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VAPC PRESCRIPTION PROCEDURES FOR KNEE ORTHOSES AND KNEE-ANKLE-FOOT ORTHOSES

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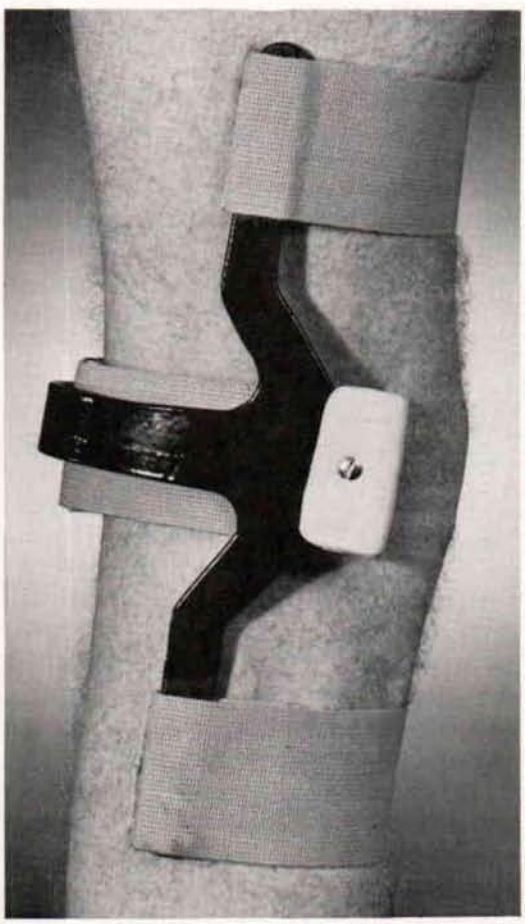


Fig. 1. Lateral view of the "Swedish Knee Cage."

It is the purpose of this paper to present the VAPC Clinic Team's approach to the prescription of knee orthoses (KO's) and knee-ankle-foot orthoses (KAFO's).

To conform to recently accepted procedure the use of eponyms has been avoided wherever possible. Because the total elimination of eponyms from orthotic literature is still in transition, the parenthetical inclusion, such as the term, "Swedish Knee Cage" (Fig. 1), will be noted in the KO-KAFO chart (Fig. 2). This is, as indicated, a metal "rigid three-point pressure KO" (1) and should be distinguished from a plastic contoured "rigid three-point pressure KO" such as the IRM SK KO (2) shown in Fig. 3.

In the accompanying KO-KAFO chart the authors have placed emphasis upon the knee. As Viel has indicated the "key problem remains knee stability" (14). AFO and shoe component charts (Figs. 4 & 5) have been included, which, with the KAFO chart, aid in the representation of a total KAFO orthotic system.

Evaluation Procedure

The development of an orthotic prescription proceeds through several stages:

1. Patient's History

VAPC PRESCRIPTION PROCEDURES FOR KO'S AND KAFO'S (ADULT) ●

ETIOLOGY	PATHOLOGY	MODIFYING FACTORS	DESIRED KNEE CONTROLS	Rx (KNEE) *	ELABORATION**
Upper Motor Neuron Defect (Spastic) (Unilateral considered here. See section I, below, for bilateral) **A**	1. Brain trauma (CVA, etc.) 2. Spinal cord trauma 3. CNS Disease (Tumor, M.S., etc.) (Also applicable to section I, below)	1. With M-L stability, but hyperextension (posterior cruciate and poster. capsule laxity) — Mild Hyperext (5° to 15°) / Severe Hyperext (15° or more)	Stop hyperextension if painful or if maximum limit (allow sufficient for stability)	Rigid three-point Pressure Orthosis (Swedish knee cage)	1. Cane if needed
			Prevent excessive hyperextension	Offset knee joints*** or knee lock	
		2. With AP Instability — Knee collapse in flexion	Prevent flexion instability: Mild	Knee stabilizing AFO; Spiral KO	2. Varus-valgus knee strap or extension knee cap as indicated, with double bar KAFO.
			Mod.	Polypropylene KO or double bar KAFO, with knee lock joints	
			Severe	Same as above	
		3. With M-L Ligament Laxity — M-L instability	Resist medio-lateral joint stress: Mild	Spiral or hinged elastic knee support	
			Mod.	Polypropylene KO	
			Severe	Polypropylene KO, Double Bar KAFO	
Lower Motor Neuron Defect (Flaccid) **B**	1. Poliomyelitis 2. Guillain-Barre Disease 3. Peripheral Nerve Trauma 4. Peripheral Nerve Disease (Diabetic, alcoholic, uremic polyneuritis, etc.) 5. Other	Same as Above	Same as Above	Same as Above	Same as Above
Disruptive Injury to Knee Ligaments **C**	1. Medial collateral	Mild Laxity	Resist medio-lateral joint stress	Hinged elastic KO; Spiral KO	1. Cane if needed
	2. Lateral collateral	Mod. Laxity	As Above	Polypropylene KO; Double Bar KAFO; Double anterior loop KO (Lenox Hill)	2. Varus-valgus strap as indicated
	3. Cruciate (Anterior)	Severe Laxity	Resist A-P Joint Stress	As Above	
	4. Cruciate (Posterior)	Mod. or Severe Laxity	Stop hyperextension	Offset knee joints	Knee lock if necessary
	5. All of above	Instability in all directions	Lock Medio-Lateral and AP Joint Stress	Knee lock	Surgical intervention, or rigid knee shell if clinically indicated.
Injury to Muscles Muscle Disease (Dystrophy) **D**	Impairment of function of muscles controlling the knee	1. Extent of muscle weakness	Prevent AP instability for: Mild	Spiral KO; cane; knee stabilizing AFO	1. Offset joints may be used if there is at least 5° of hyperextension
			Mod	Polypropylene KO; Double Bar KAFO (with offset joints or knee lock)	2. Extension or varus-valgus knee caps if indicated
			Severe	Same as Above	3. Knee flexion stop + extension aid
		2. Presence of contractures	Progressive correction of contractures	Double Bar KAFO with Dial Knee Lock	
Articular Impairment of Hip Joint **E**	1. Osteoarthritis 2. Post-traumatic arthritis 3. Atrophic arthritis 4. Post-infectious arthritis 5. Other	Degree of pain experienced	Knee joint must be locked to efficiently transmit forces from the floor, to the orthosis, and to the pelvis, and thereby partially unweight the hip.	1. Cane if mild pain 2. If pain mod. or severe: ischial ring or quad socket KAFO with locked knee and locked (or limited motion) ankle. If necessary, add cane or crutches.	See below
Osseous Inadequacy of the Femur **F**	1. Fracture (a) Recent (b) Delayed Union (c) Non-union 2. Metastatic Cancer 3. Paget's Disease 4. Other	Degree of unweighting necessary will be based on extent of involvement and potential or actual structural weakness of the femur, or pain	As above		Quad socket orthosis**** less efficient for unweighting at head-neck level of femur than Ischial ring;**** and more efficient at mid-shaft level or below.
		1. Minimal		Cane	
		2. Moderate		Ischial ring or quad socket KAFO and cane	
		3. Extensive		As above but crutches instead of cane	
Painful Articular Impairment of Knee Joint (or (If Ligament Laxity is present see C above) **G**	1. Osteoarthritis 2. Post-traumatic arthritis 3. Atrophic arthritis 4. Post Infectious arthritis 5. Other	1. Mild stress pain — ML / AP and/or ML	Resist ML joint stress	Hinged or spiral KO, and/or cane	
			Resist ML and/or AP joint stress	Spiral KO and/or cane	
		2. Mod. pain on stress	As Above	Polypropylene KO; Double anterior loop KO Double Bar KAFO	If varus or valgus deformity add corrective pads or straps
		3. Severe pain on stress	As above plus stop knee motion	Above with knee lock plus cane	If pain is mild to moderate then a gluteal weight-bearing corset may be used.
		4. Mod. or severe pain on weight bearing	As above plus stop knee motion	Quad socket or ischial ring KAFO *****	
Painless Articular Impairment of Knee Joint **H**	Asensory arthritis (As Charcot's Disease)	Instability	Lock knee motion ● Diminish vertical impact trauma	Quad socket or ischial ring KAFO with knee lock	Pull straps as necessary Cane
Paraplegia or functional clinical equivalent **I**	1. Functional Muscle Power absent from abdominals and below	Non-ambulator. Stand only in orthoses.	Lock knee motion	1. Polypropylene KAFO's with metal knee side bars and joints, and knee locks 2. Double bar KAFO's with knee locks 3. Ambulatory aid with above orthoses, i.e. crutches, walker, etc. (Wheelchair also needed)	1. Must be highly motivated 2. Must constantly work to develop remaining trunk and upper limb muscles 3. Functional level attained related to level of injury, but if (1) and (2) are present, a T5 may achieve exercise function.
	2. Abdominal Power Muscle retained, but muscle power absent below level of abdominals	Exercise function possible in orthoses. Occasionally a strongly motivated patient will achieve limited ambulation.			
	3. Pelvic control and hip flexors retained. More distal muscle power absent	Community ambulation possible.			

● Rx of HKAFO'S not included here

* See AFO and Shoe Component Charts for Additional Elements of the Prescription.
** If Sensation is impaired, Polypropylene Orthoses should be lined with plastazote.
*** Functional knee joints
**** If the patient has good quadriceps muscle power, the quad socket orthosis can function well with either offset knee joints or knee locks.
***** If the patient can tolerate ischial weight bearing.
****** Hemophiliac knee arthritis is a specific indication for single lateral bar quad socket orthosis to prevent trauma to the opposite limb.

Fig. 2. Prescription Procedures for Knee Orthoses and Knee-Ankle-Foot Orthoses for Adults

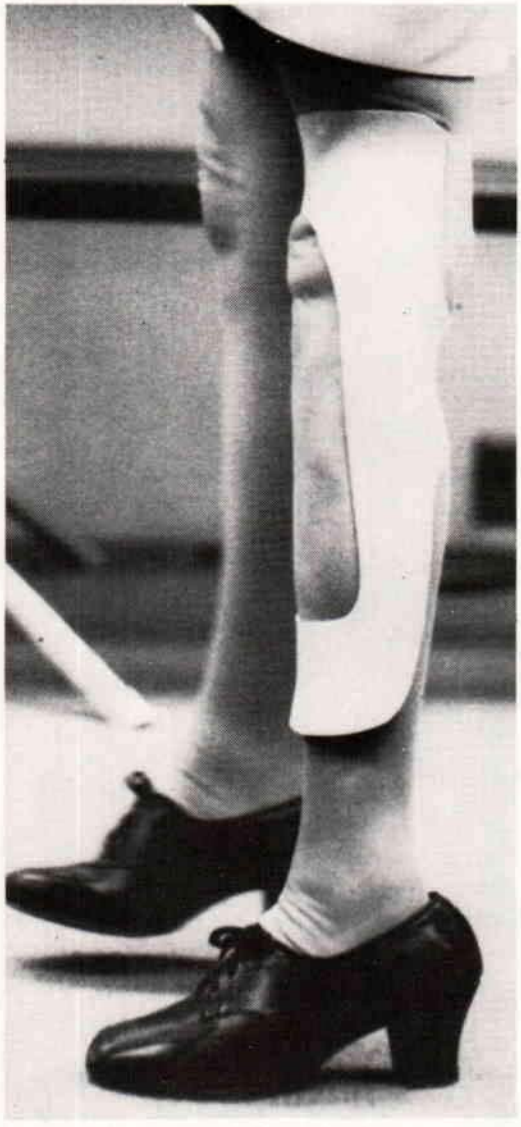


Fig. 3. The SK Knee Orthosis developed at the Institute for Rehabilitation Medicine

2. Physical Demands of Patient's Vocational and Recreational Pursuits
3. Physical Status
4. Gait Characteristics
5. Determination of Functional Requirements of Components
6. Selection of Components
7. Discussion with the Patient to Obtain His Acceptance of the Prescription
8. Prescription of the Orthosis

History

Information should be elicited about the character of the terrain where the patient will walk and, when indicated, frequency and duration of clonic episodes, conditions within the home environment (stairs, etc.), age, general health and past experience with orthoses.

Physical Demands of the Patient's Vocational and Recreational Pursuits

These factors will directly influence selection of components. An example of this consideration is given later. Most patients present unique problems which can be evaluated only on an individual basis.

Physical Status

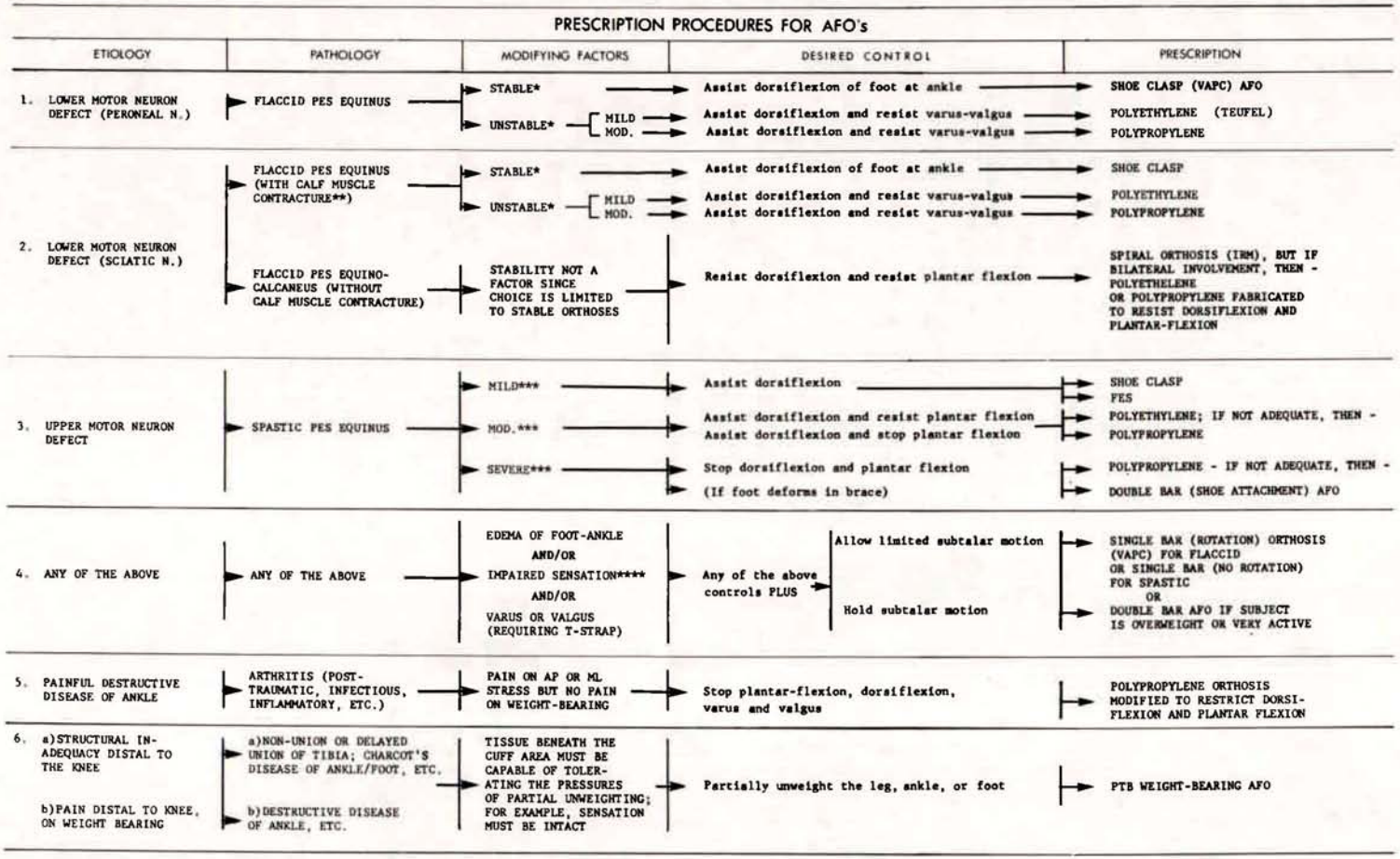
When clinically indicated, a referral to an internist for an examination including cardio-pulmonary evaluation should be made, especially when a great amount of effort will be required, as with bilateral KAFO's. Neuro-musculo-skeletal evaluation including the conditions of joints and their supporting structures should be given particular attention by the Clinic Team. Other consultants should be called upon for opinions where necessary, as, for example, dermatologists.

Gait Characteristics

The patient who can ambulate or stand should be required to do so, even if assistance or parallel bars are needed. The problems that are manifested, in association with the findings of the first three stages, will lead the Clinic Team directly to the next stage, determination of the functional requirements of the orthoses.

Determination of the Functional Requirements of the Components Needed

The format developed by McCollough (1) is very useful. He suggests the use of the following symbols "to indicate desired control of designated function":



* Stability is: a. evaluated during trial of a stock brace (VAPC shoe clasp, Teufel, Polypropylene) on the patient by the Clinic Team, or, b. can be assumed by the nature of the terrain the subject may walk upon (fields, golf courses, etc.).

** Many patients with sciatic nerve injuries develop calf contractures sufficient to stabilize the ankle at about 90°, in the weight bearing position. These patients need only a correction for the flaccid pes equinus.

*** During the clinic team evaluation of orthoses, the degree of spasticity is related to the "triggering" of spastic equinus (or equino-varus) by the stock braces tested directly on the patient as part of the evaluation procedure. For example, if the stock shoe clasp triggers the foot into spastic equinus, one must try the stock Teufel, or finally, the stock Polypropylene. If the foot deforms within the Polypropylene, external (shoe) attachment bracing is required. Very severe spasticity cannot be controlled by a brace.

**** Most such patients will tolerate a properly fitted shoe insert brace, or a shoe clasp. Those who develop areas of irritation should be changed to external bracing with individualized shoe modifications, if indicated.

Fig. 4. Prescription Procedures for Ankle-Foot Orthoses

LOWER LIMB SYSTEM

THE ANKLE-LEG COMPONENT		THE FOOT COMPONENT*
Type	AFO Designation	Shoe Modifications
Dorsiflexion Assist AFO	1- Shoe Clasp →	1- Hard counter; Blucher shoe*
	2- Polypropylene Posterior Leaf Spring →	2- Depth shoe** with thin inlay
	3- Ortholene Posterior Leaf Spring →	3- Depth shoe** with thick inlay
	4- Conventional →	4- Solid stirrup or caliper stirrup footplate and a very strong shank; Blucher shoe*
Dorsiflexion Assist plus spring-loaded varus control	Posterior Leaf Spring Orthosis with spring-loaded varus correction →	Posterior caliper stirrup footplate with Blucher shoe* and outflare heel
AFO with plantarflexion stop***	1- Polypropylene →	1- Depth shoe with thin inlay
	2- Conventional Double Bar →	2- Solid stirrup or caliper stirrup footplate; strong shank; Blucher shoe*
	3- Single Bar →	3- Solid stirrup or caliper stirrup footplate; strong shank; Blucher shoe*
AFO with dorsiflexion stop	Conventional Double Bar →	Solid stirrup or caliper stirrup footplate; rocker bar; long steel spring; Blucher shoe**
AFO with limited motion ankle	1- Conventional Double Bar →	1- Solid stirrup or caliper stirrup footplate, SACH heel; rocker bar long steel spring; Blucher shoe*
	2- PTB Orthosis →	2- Solid stirrup; SACH heel; rocker bar, long steel spring; Blucher shoe*

Fig. 5. Shoe Components for Lower-Limb Orthoses

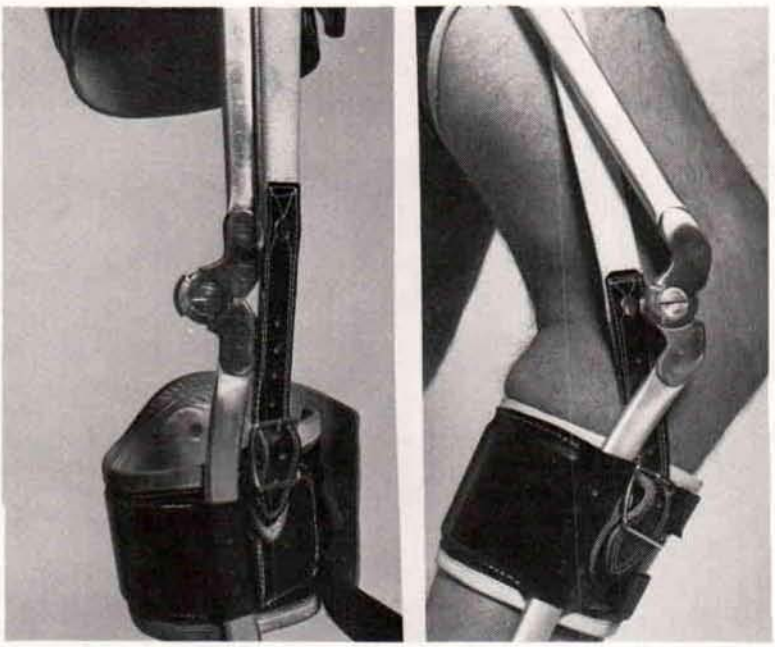


Fig. 6. Knee Orthosis with Offset Knee Joints

F = FREE — Free motion.

A = ASSIST — Application of an external force for the purpose of increasing the range, velocity, or force of a motion.

R = RESIST — Application of an external force for the purpose of decreasing the velocity or force of a motion.

S = STOP — Inclusion of a static unit to deter an undesired motion in one direction.

v = Variable — A unit that can be adjusted without making a structural change.

H = HOLD — Elimination of all motion in prescribed plane (verify position).

L = LOCK — Device includes an optional lock.

The authors use in a clinical trial a stock shoe clasp or a stock polypropylene AFO to aid in evaluation of the anticipated response to AFO's. This is particularly helpful to determine if spring loading will precipitate clonus when mild to moderate spasm exists.

Selection of the Most Desirable Components For the Individual Patients

This decision will take into account not only the function of the components but also the weight, cosmesis, and sturdiness of the materials. A 118-lb. city-dwelling female will usually require a different prescription for the same condition than would a 250-lb. male farm worker. For the farm worker, in contrast to the city dweller, it would usually be advisable to sacrifice cosmesis for strength and durability of components. As indicated above, the AFO components (Fig. 4) and the shoe components (Fig. 5) have been charted separately and those charts should be used in conjunction with the KAFO chart to arrive at a prescription.

Discussion With the Patient

The prescription developed by the Clinic Team should be discussed with the patient to obtain his cooperation. When possible, a device similar to that planned for him should be shown to the patient. He may refuse to accept change and prefer to continue with an orthosis of a type to which he is accustomed rather than a more modern orthosis. Prescription over the patient's objection will almost invariably lead to rejection.

Prescription

When all of the factors discussed above have been considered thoroughly the prescription will usually "fall into place."

KO's and KAFO's

The following orthoses are discussed briefly in the order in which they are referred to in Figure 2.

Rigid Three-Point Pressure KO (Figs. 1)

There are several variants of this KO. The simplest is of metal and fabric, the metal rigid three-point pressure KO (Fig. 1). Examples of plastic "rigid three-point pressure KO's" have been demonstrated by Lehneis (1) (the IRM SK KO), (Fig. 3) and by Nitschke (the PTS KO) (1). The metal device is available commercially and the latter two require custom fabrication. The area of clinical application of these orthoses is described in the chart. Their principal function is to limit knee hyperextension by virtue of the three-point pressure design. The mediolateral support that is provided by rigid orthoses of this type is only present in the hyperextended position. As soon as knee flexion occurs the effectiveness of the M-L support is lost.

KO With Offset Knee Joints or Knee Locks (Figs. 6 and 7)

These may be used to stop or lock the knee to control hyperextension. If the knee hyperextension is between 5 deg. and 15 deg. the offset knee joints may be satisfactory and a trial with offset joints should be made since knee motion will be retained. If these joints are not adequate, i.e., if the knee is in slight flexion, or in excessive hyperextension, it will be necessary to use knee locks. For the offset knee joints to function properly and prevent knee collapse in flexion several prerequisites must exist, 1) the knee must hyperextend at least 5 deg., 2) there should be no hip flexion contracture, 3) there should be no ankle dorsiflexion deformity, and 4) there should be adequate power from the gluteus maximus and the soleus.

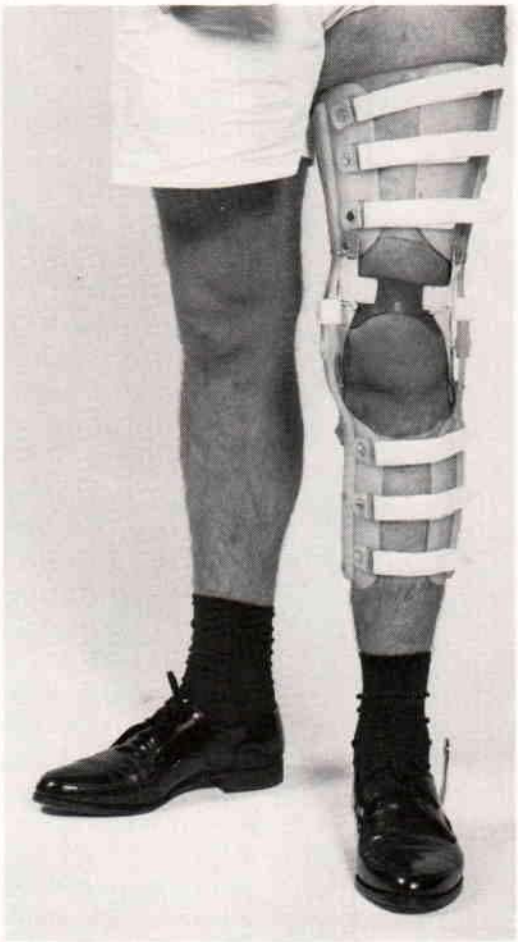


Fig. 7. Knee Orthosis With Knee Joint Lock

Knee Stabilizing AFO (Fig. 8)

This design is designated an AFO because no component of the orthosis crosses the knee joint; nevertheless, its principal action is on the knee joint (9), and it, therefore, is included here. It may be used if, in addition to the need for knee stabilization, there is a concommitant requirement for an ankle orthosis. The ankle orthosis should incorporate a dorsiflexion stop adjusted in plantarflexion to produce a knee extension force. There must also be an absence of hip flexion contracture as well as retention of fair hip extensor power (7). The authors pre-

Fig. 8. Ankle Foot Orthosis Designed to Provide Stabilization About the Knee

fer to use this orthosis when quadriceps power is rated not less than "poor" and with an intact opposite lower limb. When the indications for its use are present, this orthosis allows the patient to retain an important freedom, knee motion. It is useful when mild or moderate knee flexion instability is present.

The Spiral KO (Fig. 9)

The Spiral KO is an elastic fabric KO reinforced with flexible stays. It is useful only for mild instability and functions primarily as a "reminder" type of orthosis, i.e., as the patient ambulates the restraints introduced "remind" him to bring his knee to full extension on weight-bearing, and thereby stabilize the knee. Its presence also "reminds" the patient to favor the knee when it is used for mild medio-lateral instability. The stays add only minimal resistance to knee instability.

Polypropylene KO (Fig. 10)

This orthosis (2) includes the unique fea-

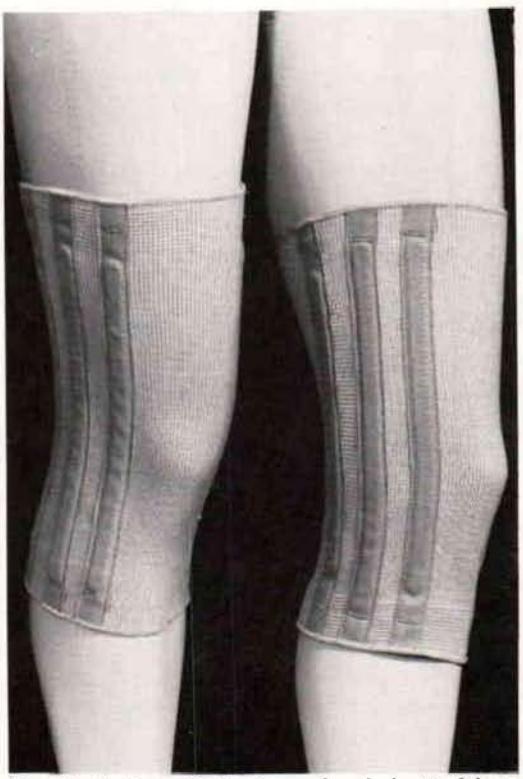


Fig. 9. A Knee Orthosis made of elastic fabric, known as the Spiral KO

Fig. 11. Single bar knee-ankle-foot orthosis developed at the VAPC.

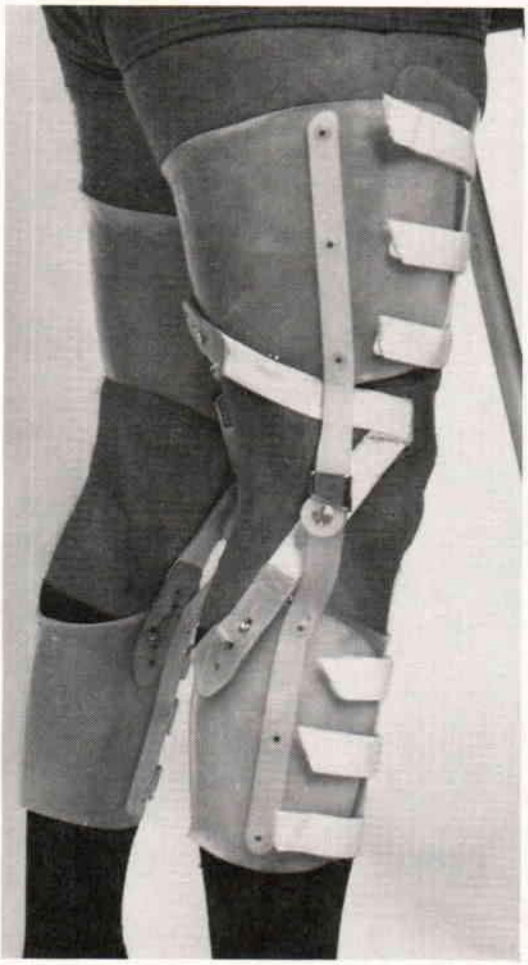
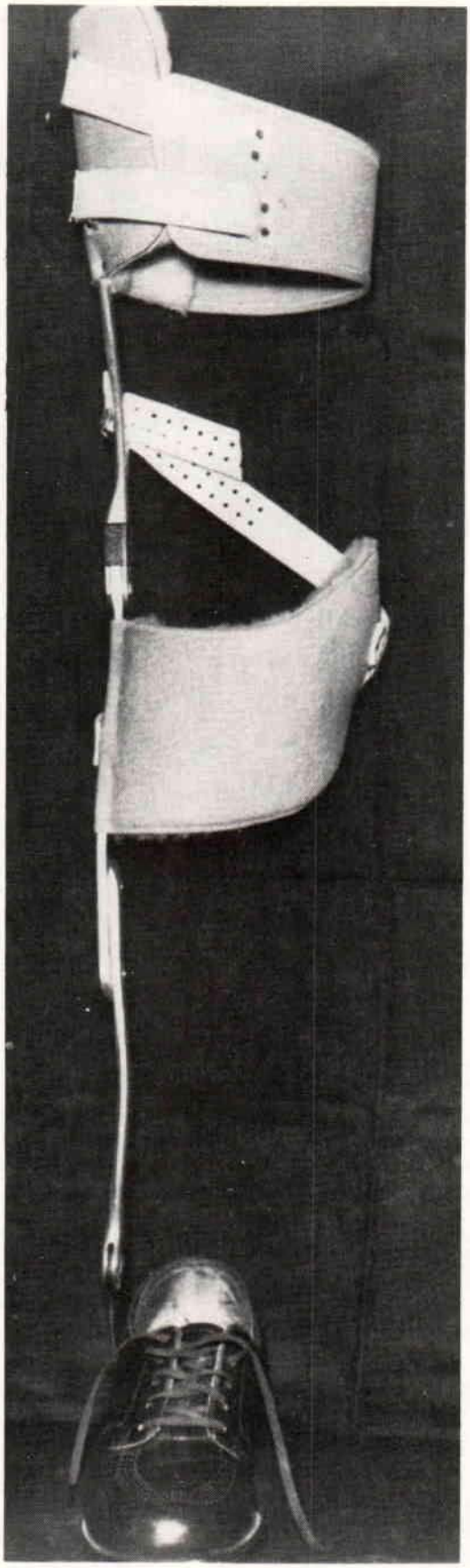


Fig. 10. A polypropylene knee-orthosis developed at the VAPC. This model has a knee lock.

ture of suprapatellar-cuff suspension in the manner of the cuff suspension of the PTB prosthesis. It can be fabricated with drop locks at the knee for moderate or severe flexion instability. When used to resist mediolateral ligament laxity, a knee lock is unnecessary except in extreme cases.

Double-Bar or Single-Bar KAFO (Fig. 11)

Traditionally this is the term used to describe a KAFO fabricated with either aluminum or steel medial and/or lateral bars, with or without (as specifically indicated) an ankle joint, and with either a solid stirrup or a split stirrup. Offset knee joints or knee locks may be used. Variants may employ all



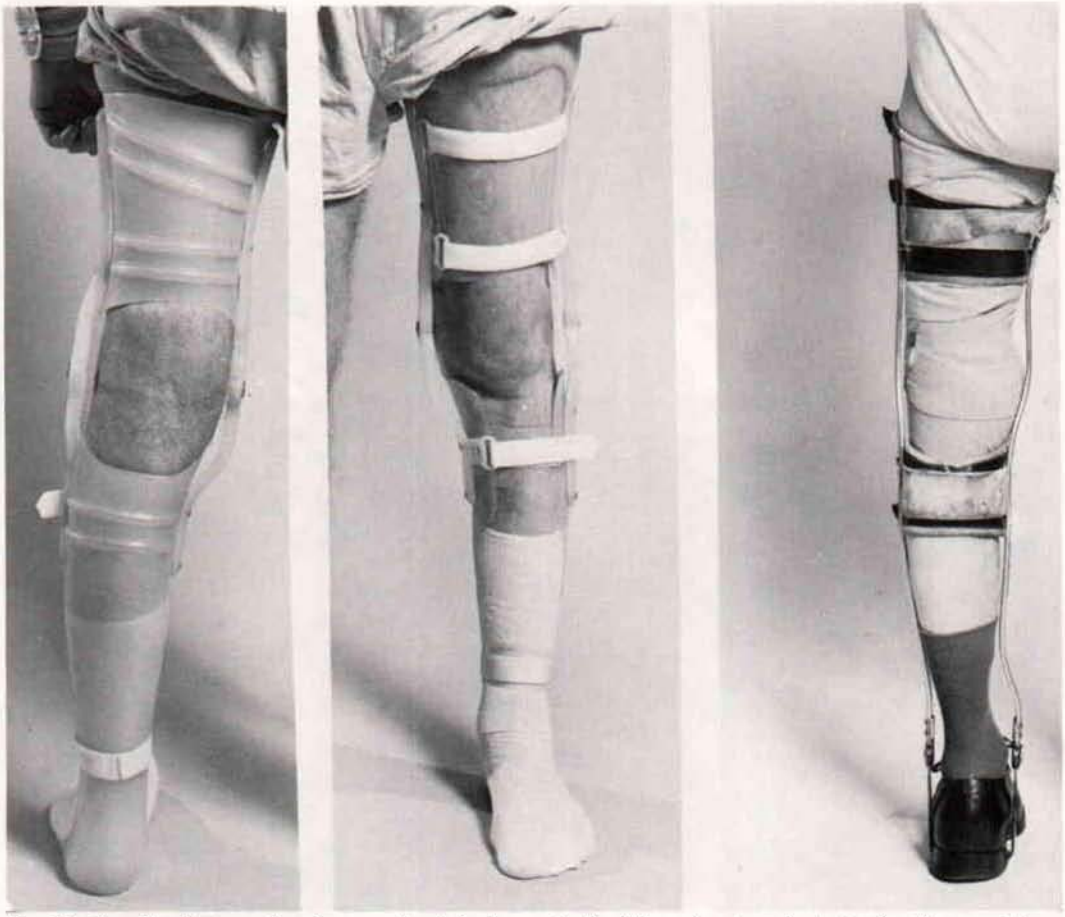


Fig. 12. An all polypropylene knee orthosis is shown in the left and center photographs. A conventional metal knee-ankle-foot orthosis is shown in the photograph on the right.

polypropylene (Fig. 12), polypropylene and polyethylene (Fig. 13), pneumatic knee joint locks (Fig. 14), or a KAFO of polypropylene plus a shoe clasp (Fig. 15).

Hinged Elastic KO (Fig. 16)

The hinged elastic KO is slightly more effective for resistance to medio-lateral knee ligament laxity than is the spiral KO, and is used if the complaints are mild. The improved resistance to M-L displacement and the addition of limited A-P displacement resistance are achieved with hinged medial and lateral metal struts and knee locks. These provide resistance restraints rather than true locking because of the elasticity of the cuffs.

Double Anterior Loop KO (Lenox Hill Derotation Orthosis) (Fig. 17)

The double anterior loop KO is essentially a metal KO fabricated to provide resistance to medio-lateral displacement and limited resistance to anteroposterior placement due to ligament laxity. A stop to A-P displacement is added when knee locks are employed. Suspension is achieved by the use of circular latex-rubber straps, a disadvantage when circulatory or edema problems are present.

Plastic "Shell" KO (Fig. 18)

The plastic "shell" KO is a custom made, contoured solid knee orthosis providing

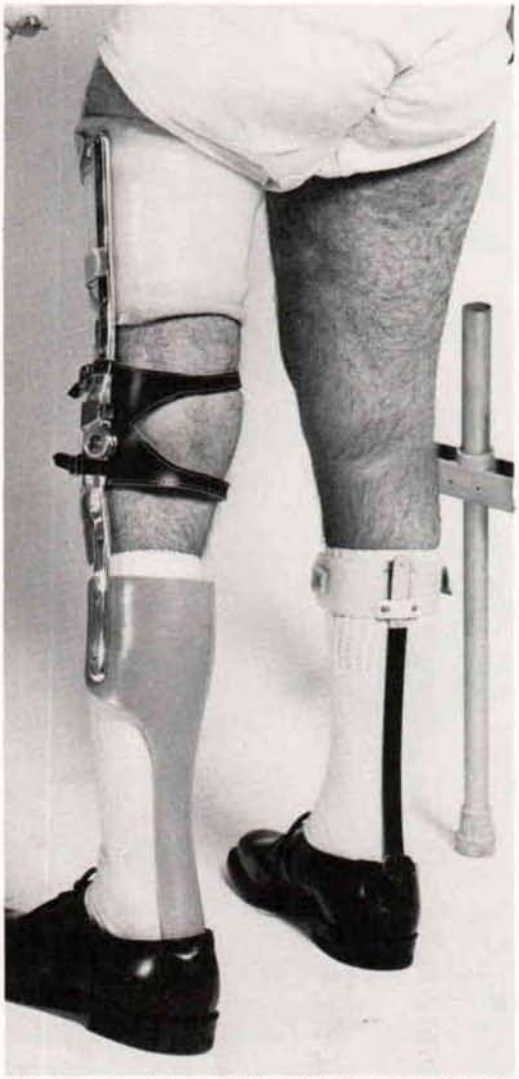


Fig. 13. A polyethylene KAFO with metal joints.

knee immobilization. The figure shows the minimum length of this device that was adequate in the illustrated instance. To achieve maximum efficiency the orthosis should reach as far as possible proximally and distally and yet allow hip and ankle motion. Suspension is achieved by contouring the orthosis over the suprapatellar area and above the flare of the femoral condyles.

Ischial Ring KAFO (Fig. 19)

This double bar KAFO utilizes a knee lock and limited-motion or locked ankle joints to achieve direct weight transmission from the ischial tuberosity to the floor. If weight-bearing is accomplished efficiently on the ischial seat, the hip joint can be at least partially protected against vertical impact trauma. The difficulty with this orthosis is that many patients will not tolerate the required extent of localized pressure on the ischial tuberosity and will release the anterior strap of the orthosis to allow the ischial tuberosity to slip forward and down (4).

Double-Bar KAFO With Dial Knee (Fig. 20)

The Dial Knee is employed to achieve gradual correction of a knee flexion contracture which is still amenable to correction and not rigidly fixed. The dial permits the knee to be locked into increasingly greater degrees of extension.

Double-Bar KAFO With Knee Flexion Stop And Extension Aid (Fig. 6)

This orthosis is useful for unilateral knee flexion instability, in the presence of poor or absent quadriceps function and an intact opposite extremity. A flexion stop at no more than 60 deg. will give the patient an opportunity to recover from sudden knee flexion collapse, and the extension aid, plus gravity, will then help him restore stability by bringing the leg to extension against the stop of offset knee joints (Fig. 6) (13).

The Quadrilateral Socket KAFO (Fig. 21)

This design provides ischial, gluteal, and proximal thigh-bearing; i.e., the socket, as it encompasses the thigh, provides supportive features. The upward forces on the hip joint are therefore greater than in the case of a properly worn ischial ring orthosis, and toleration by the patient is also greater. This orthosis is useful for partially unweighting the femur just below the hip, and useful to a more limited degree for unweighting the hip joint itself (7).

As indicated in Section G of Figure 2, under the column labeled "Elaboration," when a lesser degree of unweighting is required

Fig. 14. The ORTHO-WALK pneumatic orthoses

than would be provided with the quadrilateral socket KAFO, a gluteal corset KAFO may be employed. When the patient has good control of extensor power at the knee, offset knee joints can be used. Otherwise the orthosis should be fabricated with knee locks. The orthosis illustrated in Figure 22 was fabricated for a patient who could not wear the PTB orthosis because of peripheral neuritis and absence of sensation in the PTB cuff support area. This device is quite similar to the immediate precursor of the VAPC PTB orthosis (8).

Bilateral Double-Bar KAFO's For the Paraplegic (Fig. 23)

In KAFO's for the paraplegic patient, the knees must locked in the neutral position, ankles must be dorsiflexed about 10 deg., and the patient must lean his pelvis forward and his trunk backward to allow the patient to balance with the center of gravity over the mid-foot, as illustrated by the Scott-Craig orthosis (5, 11). Because of the retention of proprioception the poliomyelitis patient knows where his lower limbs are but the spinal cord patient must learn to sense position, and, as a result "polio patients accomplish greater levels of ambulation than spinal cord injured patients with the same motor deficit" (3).

Single Lateral-Bar Quadrilateral Socket KAFO (Fig. 24)

The single-lateral bar quadrilateral socket KAFO is not only useful for the patient with hemophiliac knee arthritis (6) as recorded on the chart, but, when not used with a quadrilateral socket, lightweight patients who need bilateral orthoses will frequently find single lateral-bar KAFO's more comfortable. The impact of medial bars against

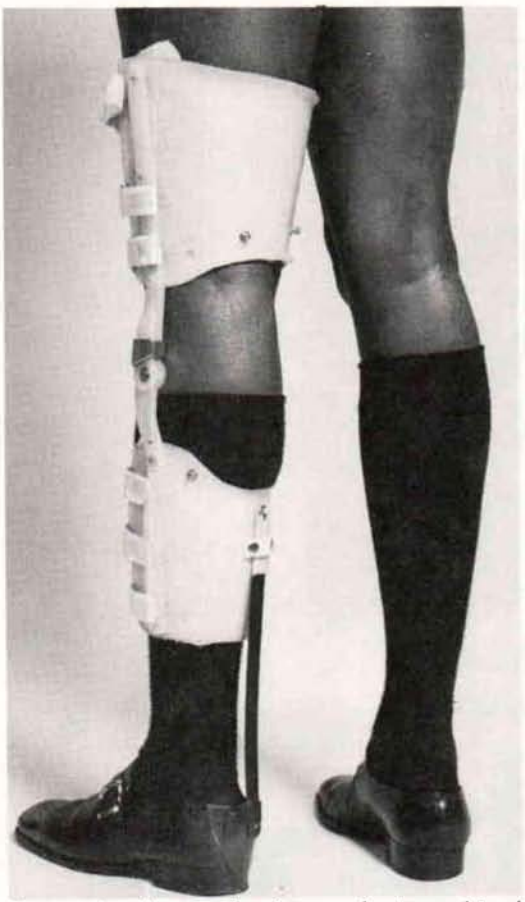


Fig. 15. A polypropylene knee orthosis combined with the VAPC shoe clasp type of ankle-foot orthosis to provide a knee-ankle-foot orthosis.

Fig. 16. A hinged elastic knee orthosis

each other is obviated. In the specific instance of the patient with hemophilia, the elimination of the medial bar removes a potential source of contusion of the opposite limb.

In the case of the hemophiliac knee with a quadrilateral socket KAFO, it may be found worthwhile to hinge the socket laterally rather than medially, to avoid the possibility of inadvertent contusion against the scrotum as the patient swings the socket open, a problem which we have encountered.

Summary

An attempt has been made to outline in a concise form our Clinic Team's basic approach to lower-limb orthosis prescription. The word "basic" should be empha-

Fig. 17. The Lenox Hill Derotation Orthosis

Fig. 18. A plastic shell knee orthosis for complete immobilization of the knee joint.

sized since the Clinic Team does not limit itself to the devices described here, but have used, at various times, other devices as they are reported. These have not been discussed since an encyclopedic approach has not been attempted. It has been our purpose to present our point of view, and, therefore, the charts included illustrate the foundation upon which we build. They are intended to have one function only—that of teaching tools. The authors do not presume to instruct certified orthotists or physicians with long experience in prescription procedures.

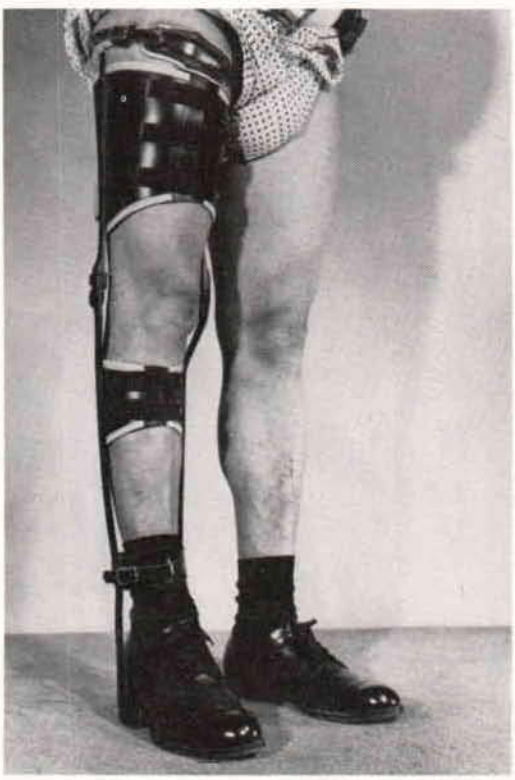


Fig. 19. Conventional double-bar knee-ankle-foot orthosis with knee lock.

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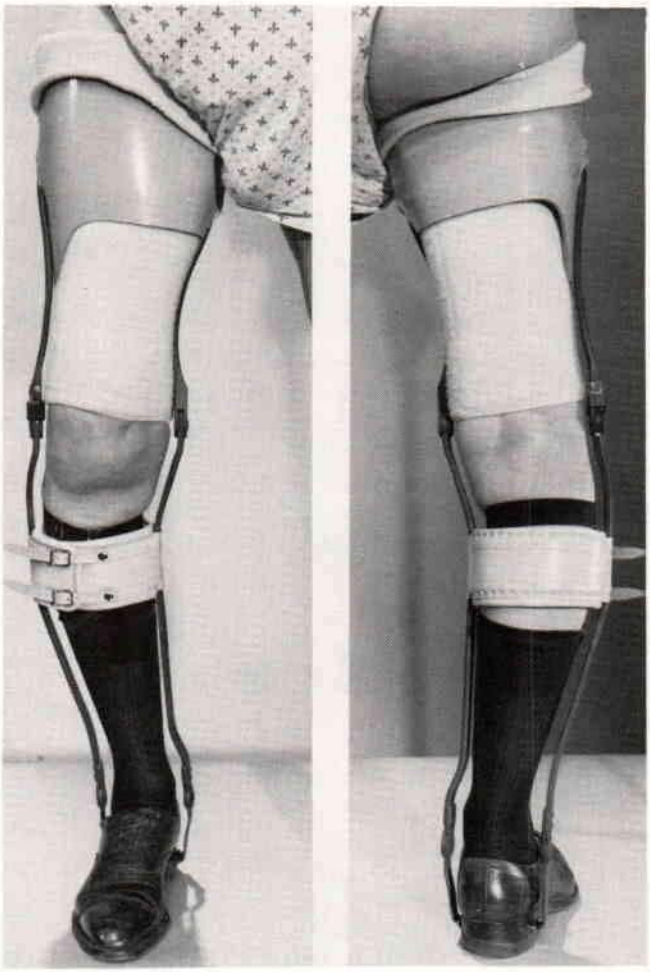

Fig. 21. Anterior and posterior views of a KAFO with a quadrilateral cuff.

Fig. 20. The Dial Knee Unit disassembled.

Fig. 22. Lateral view of a KAFO with a gluteal corset.

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Fig. 23. Double bar KAFO's for a paraplegic patient.

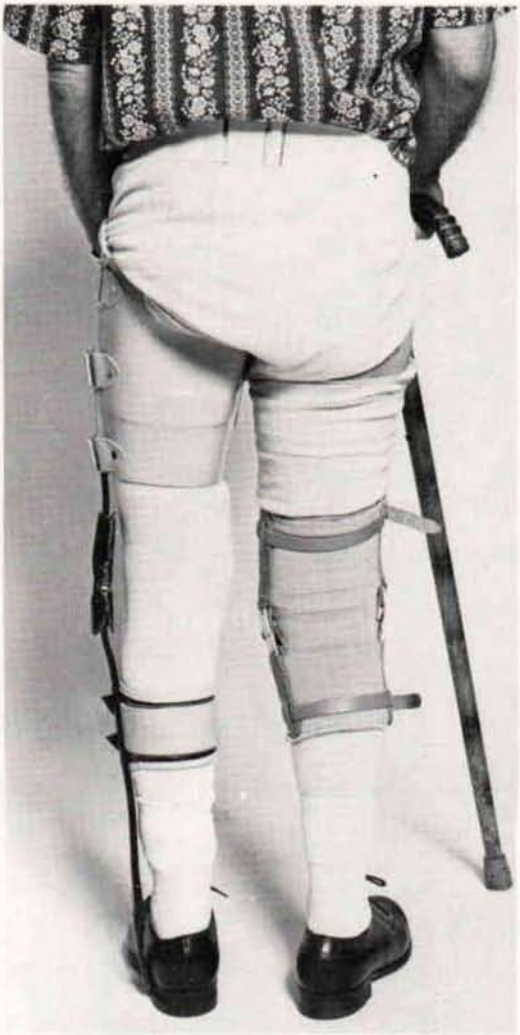

Fig. 24. The patient is wearing a lateral-bar KAFO with a quadrilateral cuff on the left side.

Footnotes

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