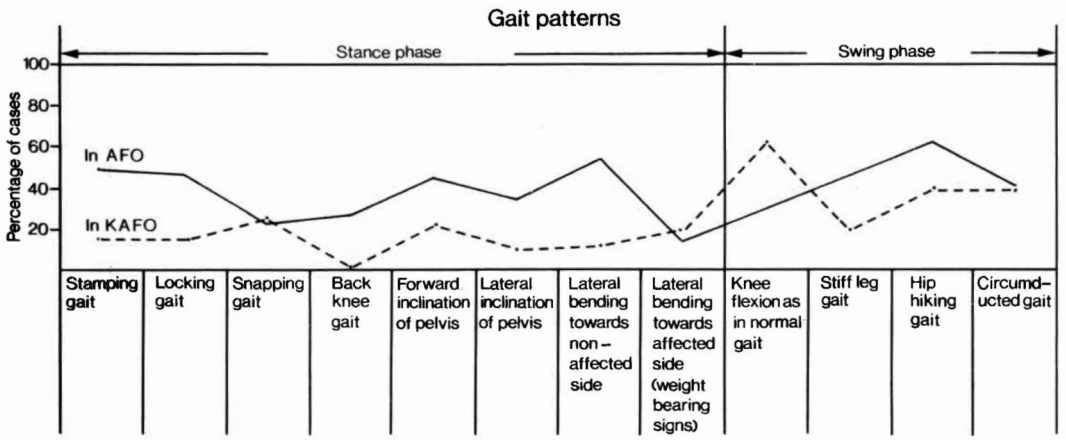

Fig. 5. Improvement of gait pattern in KAFO compared with AFO.

(1) Twenty five cases fitted with KAFO's (Group A) were compared with fifty cases fitted with AFO's (Group B) by evaluating twelve characteristics of gait (Fig. 5).

These comprised ten unfavourable signs (stamping gait – foot stamping on the ground; locking gait – knee fixed in full extension by spasticity; snapping gait—the knee snapping into full extension; back-knee gait – hyperextended knee; forward inclination of pelvis; lateral inclination of pelvis; lateral bending towards non-affected side; stiff leg gait; hip hiking gait; circumducted gait) and two favourable signs (weight-bearing by the affected leg in the orthosis and knee flexion during swing phase). All cases were graded as stage 3–3·5 in Brunnstrom's functional classification. Group B showed many more unfavourable signs than Group A, for example, stamping gait, locking gait, back-knee gait, forward inclination of pelvis, lateral bending towards non-affected side, stiff leg gait, hip hiking gait. Knee flexion was better in Group B compared to Group A.

(2) The necessary time to walk for a distance of 5–10 m was investigated. The above-mentioned two groups and a third control group (C), which comprised thirty normal adult males, were studied. Three estimations were performed, namely, the time necessary for walking 10 m in a straight line drawn on the floor, walking and returning a distance of 10 m in an L-shaped line (a total of 20 m), and walking and returning for a distance of 5 m in an S-shaped line to (a total of 10 m) (Fig. 6).

Group A showed about half to one third the times as compared with group B. The times of group A were only slightly longer than those of group C. Almost all of group A seemed able to turn easily and ambulate on the S-shaped line smoothly.

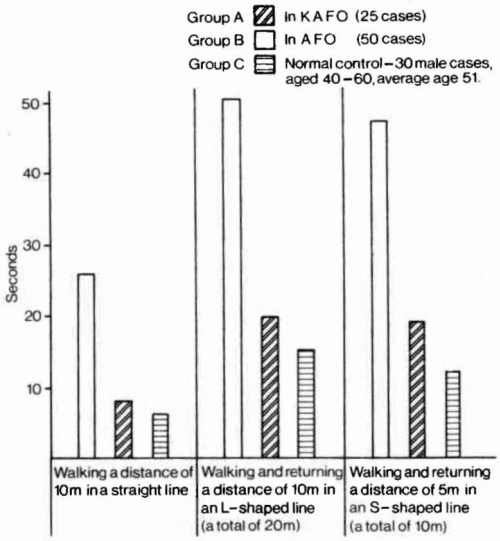

Fig. 6. Walking times, KAFO (Group A) and AFO (Group B) compared. Group C normal controls.

(3) EMG investigations were carried out during walking to compare the KAFO user with the AFO user.

Figure 7 shows typical records of the EMG obtained from the main leg muscles of the affected side by means of surface electrodes. The KAFO user exhibits periodic patterns typical of normal gait.

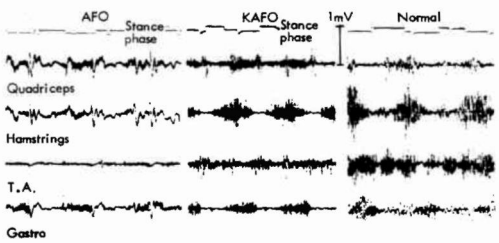

Fig. 7. EMG of a typical subject walking in AFO and KAFO (see text).

Indications

This KAFO is principally indicated for hemiplegics graded as stage 3–3·5 in Brunnstrom's functional classification aimed at ambulation in braces.

The above-mentioned hemiplegics can ambulate in the KAFO, showing significant improvement of unfavourable signs, such as stamping gait, locking gait, back-knee gait, forward inclination of pelvis, lateral inclination of pelvis, lateral bending towards non-affected side, stiff leg gait, hip hiking gait, circumduction. These unfavourable signs are not significantly improved upon in hemiplegics by using an AFO. As the results of the application show, this KAFO has a wider range of indication, in that it can be applied to hemiplegics with leg muscle weakness, or instability of knee or ankle joints (or both joints) and also with less severe deformities.

Summary

The KAFO described provides hemiplegics with effective and dynamic ambulation, because of its light weight, easy application, reasonably located genucentric knee and ankle joints, together with the flexibility of thigh and lower leg cuffs and arch support. The flexibility of this orthosis permits proper torsion of thigh and lower leg cuff.

After application of the KAFO, hemiplegics become able to extend or flex their hip or knee joints in a wide range of motion.

As the result of these characteristics, hemiplegics can ambulate smoothly and effectively in the KAFO as described in the results and practical investigations.

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