DEVELOPMENT OF REFINED FITTING PROCEDURES FOR LOWER-LIMB PROSTHESES

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Our contract title is "Development of Refined Fitting Procedures for Lower-Limb Prostheses" because our past work has centered around lower-limb prosthetic suspension systems. The patellar tendon supracondylar (Fig. 1) system with soft medial wedge was developed at the University of Miami Medical School and is now our standard means of treatment for below-knee amputees. Also, the expandable Syme prosthesis (Fig. 2) providing suspension without windows was developed by the University of Miami Medical School and has become the routine device for Syme's amputees here. Many years of research have gone into the Taslon suspension for above-knee and below-knee amputees (Fig. 3), but this project has been temporarily set back until a better material can be found. In the meantime a system utilizing thermoplastic removable sockets is being developed. With this system, a socket is hand-formed from polypropylene with the aid of vacuum (Fig. 4), and a rigid, polyurethane outer structure is fabricated around it (Fig. 5). The final prosthesis is then laminated over the formed foam structure (Fig. 6). The socket is then removable, for ease of modification as the stump dimensions change (Fig. 7). The socket may be reheated locally for minor adjustments or a new socket fabricated for major adjustments. Then the new or modified socket is placed back in the old prosthesis with a small additional amount of urethane foam to refit the socket to the system. Above-knee, below-knee, and below-elbow patients have been successfully fitted with this system to date.

[a]This paper was presented by Dr. Edward Peizer.

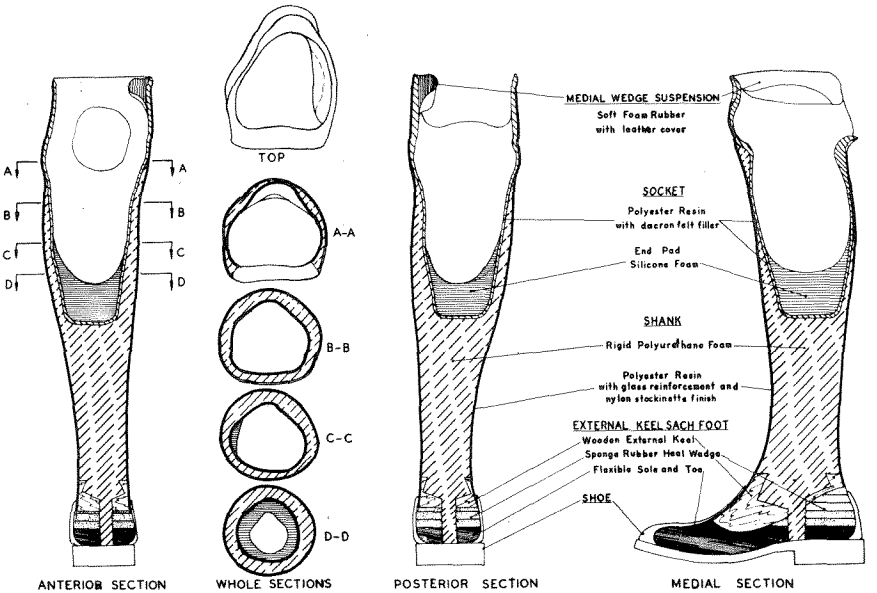


FIGURE 1.—Patellar tendon supracondylar system.

FIGURE 2.—Expandable Syme prosthesis.

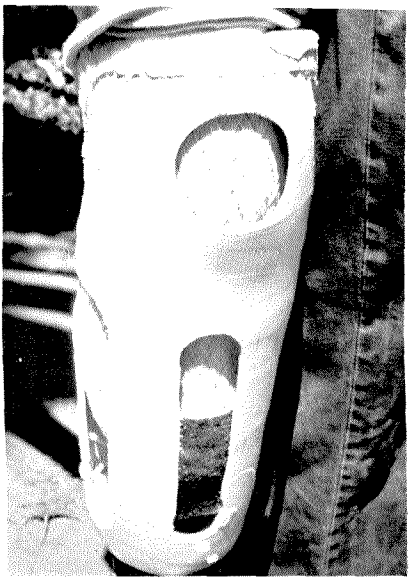


FIGURE 3.—Taslon socket system.

FIGURE 4.—Forming polypropylene socket below knee.

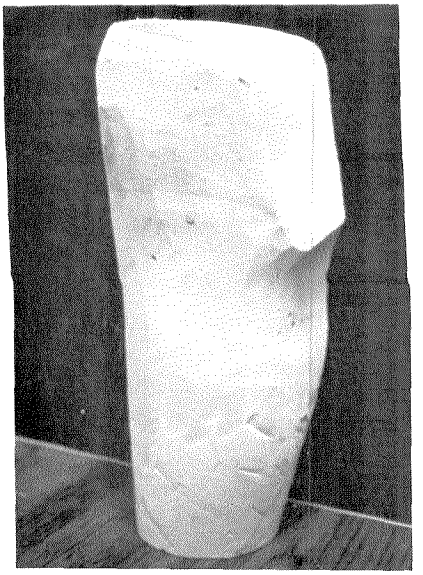


FIGURE 5.—Polypropylene socket in rough polyurethane foam shell, below knee.

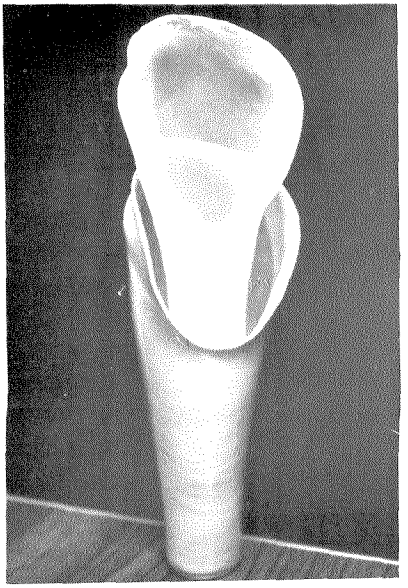


FIGURE 6.—Final prosthesis with laminated shell, below knee.

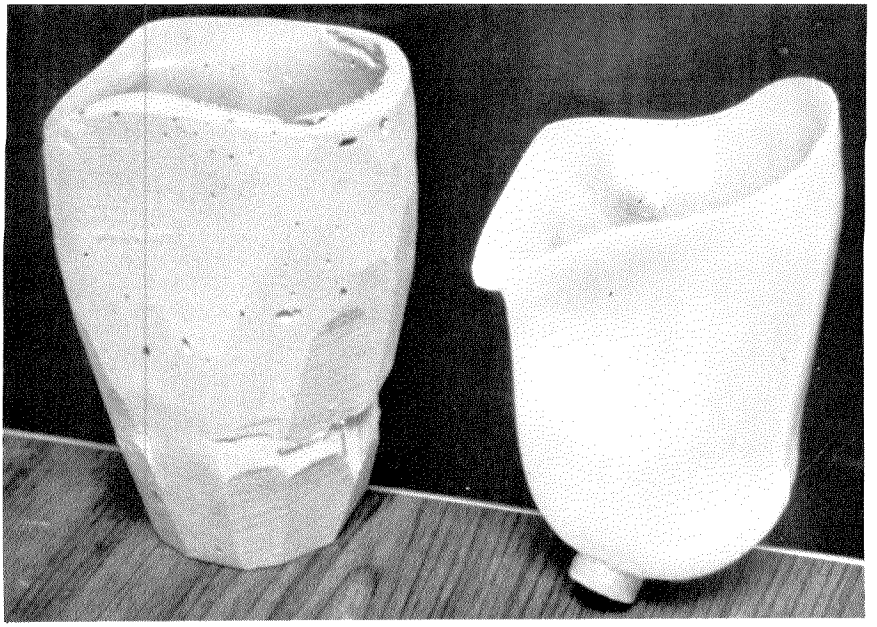


FIGURE 7.—Polypropylene socket removable from polyurethane shell, above knee.

All during this time, developments have been progressing in fracture orthoses. In the past 2 years this clinically applied research has accelerated, and the use of thermoplastics has provided lighter, more functional and more versatile orthotic designs (Fig. 8). Intra-articular fractures of the tibial plateaus are now being braced with modifications to the tibial fracture orthosis (Fig. 9). Either a medial knee joint, and/or a lateral knee joint may be added with a thigh extension to the existing orthosis to suit the particular geometry of the plateau fracture. Fractures of the femur which normally could not be treated by bracing, may now be treated with an orthosis which has an added pelvic sling. Forearm fractures are treated in an orthosis which allows elbow and wrist motion but no supination or pronation (Fig. 10). Colles fractures are also being treated with an orthosis which provides use of the limb. The wrist and elbow are free in flexion but limited in extension, and the forearm is held in supination (Fig. 11). Special additions for difficult cases include an elbow joint extension (Fig. 12). Humeral fractures are also being braced now on an experimental basis allowing wrist, elbow, and shoulder motion (Fig. 13).

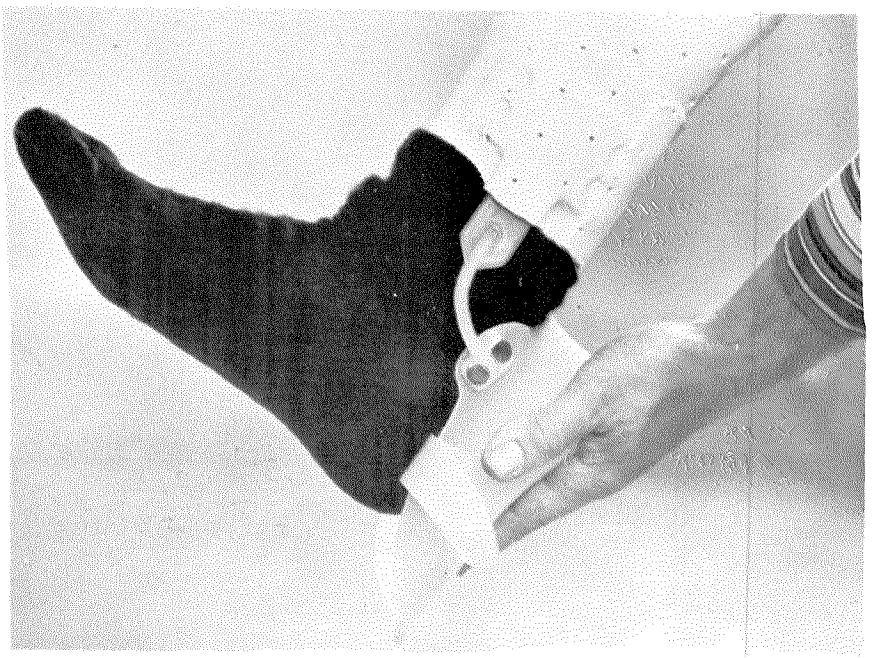


FIGURE 8.—Polypropylene insert development for tibial fracture brace.

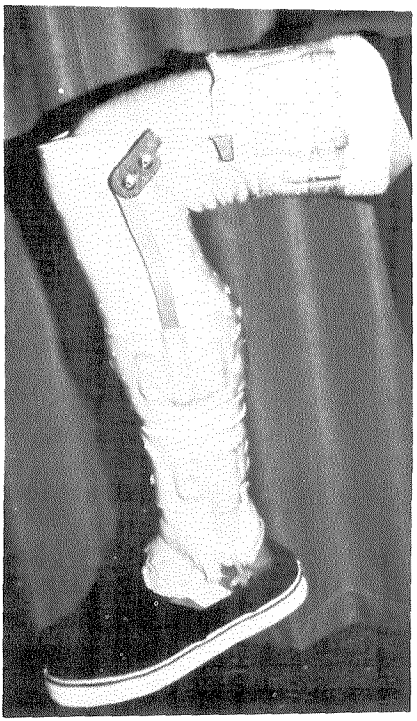
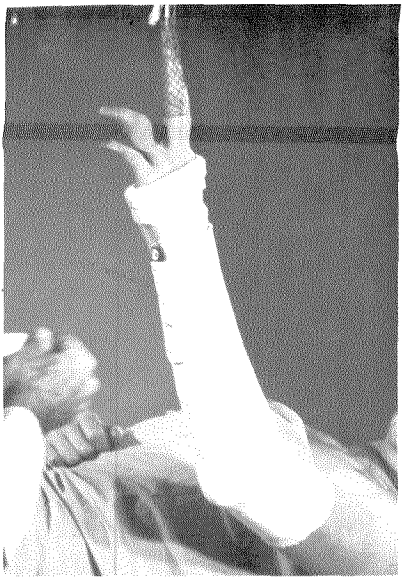


FIGURE 9.—Tibial fracture brace with knee joints and thigh extension.



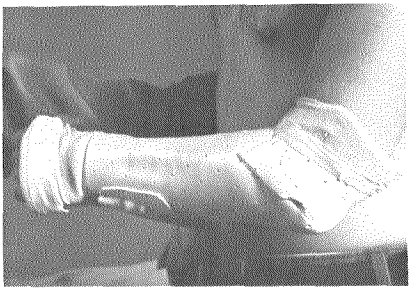
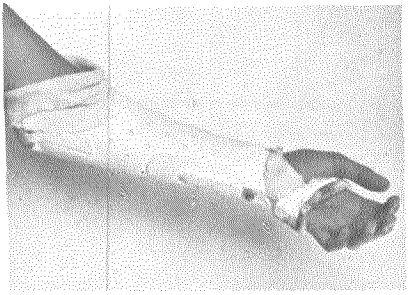


FIGURE 10.—Forearm fracture brace holds forearm in neutral position, allows full volar and dorsal flexion of wrist, and allows flexion but not full extension of elbow.



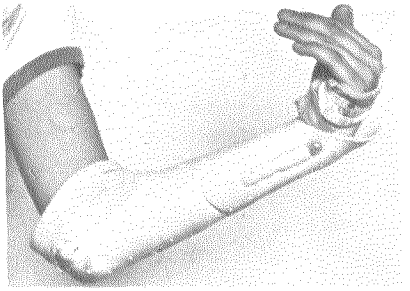


FIGURE 11.—Colles fracture brace holds forearm in supination, allows volar but not dorsiflexion of wrist, and allows flexion but not full extension of elbow.

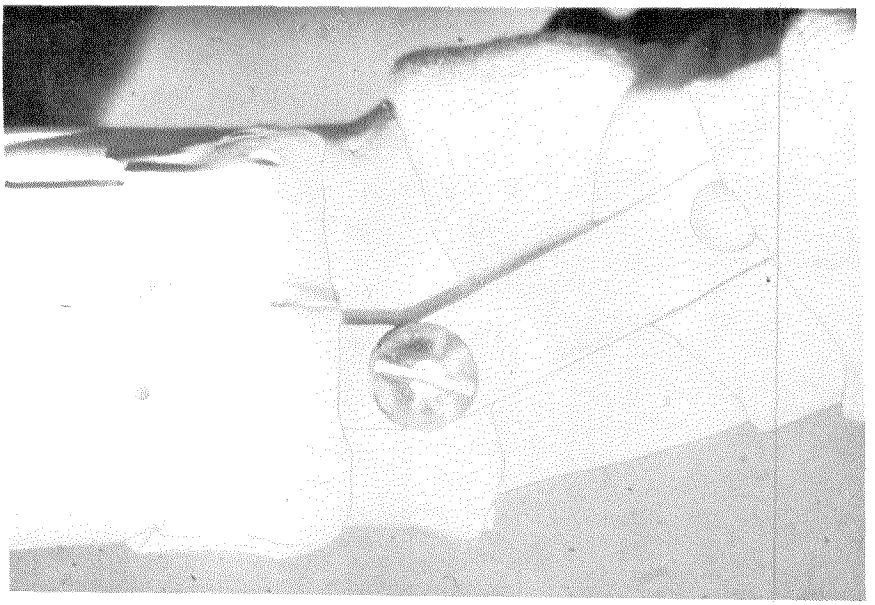


FIGURE 12.—Elbow joint extension for Colles fracture brace to aid in limitation of pronation-supination.

FIGURE 13.—Humeral fracture brace allows flexion and extension of elbow and shoulder.

Also, in orthotics design a series of polypropylene AFO's have been developed in four standard sizes to be used as an "off the shelf" item for patients with minimal ankle involvement (Fig. 14). It has been our experience that about 80 percent of the hemiplegic patients requiring thermoplastic AFO's can be adequately fitted with this standard, non-custom design. Recently, standard modifications have been developed as "add-on" devices to the standard AFO for patients with minimal knee involvement or those which require more ankle support (Fig. 15).

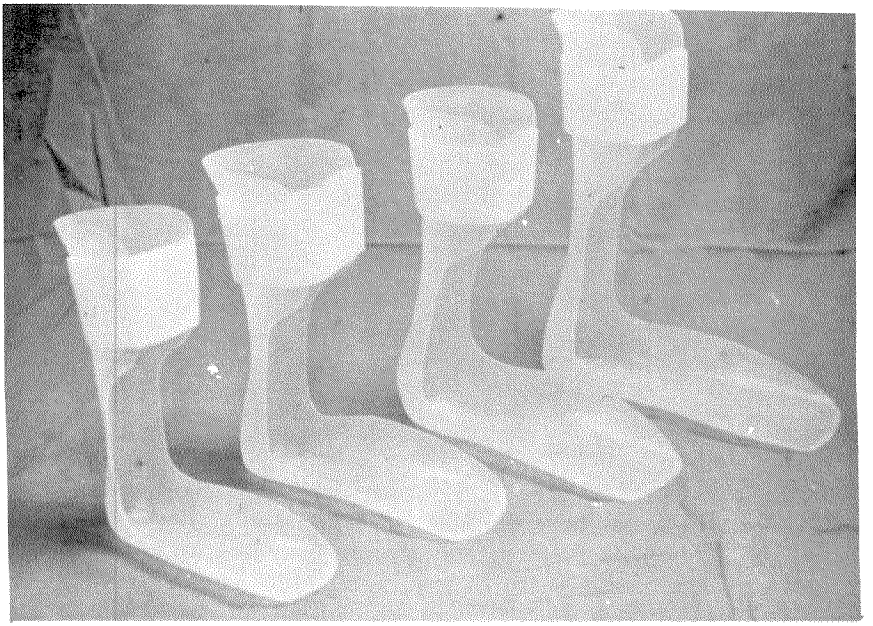


FIGURE 14.—Polypropylene AFO's in standard sizes.

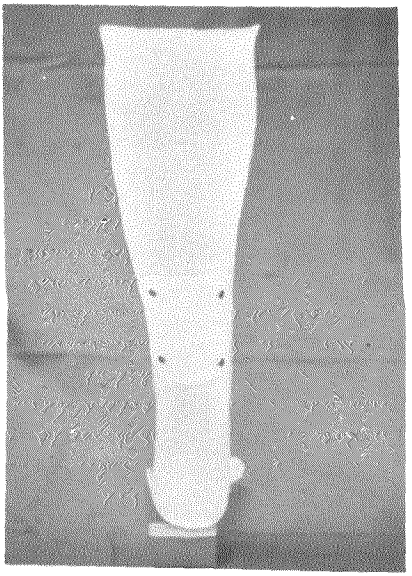


FIGURE 15.—Polypropylene AFO's with extensions.

With this background in orthotics as well as prosthetics it has been decided that all types of orthotic, lower-limb cases should be included as possible candidates for development work along with prosthetic cases. Therefore, our present research centers on difficult and unusual problem cases in lower-limb orthotics and prosthetics. Individual nonroutine cases, rather than general classes of problems or devices, are treated and documented for research. Prospective cases are evaluated for the program by a team consisting of physician, orthotist-prosthetist, and engineer. Initial evaluation consists of:

1. Decision to include or exclude from research program.
2. Physical examination by standard forms if prosthetic patient. Physical examination by technical analysis form if orthotic patient.
3. Prescription for new type of device.
4. Photos of patient with and without old device, and gait analysis with and without old device.
5. Initiation of file for the patient containing records of the above plus a list with brief comments on each visit the patient makes, a cover sheet with vital patient information and brief history, and a form for each major visit which records: a. evaluation of treatment by clinical team and by patient; b. gait analysis calculations of rate of ambulation, stride length, and stride rate; and c. description of device used at that visit. The patient file is updated with each visit. Once an experimental device is deemed adequate by the patient and the clinical team without further major modification, the patient is scheduled for a series of routine followup visits to commence within 2 weeks and repeat once per

month for a minimum of 1 year. Each scheduled visit includes a gait analysis (Fig. 16) and evaluation of progress by clinical team and patient.

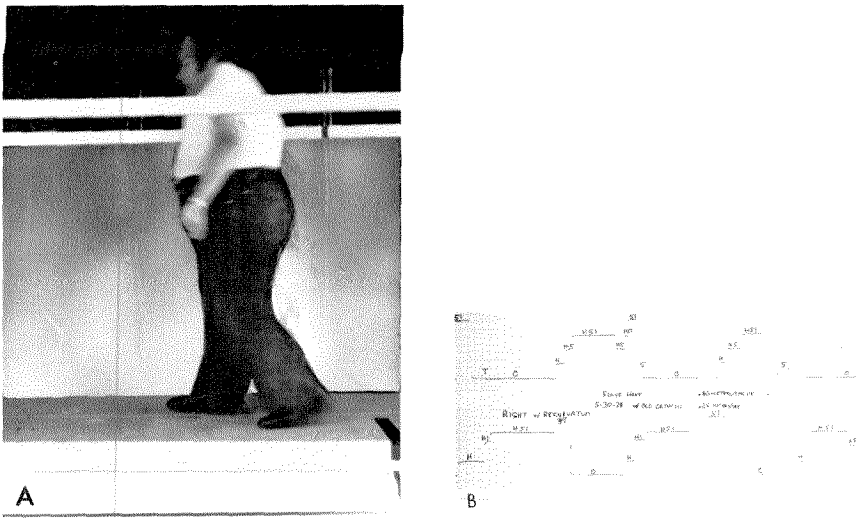


FIGURE 16.—a. Gait analysis includes load distribution and foot position analysis by barograph and rate and sequencing analysis using Dr. Perry's foot switch system. b. Recording time of heel (H), first metatarsal (1), fifth metatarsal (5), and toe (T) contact with the floor.

Presently, two prosthetic patients and seven orthotic patients have been included in the case study program. An example orthotic case is shown in Figures 17 through 30.

FIGURE 17.—Patient with original orthosis.

FIGURE 18.—Patient without orthosis.

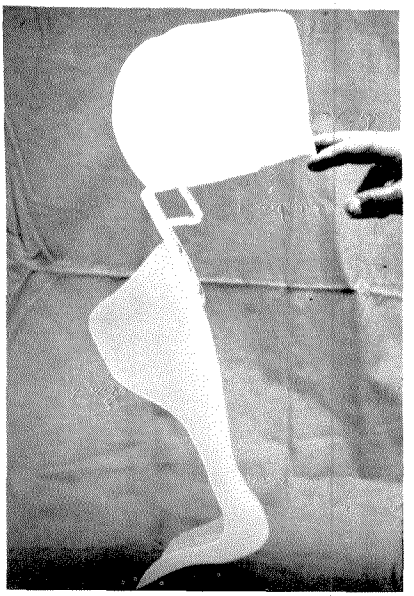


FIGURE 19.—First experimental orthosis-posterior upright with polypropylene hinge.

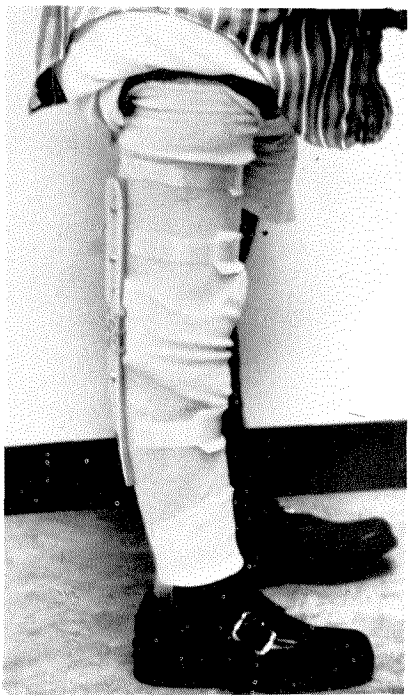


FIGURE 20.—Second experimental orthosis with polycarbonate compression members for extension stop.

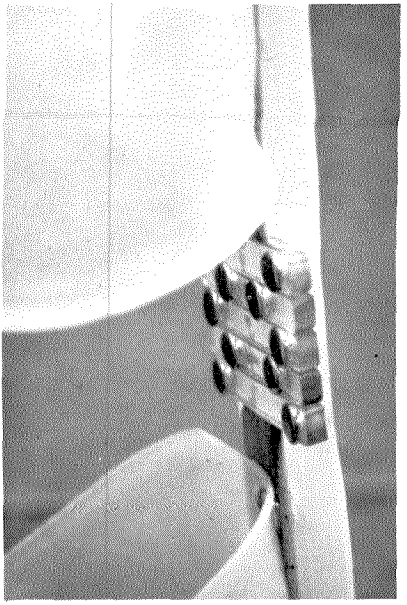


FIGURE 21.—Closeup of second experimental knee mechanism.

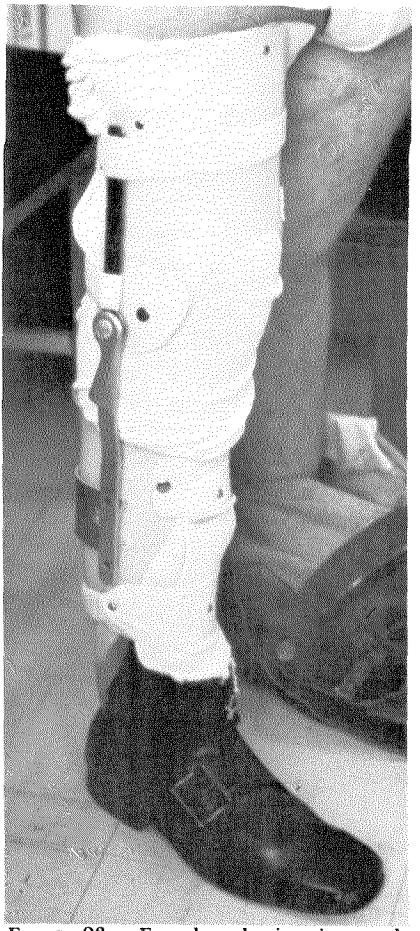


FIGURE 23.—Fourth orthosis using modified ankle joints and polypropylene shells.

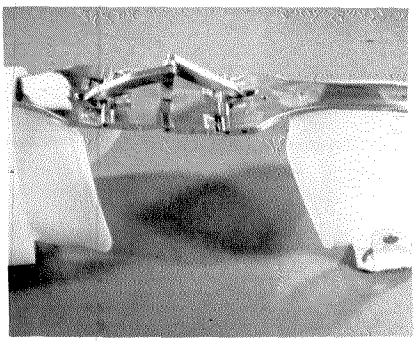


FIGURE 22.—Third orthosis with aluminum linkage.

NAME: [redacted] HOSPITAL #

ADDRESS: 10100 SW 42 ST PHONE # 226-5394

SEX: M AGE: 22 INITIAL DATE: 4-10-74

REASON FOR INCLUSION IN PROGRAM:

SUMMARY OF DIAGNOSIS

PRIMARY:

SECONDARY:

INITIAL SOLUTION: LOCK RIGHT KNEE (OFFSET KNEE JTS) FREE LEFT KNEE PP SHELLS, DOUBLE UPRIGHT ALUMINUM, ANKLE JTS. SAME AS BEFORE

SECONDARY SOLUTION:

RESULTS AND CONCLUSIONS:

FIGURE 24.—Patient information form.

TECHNICAL ANALYSIS FORM **LOWER LIMB** **Revised July 1972**

Name [redacted] No. _____ Age 23 Sex M

Date of Onset age 3 mo Cause [illegible]

Occupation _____ Present Lower-Limb Equipment [illegible]

Diagnosis [illegible] (signature) [illegible]

Date [illegible]

Ambulatory ☐ Non-Ambulatory ☐

MAJOR IMPAIRMENTS:

A. Skeletal
1. Bone and Joints: Normal ☐ Abnormal [illegible]
2. Ligaments: Normal ☑ Abnormal ☐ Knee: AC ☐ PC ☐ MC ☐ LC ☐ Ankle: MC ☐ LC ☐
3. Extremity Shortening: None ☑ Left ☐ Right ☐
   Amount of Discrepancy: A.S.S.-Heel _____ A.S.S.-MTP _____ MTP-Heel _____

B. Sensation: Normal ☑ Abnormal ☐
1. Anaesthesia Hypaesthesia ☐ Location: _____
   Protective Sensation: Retained ☑ Lost ☐
2. Pain ☐ Location: _____

C. Skin: Normal ☑ Abnormal: _____

D. Vascular: Normal ☑ Abnormal ☐ Right ☐ Left ☐

E. Balance: Normal ☑ Impaired ☐ Support: [illegible]

F. Gait Deviations: [illegible]

G. Other Impairments: _____

LEGEND

= Direction of Translatory Motion

= Abnormal Degree of Rotary Motion (60°)

= Fixed Position (30°, 1 CM)

= Fracture

Volitional Force (V)
- √ = Normal
- G = Good
- F = Fair
- P = Poor
- T = Trace
- Z = Zero

Hypertonic Muscle (H)
- M = Mild
- Mo = Moderate
- S = Severe

Proprioception (P)
- √ = Normal
- I = Impaired
- A = Absent

D = Local Distension or Enlargement

= Pseudarthrosis

= Absence of Segment

FIGURE 25.—Technical analysis form, page 1.

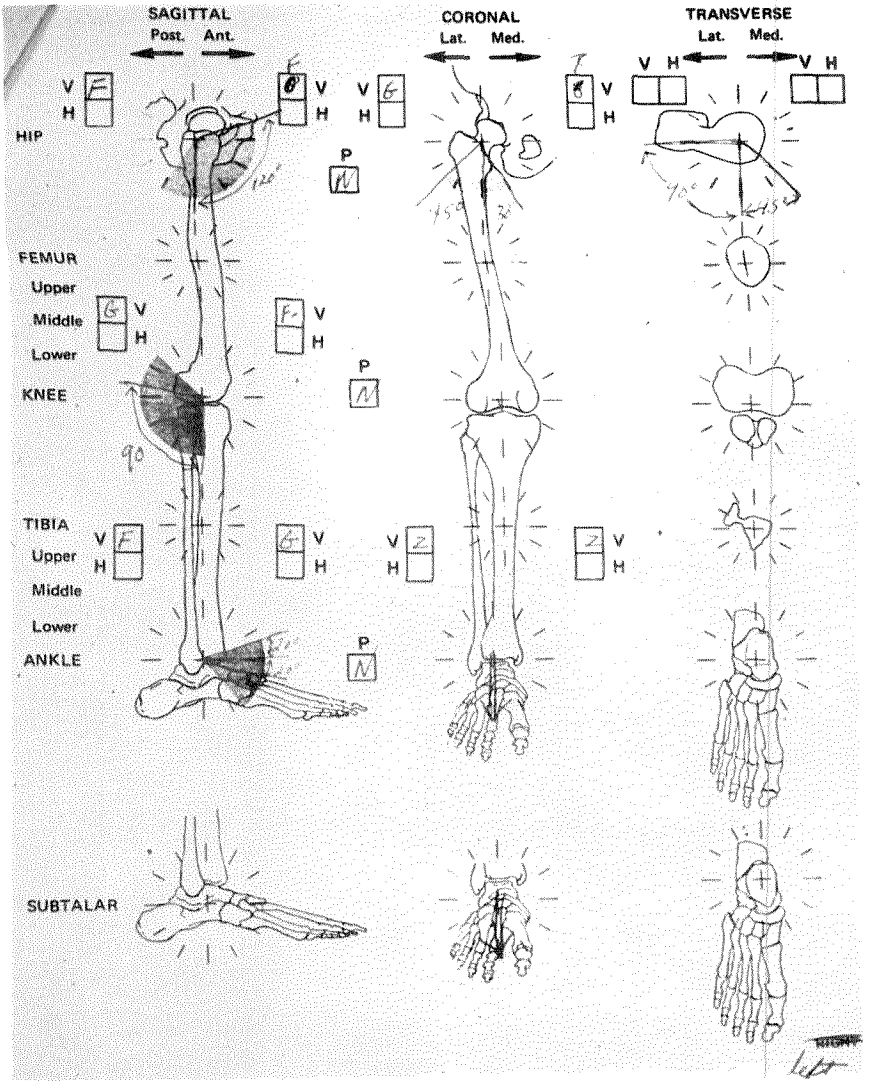


FIGURE 26.—Technical analysis form, page 2.

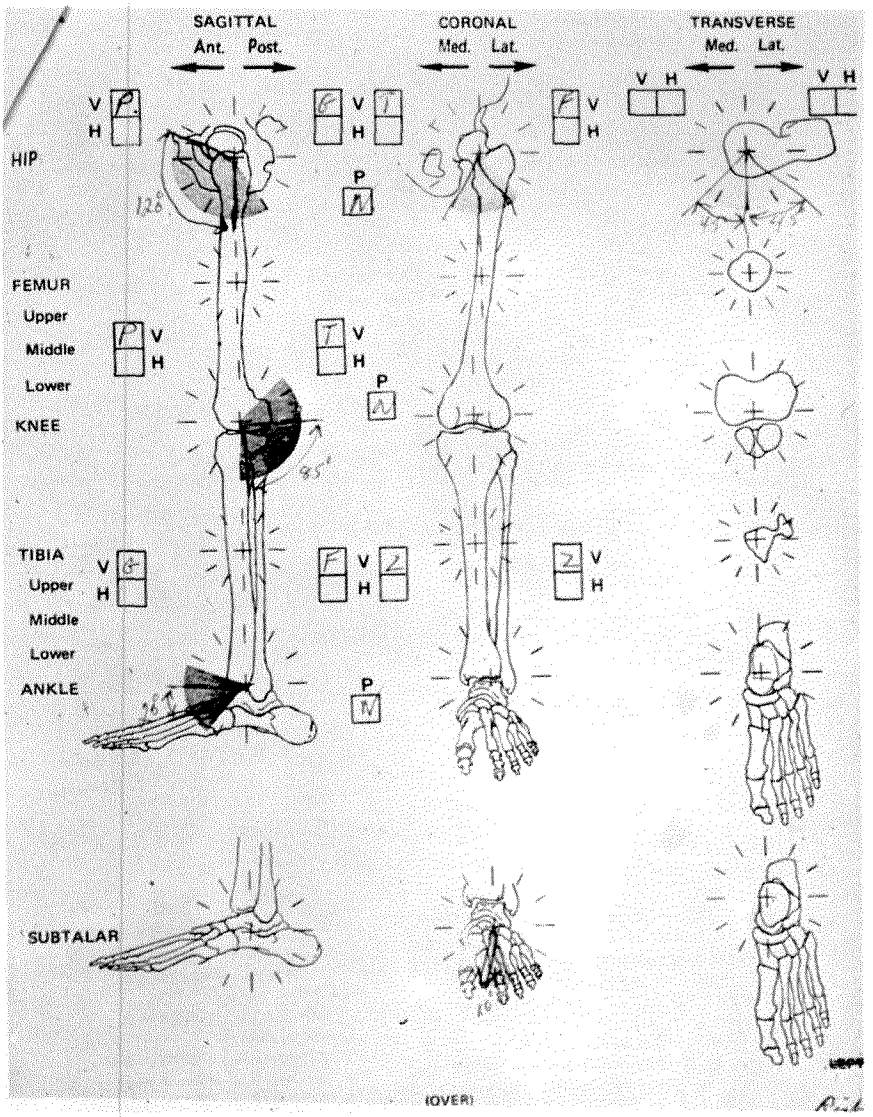


FIGURE 27.—Technical analysis form, page 3.

Summary of Functional Disability

Difficulty donning (L) AKO

[illegible] for [illegible] knees

Treatment Objectives:

Prevent/Correct Deformity	☐	Improve Ambulation	☑
Reduce Axial Load	☐	Fracture Treatment	☐
Protect Joint	☑	Other	Facilitate ease of donning

ORTHOTIC RECOMMENDATION

LOWER LIMB		(R) FLEX (L)		(R) EXT (L)		(R) ABD (L)		(R) ADD (L)		ROTATION Int.		ROTATION Ext.		AXIAL LOAD
HKAO	Hip	F	F	F	F	F	F	F	F	F	F	F	F	
KAO	*Thigh*													
	Knee	H	F	H	F	H	H	H	H					
AFO	*Leg*													
	Ankle	F (Dorsi)	S 90°	S 90° (Plantar)	F									
	Subtalar									(Inver.) H		(Ever.) H		
FO Foot	Midtarsal	F	F	F	F									
	Met.-phal.	F	F	F	F	F	F	F	F					

REMARKS: Modify present AKO on (L) to above specifications, then fabricate single upright AKO if possible to walk to free knee on (L). Leave present (R) AKO as is

KEY: Use the following symbols to indicate desired control of designated function:

- 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.

FIGURE 28.—Technical analysis form, page 4.

APRIL 12. ATTEMPTED POSTERIOR UPRIGHT ORTHOSIS AGAIN WITH FLEXIBL PP STRAP & PC BLOCK COMPRESSION STOPS IN EXTENSION & PP MOLDED SHELLS. ADDED SS CABLE TENSION MEMBER FOR ADDED STRENGTH BUT CABLE FITTINGS PULLED OUT. TRY 4 BAR LINKAGE NEXT.

MAY ?. POSTERIOR 4-BAR DOEN'T STOP ADEQUATELY MADE IN ALUM. NEED SUPPLT LINKS TO STOP IN EXTENSION. ALSO NEEDS NEW HIGH ANTERIOR WALL ON THIGH SECTION TO CONTROL HIP EXTENSION

MAY 30 POSTERIOR 7-BAR LINKAGE STOPS IN EXTENSION ADEQUATELY BUT HIP FLEXION MOMENT PUSHES ON HIGH ANTERIOR WALL OF THIGH SHELL WHEN BEING SEATED, THUS CAUSING KNEE TO FLEX INAPPROPRIATELY. NEED FORCED FLEXION IN KNEE LINKAGE. MODIFIED PRESENT ORTHOSES FOR TEMPORARY USE.

JUNE 19 NEW SHELLS WITH DOUBLE UPRIGHT CHILDS TOE LIFT ANKLE EXTENSIONS FOR KNEE JOINTS GIVES ADJUSTABLE CONTROL OF KNEE EXTENSION STOP. BUT THIGH SECTION TOO LOW ANTERIORLY AND IMPINGES ON DISTAL, MEDIAL PORTION OF THIGH FOOT & CALF SECTION TOO FLEXABLE AT ANKLE NEEDS RIBBING + LESS TRIMMING IN POSTERIOR SECTION. PT. SUGGESTED SINGLE AXIS ANKLE JOINT IN THE PP PARTS IN STEAD OF POSTERIOR LEAF. OLD ORTHOSIS BEYOND REPAIR

JUNE 27

FIGURE 29.—Record of each individual visit.

EVALUATION OF DEVICE

DATE: 4-19-74 VISIT: 1 POST FITTING: -2 WKS

A. EVALUATION BY PATIENT

COMFORT: _____

COSMESIS: _____

FUNCTION: _____

B. EVALUATION OF CLINICAL TEAM

COSMESIS: _____

FUNCTION: _____

C. GAIT ANALYSIS

RATE OF AMBULATION: _____

STRIDE LENGTH: _____

STRIDE RATE: _____

D. DESCRIPTION OF DEVICE ☒ ORIGINAL DEVICE ☐ EXPERIMENTAL DEVICE

DOUBLE UPRIGHT, POLYESTER LAMINATED, BILATERAL ORTHOSES WITH EXTENSION LOCKS ON KNEE JOINTS, AND LIMITED MOTION ANKLE JOINTS. QUAD BRIMS, PRETIBIAL SHELLS, 90° PLANTAR FLEXION STOP [illegible] UCB FOOTPLATES.

FIGURE 30.—Major followup visits form.