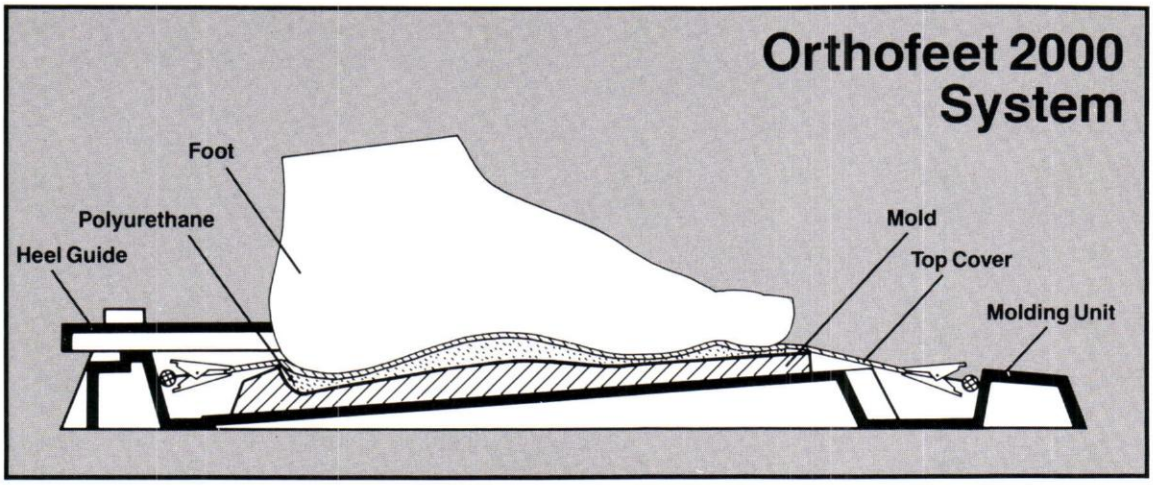
Spring 1987
Volume 41
Number 1

Orthotics and Prosthetics

Journal of the American Orthotic and Prosthetic Association

Directly Molded Orthotics ...In 15 Minutes



REVOLUTION IN ORTHOTICS

The Orthofeet 2000 system enables you to take measurements and build the orthotics in one action, without having to take impression casts.

It consists of a molding unit and a set of seven pairs of molds, suitable for most foot sizes. Kits are supplied, which include all the materials to mold the orthotics. Simply mix the two component materials (special grade foaming Poly-Urethane), pour it into the mold and hold the foot on the molding unit. The material foams and conforms precisely to the bottom of the foot. Within 3 to 5 minutes, the final hardened orthotic is ready, complete with its top cover and posting. No additional processing is normally required.

FINALLY, A TRULY FUNCTIONAL ORTHOTIC

With Orthofeet 2000 the orthotics are molded directly to the foot, while the foot is being held in the neutral position. It automatically builds intrinsic posting which keeps the foot in this position inside the shoe.

CONSTRUCT ANY ORTHOTIC

With Orthofeet 2000's big selection you can construct any type of orthotic: functional, biomechanical, as well as accommodative. You can treat any foot deformity and construct ultimate devices for sport activities, arthritic, geriatric and diabetic patients.

The system also comes with a selection of three molding materials: **Rigid** - for ultimate control and support, **Soft** - for accommodative orthotics with superior cushioning and comfort, and **Semi-rigid** - for patients who cannot tolerate firm orthotics.

With our molding process you can precisely incorporate a metatarsal pad, a U pad, and create a depression for a sensitive metatarsal or heel spur.

You can also form the orthotics to any shape: Full length, or trimmed to the sulcus, to the metatarsals, or for the Morton extension.

You can make it very thin to fit dress shoes or women's high heels. And with additional layers, it achieves forefoot accommodations and extra cushioning.

ECONOMICAL AND PROFITABLE

With Orthofeet 2000 you are in fact, "buying time". You spend only 15 minutes for a complete pair of orthotics, with no need for repeat visits of your patients.

What's more, the system will come equipped with free materials, so you can cover your initial investment right away.

So, Orthofeet 2000 not only means better orthotics. It also means more orthotics. Result: you can take care of more patients more profitably than ever before.

CLINICALLY TESTED

Hundreds of foot specialists are already using the Orthofeet 2000 system with great success. Their results are impressive. They make more orthotics than ever before, while gaining excellent acceptance by their patients.

For further information, call:
1-800-524-2845

* Patent Pending

Orthotics and Prosthetics

Spring, 1987 **Volume 41, Number 1**

CONTENTS

Orthotics and Prosthetics (ISSN 0030-5928) is published quarterly by the American Orthotic and Prosthetic Association, 717 Pendleton Street, Alexandria, VA 22314. Subscriptions: $50 domestic (U.S., Canada, Mexico); $50 foreign; $60 foreign airmail. Membership dues of $24 for each member are set aside for *Orthotics and Prosthetics*. Second-class postage paid at Alexandria, Virginia and additional mailing offices. POSTMASTER: Send address changes to *Orthotics and Prosthetics*, 717 Pendleton Street, Alexandria, VA 22314.

To be inserted on page 1, replacing the contents page of the Winter, 1987 Orthotics and Prosthetics *journal, Volume 40, Number 4. The contents page was inadvertently published without a complete listing of the articles. This reprint of the contents page is provided for the convenience of our readers. It is suggested that this reprint be inserted in your Winter, 1987* Orthotics and Prosthetics *issue.*

Orthotics and Prosthetics

Winter 1987 **Volume 40, Number 4**

CONTENTS

Orthotics and Prosthetics (ISSN 0030-5928) is published quarterly by the American Orthotic and Prosthetic Association, 717 Pendleton Street, Alexandria, VA 22314. Subscriptions: $50 domestic (U.S., Canada, Mexico); $50 foreign; $60 foreign airmail. Membership dues of $24 for each member are set aside for *Orthotics and Prosthetics.* Second-class postage paid at Alexandria, Virginia and additional mailing offices. POSTMASTER: Send address changes to *Orthotics and Prosthetics,* 717 Pendleton Street, Alexandria, VA 22314.

Meetings and Events

Please notify the National Office immediately concerning all meeting dates. It is important to submit meeting notices as early as possible. In the case of Regional Meetings, you must check with the National Office prior to confirming dates to avoid conflicts in scheduling.

1987

May 4–13, UCLA CAT-CAM/Narrow ML Above Knee Prosthetics Course, Los Angeles, California. Contact: Timothy B. Staats, MA, CP, UCLA POEP, Room 22-46, 1000 Veteran Avenue, Los Angeles, California 90024.

May 7–10, AOPA Regions II and III Combined Annual Meeting, Hershey, Pennsylvania.

May 7–10, SinoMed '87, an international exhibition and conference program, Shanghai Exhibition Centre, Shanghai, People's Republic of China. Contact: Kallman Associates, Five Maple Court, Ridgewood, New Jersey 07450; tel. (201) 652-7070.

May 13–15, Hosmer Electric Systems Workshop and Seminar, Memphis, Tennessee. Contact: Catherine Wooten, Hosmer Dorrance Corporation, 561 Division Street, Campbell, California 95008; tel. (800) 538-7748 or (408) 379-5151.

May 15–16, Academy Continuing Education Conference, "The Foot: Orthotic and Prosthetic Consideration," Royal Sonesta Hotel, Cambridge, Massachusetts. Contact: Academy National Headquarters (717) 836-7118.

May 21–23, NYU course, the ISNY Below-Knee Flexible Socket, New York, New York. Contact: Registrar, Prosthetics and Orthotics, 317 E. 34th Street, New York, New York 10016; tel. (212) 340-6686.

May 27–29, NYU course, The Narrow ML Above-Knee Socket, New York, New York. Contact: Registrar, Prosthetics and Orthotics, 317 E. 34th Street, New York, New York 10016; tel. (212) 340-6686.

May 27–30, UCLA Total Surface Bearing Suction Below Knee Prosthetics Course, Los Angeles, California. Contact: Timothy B. Staats, MA, CP, UCLA POEP, Room 22-46, 1000 Veteran Avenue, Los Angeles, California 90024.

May 28–31, AOPA Region V Annual Meeting, Grand Traverse Hotel, Traverse City, Michigan.

June 3–5, NYU course, The ISNY Below-Knee Flexible Socket, New York, New York. Contact: Registrar, Prosthetics and Orthotics, 317 E. 34th Street, New York, New York 10016; tel. (212) 340-6686.

June 4–6, Annual Meeting of the Association of Children's Prosthetic-Orthotic Clinics, Vancouver, British Columbia. Paper submissions: Francis J. Trost, M.D., Program Chairman, 2545 Chicago Avenue, South, Minneapolis, Minnesota 55404. Registration: Sidney Fishman, Ph.D., c/o NYU PGMS, 317 E. 34th Street, New York, New York 10016. Information: Yoshio Setoguchi, M.D., Child Amputee Prosthetics Project, UCLA Rehabilitation Center, 1000 Veteran Avenue, Room 25-26, Los Angeles, California 90024.

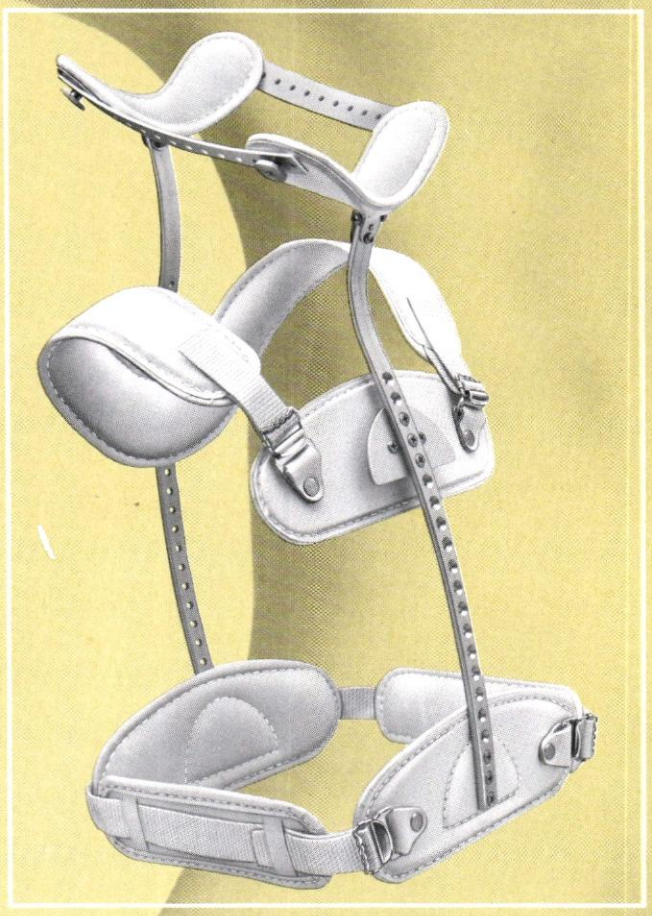
June 5–7, AOPA Region IX, COPA, and the California Chapters of the Academy Combined Annual Meeting, Doubletree Inn, Monterey, California.

June 8–17, UCLA CAT-CAM/Narrow ML Above Knee Prosthetics Course, Los Angeles, California. Contact: Timothy B. Staats, MA, CP, UCLA POEP, Room 22-46, 1000 Veteran Avenue, Los Angeles, California 90024.

June 8–12, Motion Control course, "Fitting Procedures for the Utah Artificial Arm and Hand Controller," Northwestern University, Post-Graduate Medical School, Dept. of Prosthetics and Orthotics, Chicago, Illinois. Contact: Harold Sears, Ph.D., 95 South Elliott Road, #105, Chapel Hill, North Carolina 27514, (919) 968-8492.

June 10–13, AOPA Regions VII, VIII, X, and XI Combined Annual Meeting, Fairmont Hotel, Dallas, Texas.

June 12–14, Association of Cytogenetic Technologists Annual Meeting, Estes Park, Colorado.



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June 18–21, AOPA Region VI and the Midwest Chapter of the Academy Combined Annual Meeting, Embassy Suite, Indianapolis, Indiana.

June 19–23, RESNA '87, the 10th Annual Conference on Rehabilitation Technology, San Jose, California. Contact: RESNA, Suite 700, 1101 Connecticut Avenue, NW, Washington, D.C. 20036; tel. (202) 857-1199.

June 24–27, Tenth INTERBOR Congress, Barcelona, Spain. Contact: Jose Ma Camos, Secretary of the Congress, Grau Soler, Buenos Aires, 52, Argentina.

July 5–10, International Conference on Disability Education, Jerusalem, Israel. Contact: Israel Rehabilitation Society, 18 David Elazar Street, Tel Aviv 61901, Israel.

July 12–16, International Conference of Rehabilitation Journalists, Jerusalem, Israel. Contact: Israel Rehabilitation Society, 18 David Elazar Street, Tel Aviv 61901, Israel.

July 17–18, Academy Continuing Education Conference, "Upper Extremity Prosthetics and Orthotics," Old Town Holiday Inn, Alexandria, Virginia. Contact: Academy National Headquarters, (717) 836-7118.

August 21–22, Academy Continuing Education Conference, "Sports Injuries and Recreational Prosthetics," Amway Grand Plaza Hotel, Grand Rapids, Michigan. Contact: Academy National Headquarters, (717) 836-7118.

August 31–September 4, Motion Control course, "Fitting Procedures for the Utah Artificial Arm and Hand Controller," 916 Area Vo-Tech Institute, White Bear Lake, Minnesota. Contact: Harold Sears, Ph.D., 95 South Elliott Road, #105, Chapel Hill, North Carolina 27514, (919) 968-8492.

September 6–10, International Seminar on Prosthetics and Orthotics, Dan Accadia Hotel, Herzliya, Israel. Contact: ISPO 1987, P.O. Box 50006, Tel Aviv 61500, Israel; tel. (03) 654 571; TELEX: 341171 KENS IL, Fax: 972 3 655674.

September 11–12, Ohio Orthotics and Prosthetics Association/Ohio Chapter, American Academy of Orthotists and Prosthetists combined meeting, "Bridging the Profession," Dayton, Ohio. Contact: Norma Jean Finissi, Executive Director, O.O.P.A./Ohio A.A.O.P., 4355 North High Street, #208, Columbus, Ohio 43214; tel. (614) 267-1121.

September 21–27, AOPA Annual National Assembly, Hyatt Regency Hotel, San Francisco, California. Contact: AOPA National Headquarters, (703) 836-7116.

September 28–30, Hosmer Electric Systems Workshop and Seminar, Hosmer Dorrance Corporation, Campbell, California. Contact: Catherine Wooten, Hosmer Dorrance Corporation, 561 Division Street, Campbell, California 95008; tel. (800) 538-7748 or (408) 379-5151.

October 2–3, New York State Chapter AAOP Fall Seminar, Sheraton Inn and Conference Center, Utica, New York. Contact: David Forbes, CPO, (315) 736-0161.

October 12–15, Middle East Medicare 87 Exhibition, Exhibition Centre Bahrain, Bahrain. Contact: Garald G. Kallman, Kallman Associates, 5 Maple Court, Ridgewood, New Jersey 07450; tel. (201) 652-7070.

October 23–24, Academy Continuing Education Conference, "Hi-Tech in Prosthetics and Orthotics," The Lincoln Hotel, Dallas, Texas. Contact: Academy National Headquarters, (717) 836-7118.

November 11–13, Hosmer Electric Systems Workshop and Seminar, Hosmer Dorrance Corporation, Campbell, California. Contact: Catherine Wooten, Hosmer Dorrance Corporation, 561 Division Street, Campbell, California 95008; tel. (800) 538-7748 or (408) 379-5151.

November 26–29, Medical/Hospitech 87, Bangkok International Exposition Center, Bangkok, Thailand. Contact: SHK International Services Ltd., 22/F. Tian An Centre, 151 Gloucester Road, Hong Kong.

December 7–11, Motion Control course, "Fitting Procedures for the Utah Artificial Arm and Hand Controller," UCLA Prosthetics Education Program, Los Angeles, California. Contact: Harold Sears, Ph.D., 95 South Elliott Road, #105, Chapel Hill, North Carolina 27514, (919) 968-8492.

1988

January 25–31, Academy Annual Meeting and Scientific Symposium, Newport Beach Marriott Hotel and Tennis Club, Newport Beach, California. Contact: Academy National Office, (703) 836-7118.

February 4–9, American Academy of Orthopedic Surgeons Annual Meeting, Atlanta, Georgia.

May 13–15, AOPA Region IX, COPA, and the California Chapters of the Academy Combined Annual Meeting.

May 19–21, AOPA Region V Annual Meeting, Charleston, West Virginia.

June 9–11, AOPA Regions II and III Combined Annual Meeting.

June 14–18, AOPA Regions VII, VIII, X, and XI Combined Annual Meeting, Seattle, Washington.

September 5–9, 16th World Congress of Rehabilitation International, Keio Plaza Inter-Continental Hotel, Shinjuku, Tokyo, Japan. Contact: Secretary General, 16th World Congress of Rehabilitation International, c/o the Japanese Society for Rehabilitation of the Disabled, 3-13-15, Higashi Ikebukuro, Toshima-Ku, Tokyo 170, Japan.

October 25–30, AOPA Annual National Assembly, Sheraton Washington Hotel, Washington, D.C. Contact: AOPA National Headquarters, (703) 836-7116.

1989

January 31–February 5, Academy Annual Meeting and Scientific Symposium, Wyndham Hotel, Orlando, Florida. Contact: Academy National Office, (703) 836-7118.

February 9–19, American Academy of Orthopaedic Surgeons Annual Meeting, Las Vegas, Nevada.

May 12–14, AOPA Region IX, COPA, and the California Chapters of the Academy Combined Annual Meeting.

May 18–20, AOPA Region V Annual Meeting, Hotel Sofitel, Toledo, Ohio.

October 2–8, AOPA Annual National Assembly, MGM Grand Hotel, Reno, Nevada. Contact: AOPA National Headquarters, (703) 836-7116.

November 12–17, International Society for Prosthetics and Orthotics VI World Congress, Kobe Convention Center, Kobe, Japan. Contact: VI ISPO World Congress, Secretariat, c/o International Conference Organizers, Inc., 5A Calm Building, 4-7, Akasaka 8-chome, Minato-ku, Tokyo, 107 Japan.

1990

January 22–28, Academy Annual Meeting and Scientific Symposium, Hyatt Regency Hotel, Phoenix, Arizona. Contact: Academy National Office, (703) 836-7118.

February 8–13, American Academy of Orthopaedic Surgeons Annual Meeting, New Orleans, Louisiana.

May 11–13, AOPA Region IX, COPA, and the California Chapters of the Academy Combined Annual Meeting.

September 11–16, AOPA Annual National Assembly, Sheraton Boston Hotel, Boston, Massachusetts. Contact: AOPA National Headquarters, (703) 836-7116.

1991

October 21–26, AOPA Annual National Assembly, Disneyland Hotel, Anaheim, California. Contact: AOPA National Office, (703) 836-7116.

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PEL NEWS

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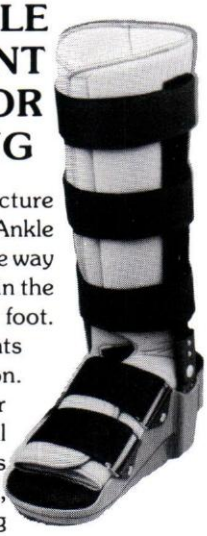

Here's the latest in functional fracture bracing from USMC. The Controlled Ankle Motion Walker (C.A.M.) is a new, unique way to provide range of motion at the ankle in the rehabilitation of injuries to the ankle or foot. The adjustable double action ankle joints provide a fixed position or range of motion. You can lock in dorsiflexion or plantar flexion or allow up to 45 degrees total range of motion. The C.A.M. restricts inversion/eversion. It is very lightweight, made of high-tech plastic and has strong malleable uprights. A one piece stirrup is molded into the footplate and there are adjustable straps with velcro closures.

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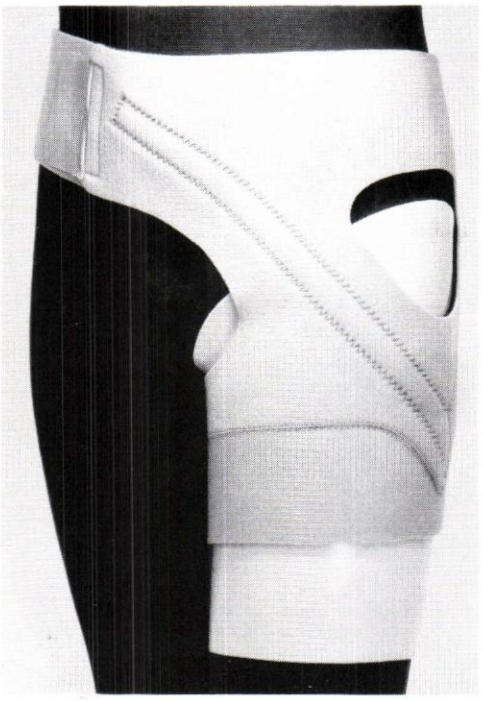
TES™ belt

(PATENT PENDING)



Syncor Ltd., manufacturer of TES belt, as advertised in the March AOPA Almanac, would like to apologize for the difficulty in obtaining TES belts from your supplier. Back orders will be filled by the end of April, at which time we will have a U.S. source for materials presently imported. Your supplier is not at fault in this delay. Thank you for understanding.

On a positive note, please refer to page 19 for a new product now available.

Syncor Ltd.

Ad Index and Hotline

Advertisers are encouraged to submit the name of a contact person within their organization for inclusion in the Ad Index.

ONE SOURCE!

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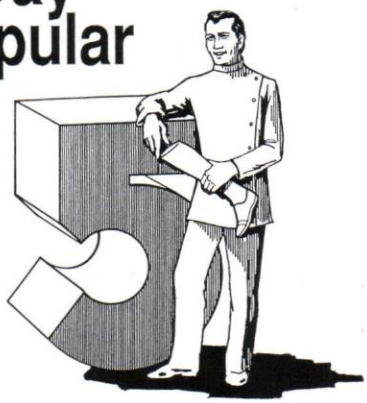

To O&P practitioners, the term "service" is a common promise. Unfortunately, it's also an abused one. Especially when it comes to Central Fab products. Sure, customers prefer order delivery "yesterday," but we know that's impossible without sacrificing professional quality.

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***Versatile...** beneficial for amputees of all ages, activity levels, and types including BK, AK, and Bilateral.*

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***Tested...** developed with input from over 900 evaluation amputees.*

***Supported...** covered by a full year of warranty and an optional trial exchange program.*

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All submitted manuscripts should include:

1. THE ORIGINAL MANUSCRIPT AND TWO COPIES. If possible, the duplicate manuscripts should be complete with illustrations to facilitate review and approval.
2. BIBLIOGRAPHY. This should be arranged alphabetically and cover only references made in the body of the text.
3. LEGENDS. List all illustration legends in order, and number to agree with illustrations.
4. ILLUSTRATIONS. Provide any or all of the following:
   a. Black and white glossy prints
   b. Original drawings or charts

   Do *not* submit:
   a. Slides (colored or black & white)
   b. Photocopies
5. A photo (black & white glossy) of each author listed on the manuscript, along with a short biographical sketch.

PREPARATION OF MANUSCRIPT

1. Manuscripts must be TYPEWRITTEN, DOUBLE-SPACED and have WIDE MARGINS.
2. Indicate FOOTNOTES by means of standard symbols (*).
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4. Write out numbers less than ten.
5. Do not number subheadings.

PREPARATION OF ILLUSTRATIONS

1. Number all illustrations.
2. On the back indicate the top of each photo or chart.
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K.C.O. Knee Joint

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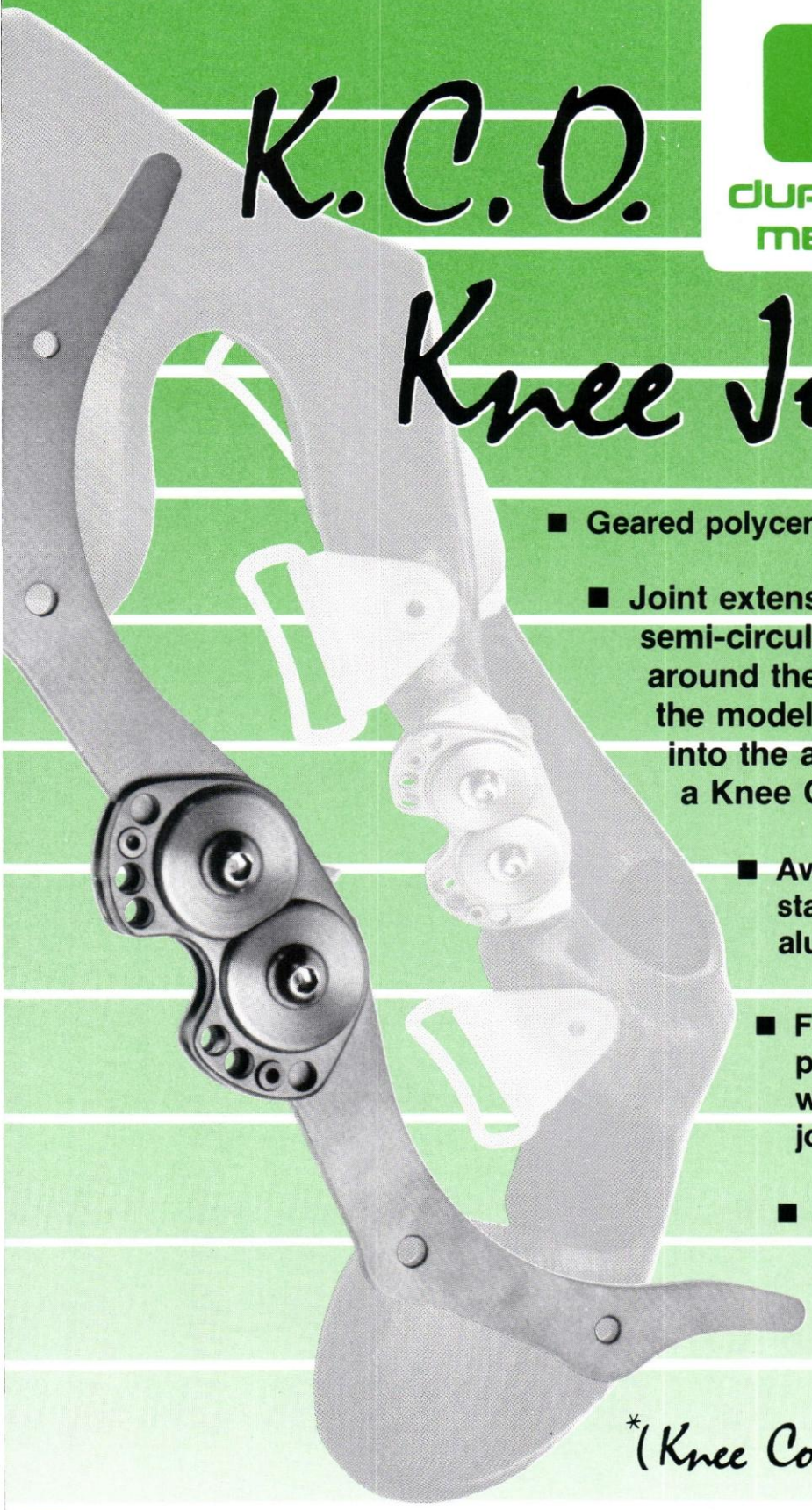

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Reprinted below is the application required by ABC for those wishing accreditation for their education programs. Please use this form when applying for credits.

American Board for Certification in Orthotics and Prosthetics

Application for Continuing Education Activities

Group A—Accredited Instruction

Educational Activity: _____

Date(s) of Program: _____

Institution and Location: _____

Sponsor: _____

Number of credit units applied for: _____

Prerequisite

A. SUBMISSION 60 DAYS PRIOR TO PRESENTATION. (If presenters or subject matter changes within the sixty days notify ABC directly.)

B. Time frames must be presented: *example—9:00 to 9:45* (in & out)

C. Brief description of subject matter.

D. Along side of, or under the presenters, his or her credentials.

E. What categories they are applying for Continuing Education Units in: *example—Scientific, Business, etc.*

Comments

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Course received late: Yes ☐ Date Received _____ No ☐

Course Approved: Yes ☐ Date Received _____ No ☐

If Disapproved or Number of Credit Units Reduced, Please State Reason(s).

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Signature Date

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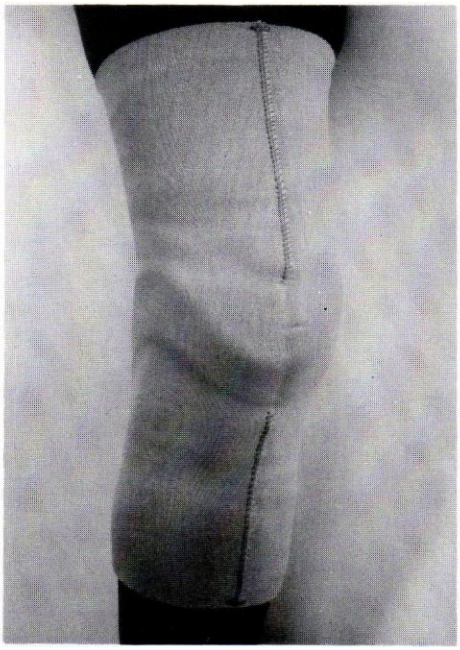

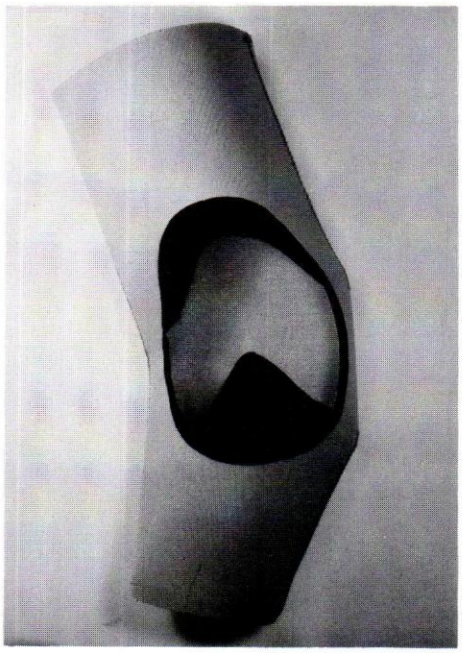

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Orthotics and Prosthetics, Vol. 40, No. 1, pp. 20–26.

A New Knee Orthosis: Clinical Evaluation of a Patellar Band

Toshiro Nakamura, O.A.
Mitoshi Fukushima, M.D.
Tetsuya Watanabe

INTRODUCTION

Patellofemoral disorder is a disease which has very recently begun to attract some attention. Patients suffering from this disease mainly complain of pain around the patella and of knee instability. As for activities of daily living, patients feel more pain when walking up and down hills and stairs and when squatting down and standing up, rather than when walking on a flat surface. They are also often incapable of kneeling on tatami floors, in the proper Japanese manner. This disease is thought to arise from the plica syndrome, malalignment of the patella, patellar subluxation or dislocation; chondromalacia patellae is also counted as one of its causes. The presence of one or a combination of these disorders manifests in patellofemoral disorder. Our aim is to treat this disease conservatively without resorting to surgery.

With this in mind, we devised a patellar band (Figure 1) and applied it to patients as a preservative (prophylactive) treatment. We also applied this patellar band to patients having undergone surgery. In the following report, the results we obtained are described, and the effects and indications of the patellar band are discussed.

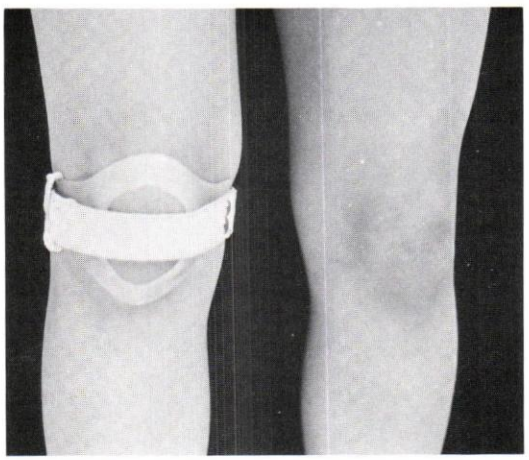


Figure 1-A. Wearing the patellar band. Frontal plane aspect (front).

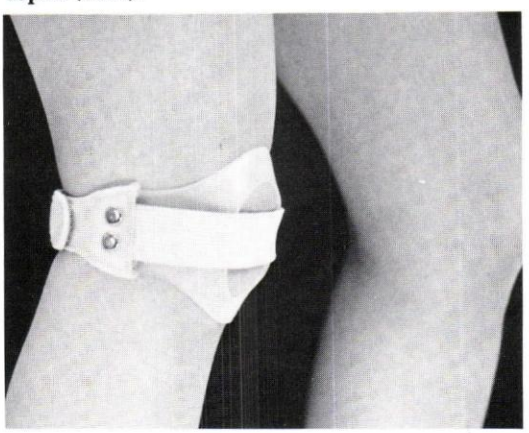


Figure 1-B. Sagital aspect (side).

MATERIALS AND METHODS

- *Patellar Band*

The band consists of a patellar part, which is made of silicone rubber, and popliteal parts, which function as orthosis bands (Figure 2). The silicone rubber part has a longitudinal elliptical hole and a small pad lateral to the patella; its medial portion is two and half millimeters in thickness and presses the patella mainly towards the medial condyle; its lateral portion is as thick as five millimeters and prevents lateral deviation of the patella. As the knee flexes, the tension of the band increases, becoming effective at more than 30° of flexion, resulting in strong compression toward the inside of the knee (Figure 3).

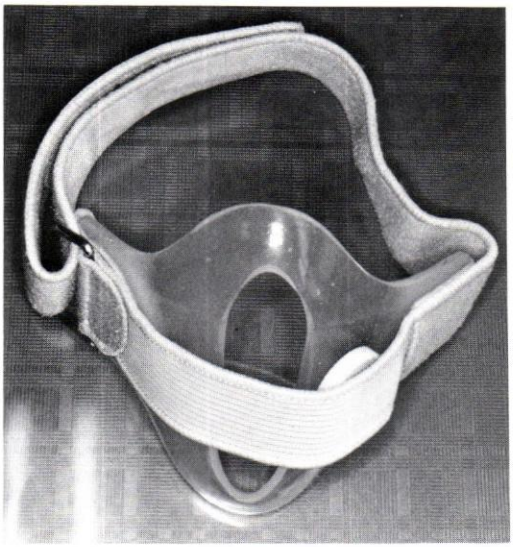


Figure 2-A. Patellar band.

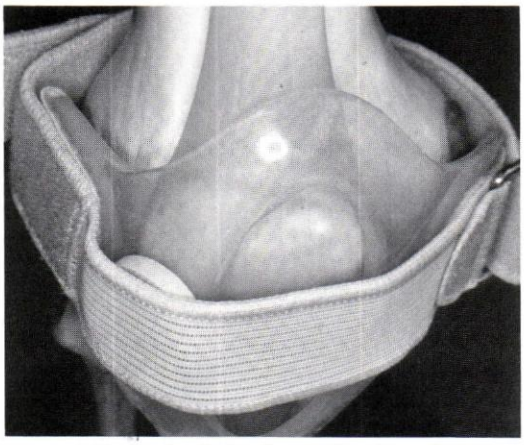


Figure 2-B. Anatomical scheme showing placement of the band.

- *The Contracture of Lateral Retinaculum Test or Determination of the Sponge Sign*

It is important to clinically evaluate degrees of medial and lateral tensions in ligaments. In our clinic, the evaluator positions himself proximally to the head and at the foot of the patient when examining the right knee and the left knee, respectively. He then examines the knee being flexed at 30°, 45° and 60°, by placing his thumbs on the patella and grasping the knee internally with his other fingers. When the patella is medially moved, replacement of subluxation in other words, the bone touches the medial condyle. At that time, it can be determined whether or not high tension in the lateral retinaculum (malalignment) is present. In a positive case, the inspector feels as if he is pressing a sponge (sponge sign), while a negative case (normal alignment) gives no such sensations because joint surfaces make proper contact with each other.

- *The Patellar Instability Test or Determination of Hypermobility and the Patient's Apprehension Sign*

Medial and lateral margins of the patella are grasped under flexion of 30° or under extension, and the patella is manipulated both medially and laterally. When the patella laterally deviates more than a width of a finger, or when a patient becomes fearful of the movement, the case is determined to be positive. During this test, the quadriceps femoris muscle should be completely relaxed.

Classification of Patients for Whom the Patellar Band Is Indicated

Group A: Patients having plica syndrome. They lack the sponge sign of the patella, but have local tenderness in the medial patellofemoral joint and

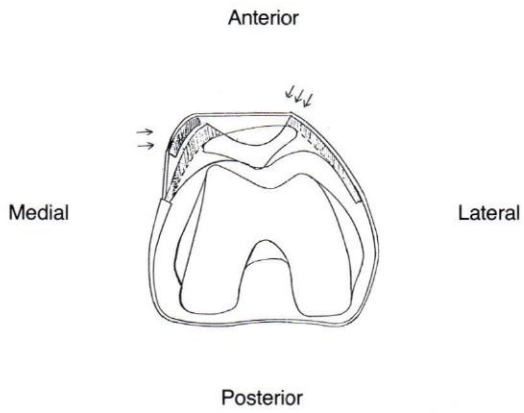


Figure 3. Functional mechanisms of the patellar band. The lateral force of the band prevents subluxation; its medial force corrects joint malalignment.

snapping of the plica, the presence of which is confirmed by arthrography.

Group B: Patients having the sponge sign of the patella. They have radiographic evidence of joint malalignment at a flexion of either 30°, 45° or 60°.

Group C: Patients having a history of patellar dislocation or showing clear evidence of the apprehension sign.

Group D: Patients having clear degeneration of the patellar cartilage. They have local tenderness in the knee on the medial and lateral sides, and are positive for the hypermobility test or show the sponge sign. Patients showing radiographic evidence of a narrowed patellofemoral joint were excluded from the study.

RESULTS

The first survey was given to 75 patients, and answers were obtained from 51 of them. These patients' main complaints were found to be: spontaneous pain, pain while moving, giving way, popliteal pain, snapping, swelling, pain when kneeling, walking up and down stairs, kneeling for a long time, and pain when sitting in the correct manner on tatami. Among these items, improvement was observed in the first three and snapping due to the stability of the patellar movement obtained by application of the band. Many of the patients showed improvement in swelling, pain, and stability of the knee. As for activities of daily living, reduction of pain was most markedly noted.

In comparison with other orthopedic appliances, our patellar band was found to have the following advantages. It is handy (being small in size) and can be carried in a handbag. Its effects appear quickly, because its application gives a feeling of stability to patients and gradually decreases pain.

The second survey was sent to 61 patients whose ages ranged from 11 to 80 years. Follow-up periods ranged from one to eight months, with the mean being six months. The following items were included (34 patients responded).

- *Preapplication evaluation:*

Points	*Pain*	*Description*
20	None	Only feelings of heaviness.
15	Slight	Pain at the time of starting to move or after walking for a long time. Slight pain present when flexing knees.
10	Moderate	Pain is present while active but disappears at rest. Complete flexion could be attained, but very painful.
5	Strong	There is strong pain during active periods and sometimes while resting. Flexion is restricted to a certain degree.
0	Very strong	Very strong pain, even while resting. Flexion is almost impossible to attain.

• *Activities of daily living:*
As for walking on a flat surface, walking up and down stairs, squatting (necessary when using a Japanese toilet), standing up from bed (from the floor) and so on, degrees of pain were scored as four = none, three = slight, two = moderate, zero = incapable of the activity. The highest score possible was 40 points; the patients' points ranged from 14 to 34, with a mean of 23 points.

• *Postapplication evaluation:*
The following items were scored:

Pain:	none = five, much decreased = four, decreased = two, and unchanged = zero.
Swelling:	disappeared = five, slightly present= four, slightly decreased = two, and unchanged = zero.
Walking:	becoming normal = five, much better = four, better = two, and unchanged = zero.
Other activities:	becoming normal = five, much better = four, better = two, and unchanged = zero.

An improvement rate was then calculated by adding the preapplication score to the postapplication score and dividing the sum by the preapplication score, as described below:

$$\text{Improvement rate (\%)} = \frac{\text{Preapplication score} + \text{Postapplication score}}{\text{Preapplication score}} \times 100$$

Totals of preapplication and postapplication scores ranged from 16 to 59 points, with a mean of 42 points. Improvement rates of each group are as follows:

Group A (7 cases)	158.3%
Group B (9 cases)	159.0%
Group C (31 cases)	142.0%
Group D (4 cases)	134.0%

There were no significant differences between the groups.

In consideration of the results of tests previously mentioned, one of the four patients in Group A underwent excision of the plica, as shown in the Table, and the remaining three showed decreases in pain after application of the band.

Almost all of the 13 patients in Group B underwent lateral release and began to walk while wearing the band one week after surgery. At the time of surgery, plica was also removed in those cases having it. Only one of the six patients in Group C underwent surgery.

In Group D, which consisted of nine patients, patients who had no radiographic evidence of degeneration in joint cartilages wore the band and intra-articularly received mucopolysaccharides.

Effects of the band were expressed as excellent (++), good (+), or effective (−). Surgical treatment was performed on ineffective cases, and such cases then wore the band after surgery. Cases showing excellent responses to the application of the band were those who did not show the sponge sign, were positive for hypermobility, and had no local tenderness on the surface of the patellofemoral joint. Among the four groups, excellent responses were most frequently seen in Group C (Figures 4 and 5).

DISCUSSION

Joint malalignment due to plica formation and due to abnormal axial rotation of the patella, patellar subluxation and dislocation are involved in patellofemoral disorder. In the presence of these disorders, the patellar cartilage is always subjected to shock and gradually degenerates into chondromalacia patellae. Needless to say, direct trauma to the patellar cartilage can also cause this disease. The abnormal axial rotation in such cases is mainly induced by hypertension in lateral ligaments, or it may occur by hypermobility of the patella as the patella laterally deviates to a large extent. Thus, it is generally agreed that there are two types of abnormal axial rotation of the patella. Our patellar band was more effective in the latter type.

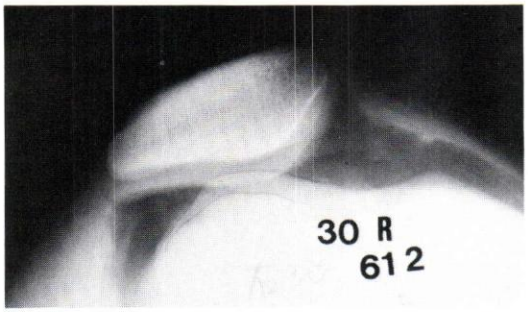


Figure 4-A. Case report: N.S., an 11-year-old girl in Group C. This patient had buckling of the knee joint and lateral deviation of the patella one year previously (examined in February, 1986). Right knee at 30° flexion.

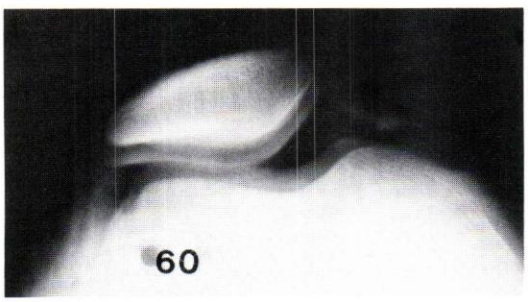


Figure 4-B. Right knee at 60° flexion.

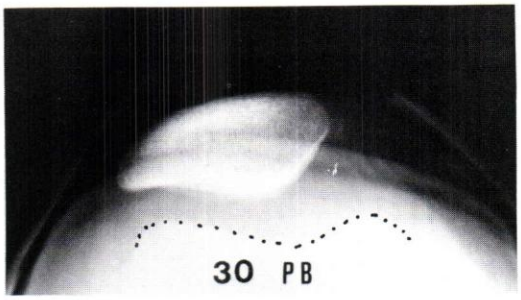


Figure 5-A. Case report: the same patient as shown in Figure 4 when wearing the band (June, 1986) with the right knee at 30° flexion.

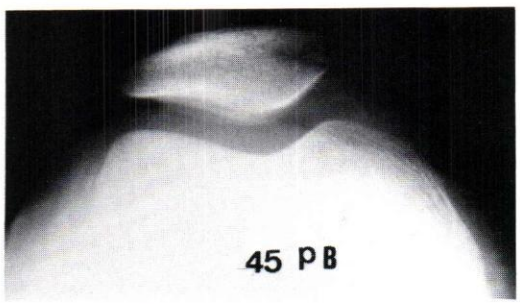


Figure 5-B. Right knee at 45° flexion.

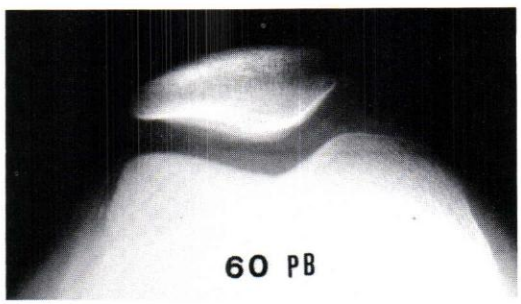


Figure 5-C. Right knee at 60° flexion.

• Group A (plica syndrome): Because the application of the band reduces or extinguishes pain, the band is only applied when the patient is playing sports. In cases with strong pain or in those showing no responses to conservative treatment, we surgically remove the medial plica.

• Group B (malalignment): Since most patients suffer strong pain and have insufficient response to the application of the band when they exhibit the sponge sign, they usually request surgical treatment. Therefore, we have recently performed lateral release in all cases included in Group B along with the excision of the plica, if present. After the operation, many cases complain of instability of the patella and of giving way of the knee joint; for these reasons the band is automatically applied after the removal of sutures in these cases. This seems to contribute to stable walking and the recovery of knee functions. Although its mechanisms are not yet clarified, the band may play a certain type of "feedback-like" role.

• Group C (subluxation and dislocation): In this group, all patients had a history of dislocation. We performed surgical treatment in one case. This patient suffered his dislocation while playing sports and was brought to our hospital by ambulance. The patient had an intra-articular hematoma, and, therefore, lateral release of the retinaculum was made during arthroscopic examination. All other cases in

Name	Age	Mal-alignment	Hyper-mobility	Ope	P.B. Duration	Effect
A M.H	Rt 21	+	−	R.P., L.R.	3 M	+
A T.H	Bil 18	−	−		3 M	+
A K.H	Bil 15	−	−		3 M	+
A H.Y	Bil 18	−	−		6 M	+
B K.K	Bil 18	+	−	R.P., L.R.	3 M (P.O.)	−
B Y.Y	Bil 27	+	−	R.P., L.R.	2 M (P.O.)	++
B A.F	Rt 21	+	−	R.P., L.R.	3 M (P.O.)	−
B S.T.	Rt 18	−	−	R.P.+L.R.	3 M (P.O.)	+
B K.T.	Bil 28	+	−	R.P.+L.R.	3 M (P.O.)	
B N.H	Bil 21	+	−	V.T.	3 M (P.O.)	−
B H.M.	Bil 22	+	+	R.P.+L.R.	3 M (P.O.)	−
B E.N.	Bil 35	−	+		4 M	++
B S.M	Bil 38	+	−	P.P.+L.R.	4 M (P.O.)	
B T.S	Bil 11	+	−	R.P.→L.R.	2 M (P.O.)	+
B M.M	Bil 11	+	+	M.T.+L.R.	3 M (P.O.)	
B T.R.	Bil 16	+	−	R.P.+L.R.	2 M (P.O.)	
B I.M.	Bil 47	+	−		1 Y 2 M	+
C N.S.	Bil 11	++	++		R 1 Y 2 M•L 1 Y	++
C T.K	Bil 38	++	++	L.R.	3 M (P.O.)	++
C T.M.	Rt 57	+	−		3 M	++
C N.K.	Bil 18	+	+	L.R.+R.P.	5 M (P.O.)	+
C N.M	Bil 18	+	+		2 M	++
C H.R.	Rt 16	+	+		2 M	++
D S.M	Rt 56	−	−	V.T.+L.R.	3 M (P.O.)	++
D I.Y	Bil 53	+	−		10 M	++
D T.M.	Lt 65	+	−		5 M	+
D T.T	Bil 30	+	−	M.T.+L.R.	3 M (P.O.)	+
D T.M	Lt 53	+	+		4 M	++
D S.S	Rt 54	−	+		5 M	++
D M.S	Lt 67	−	+		3 M	+
D Y.M	Lt 54	+	−		4 M	+
D M.E	Rt 57	+	−		1 Y 2 M	+

R.P. = Removal of plica
L.R. = Lateral release
P.O. = Post Operative

M.T. = Medial displacement of Tuberosity
V.T. = Ventralization of Tuberosity

++ = excellent
+ = good
− = unsatisfactory

Table 1. Individual responses to the application of the patellar band.

this group have so far shown no difficulties in performing daily activities and have not requested surgical treatment because of the absence of pain. We have followed up one case for one year and two months. He has worn the band as his exclusive therapy, and has not developed any problems. Radiographically, there are clear differences in alignment of the patella with and without the application of the band.

- Group D (chondromalacia patellae): Among the patients in this group, the most excellent responses were found in patients without the sponge sign, but with hypermobility. In addition to the application of the band, mucopolysaccharides and steroids were intra-articularly given to patients having a clear degenerative joint disease or to those exhibiting the sponge sign. We have followed up the longest case for one year and two months.

Functional mechanisms of the patellar band: Since symptoms of the medial plica appear more often in cases with malalignment than in cases with trauma, manifestation of the symptoms seems to result from abnormal axial rotation of the patella. Our band corrects the malalignment, and pain clearly disappears or is reduced during the application of the band. We usually apply the band for the first three months and then excise the plica under arthroscope in patients who still complain of pain. However, when arthrography reveals a large medial plica, we remove this plica without hesitation.

By means of functional radiography, it was found that sufficient prevention of subluxation was achieved at flexion angles of 45° and 60°. Even though complete prevention was not obtained at a flexion angle of 30°, neither patients nor their families requested surgical treatment because insecurity in daily activities and giving way of the joint disappeared.

There were also no difficulties in squatting or walking up and down stairs whenever patients wore the band. When patients were radiographically observed over a period of time, some of them showed gradual recovery from subluxation. These findings encourage us to continue further follow-ups. However, we still perform lateral release of the retinaculum in patients with severe subluxation and then apply the band; medial displacement of the tuberosity is needed in patients showing no improvement in x-ray films.

As for complications, many female patients developed dermatitis. (The majority of our patients were female.) Therefore, at the beginning we instruct the patients to wear the band two hours in the morning and two hours in the afternoon. A characteristic of our patellar band is that its silicone rubber closely adheres to the skin, resulting in the prevention of deviation of rotational movement of the patella. We also instruct the patients to wear the band only at times when it is required, such as while walking or playing sports. This can be easily done due to the band's handiness.

SUMMARY

The patellar band was effective against pain and instability in the patellofemoral joint. Surgical treatment was performed in patients who showed no improvement in their symptoms after wearing the band for a certain period of time (about three months). In patients undergoing lateral release of the retinaculum, the band was especially effective against postoperative buckling of the knee. Patients who already had degeneration of the cartilage have worn the band while walking or when experiencing aggravation. For a long time, some of them simultaneously receive intra-articular medication.

AUTHOR

Toshiro Nakamura, O.A., is president of Nakamura Brace Co., Ltd., Ohmori Ohda Shimane 694-03 Japan.

Mitoshi Fukushima, M.D., is chief of the orthopedic surgery, Kure National Hospital, 3-1 Aoyama Kure, Hiroshima 737, Japan.

Tetsuya Watanabe is chief research of Nakamura Brace Co., Ltd.

Orthotics and Prosthetics, Vol. 40, No. 1, pp. 27–36.

Dual-Ankle Springs (D.A.S.) Foot-Ankle System

Jerome P. Voisin, C.P.

INTRODUCTION

The Dual-Ankle Springs (D.A.S.) foot-ankle system† is a new development in multi-axial, stored energy prosthetic feet. A spring is defined as a device, as a coil of wire, that returns to its original form after being forced out of shape. Different types of spring designs have been introduced in artificial feet with varied capabilities of stored energy. These designs differ in shape and their material makeup according to the functions needed. The anatomical foot is multi-axial in function and, therefore, the shape of the spring system in the artificial foot should also be multi-axial in function. One such spring is the helical spring which also has energy storage capabilities. A leaf spring design is also capable of energy storage, but is limited in its multi-axial function, particularly in medial lateral movements. An attempt to provide a multi-axial foot-ankle system with the capabilities of absorbing, storing, and returning the energy generated in walking, has led to the development of the Dual-Ankle Spring foot-ankle system.

Material makeup of the spring is also important. Just as there are different types of carbon-composite materials, there are different alloy type spring steels. A chrome-vanadium alloy spring steel is used in the D.A.S. foot-ankle system and offers increased elasticity and tensile strength over the regular steel spring which is more brittle.

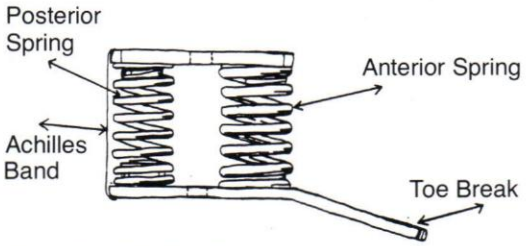
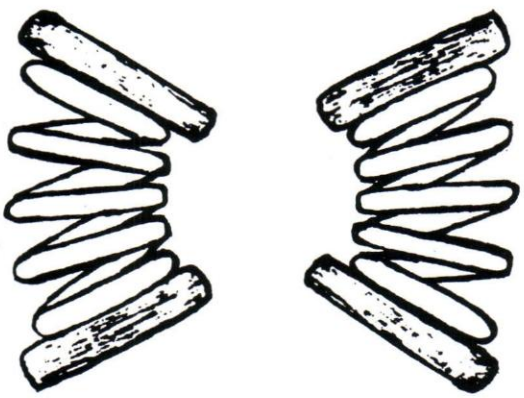
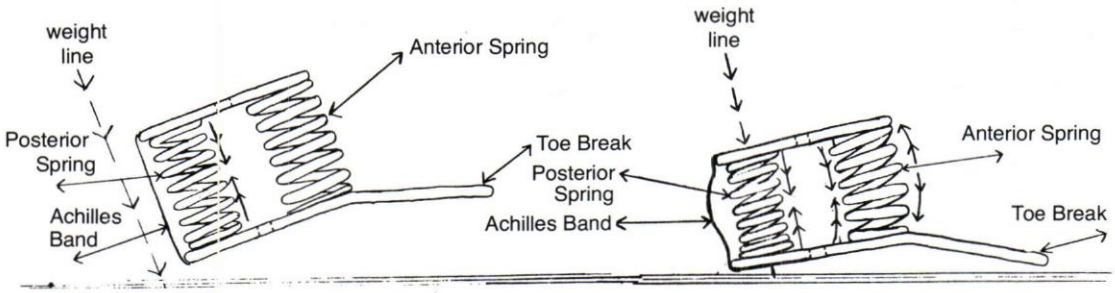


Figure 1-A. The D.A.S. foot-ankle system: 1) anterior spring, 2) posterior spring, 3) Achilles band, 4) toe break.

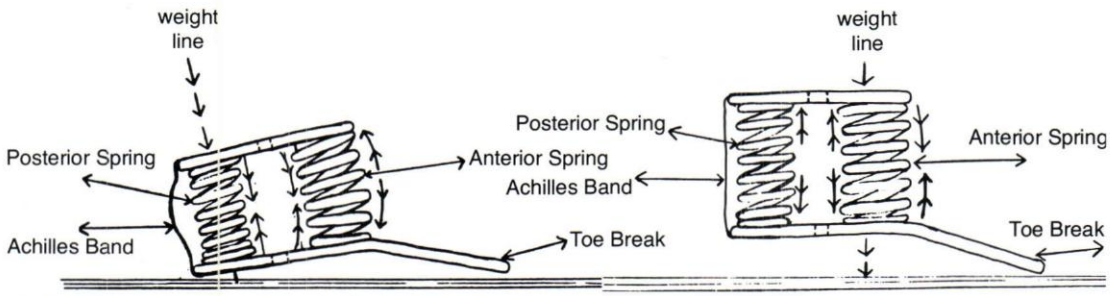


Figures 1-B and 1-C. A posterior view of the left foot, inversion (left) and eversion (right).

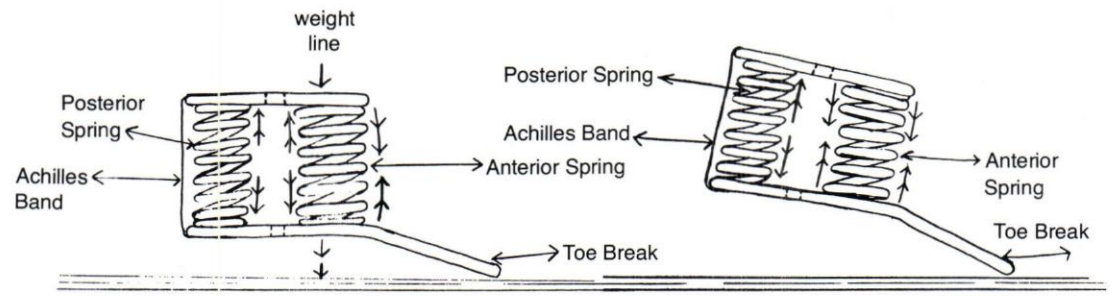
†Patent pending.



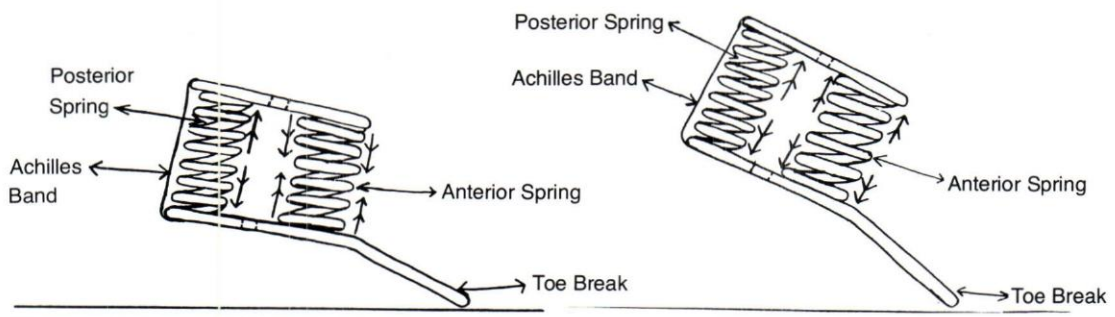
Figures 2-A (left) and 2-B (right). Heel strike and foot flat.



Figures 3-A (left) and 3-B (right). Foot flat and mid-stance.



Figures 4-A (left) and 4-B (right). Mid-stance and heel-off.



Figures 5-A (left) and 5-B (right). Heel off and toe off.

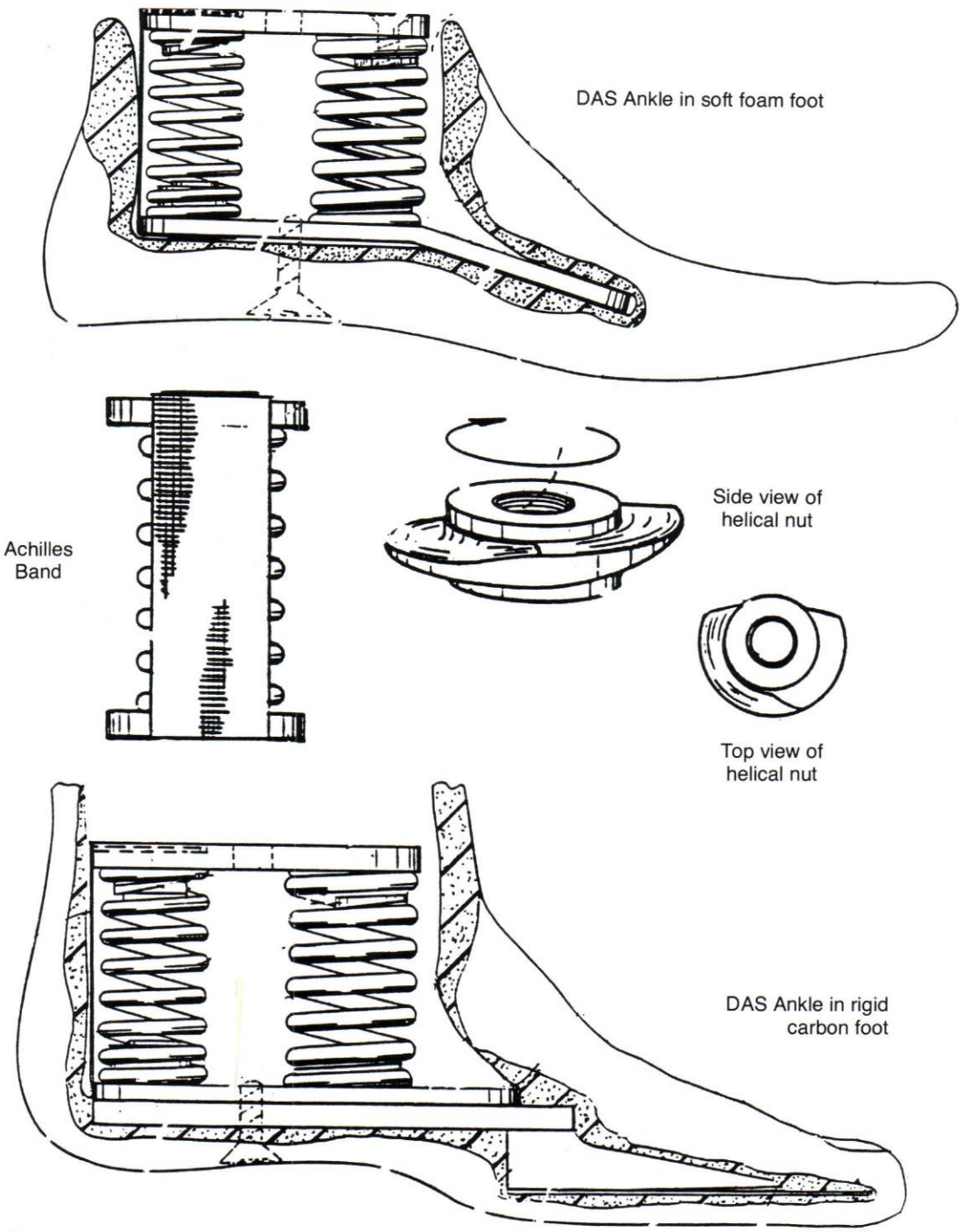

DAS Ankle in soft foam foot
Achilles Band
Side view of helical nut
Top view of helical nut
DAS Ankle in rigid carbon foot

Figure 6.

DESIGN

The D.A.S. foot is basically composed of two flat die helical springs attached proximally to an ankle plate and distally to a plantar plate. These plates are T4 2024 aircraft aluminum with a tensile strength of 68,000 lbs. per square inch.

The method of attachment is by a helical nut[††] (Figure 6). This rigidly attaches these springs to the plates themselves. Unlike welding or tapping, the helical nut method attachment does not change any temper properties of the springs. Substitutions are easily made using different compression strength springs according to the varying needs of the amputee. This may be done at a facility and need not be sent back to the manufacturer for adjustment or exchange.

This system has a posterior positioned flexible member made of Kevlar® covered with buckskin leather extending from the upper ankle plate to the plantar plate which serves as an "Achilles tendon" (Figure 6). This flexible member allows compression of both springs in any direction, but disallows elongation of the posterior spring beyond a certain point. The tensile strength is 8,800 lbs. per square inch.

The flat die helical springs are custom designed individually for each foot and are virtually impossible to deflect with normal usage, due to the memory factor of the alloyed metal (Figure 13). The D.A.S. foot-ankle has no moving components, i.e. cantilevers, ball and socket hinge, hydraulic pistons, valves, universal coupling, or two way hinge, etc., which may lead to malfunction and increase service labor. The D.A.S. foot-ankle system has proven beneficial to below-knee, knee disarticulation and above-knee amputees. This system provides these patients with maximum energy efficiency and stability. The D.A.S. foot-ankle can be used with either endoskeletal or exoskeletal prostheses. If the previous alignment is correct, the D.A.S. foot-ankle may readily be adapted to the amputee's present prosthesis. This system is compatible with many standard artificial knee units, including some hy-

[††]Patent pending.

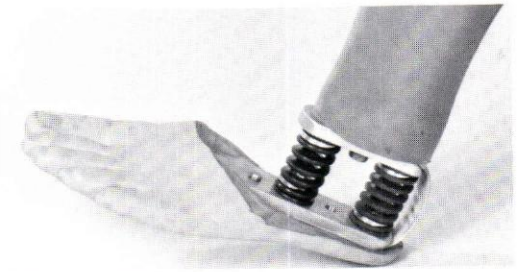


Figure 7-A. Heel Strike.

Figure 7-B. Foot Flat.

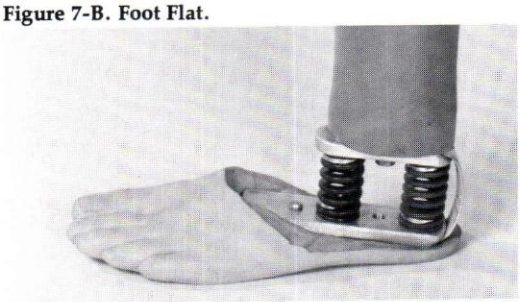


Figure 7-C. Mid-stance.

Figure 7-D. Heel-off.

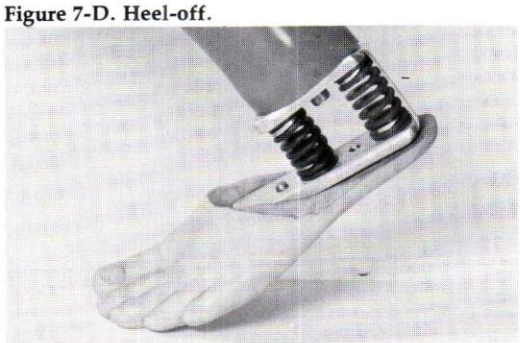


Figure 7-E. Toe-off

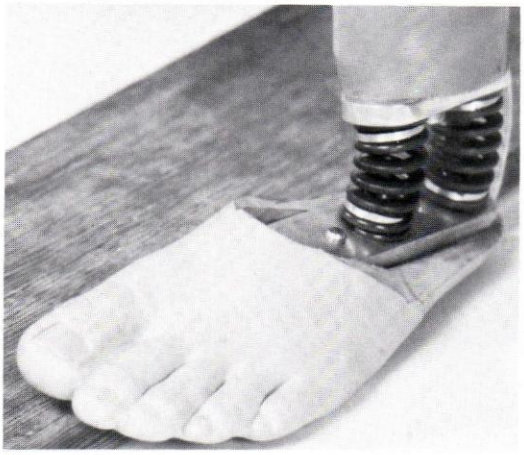


Figure 8. Inversion.

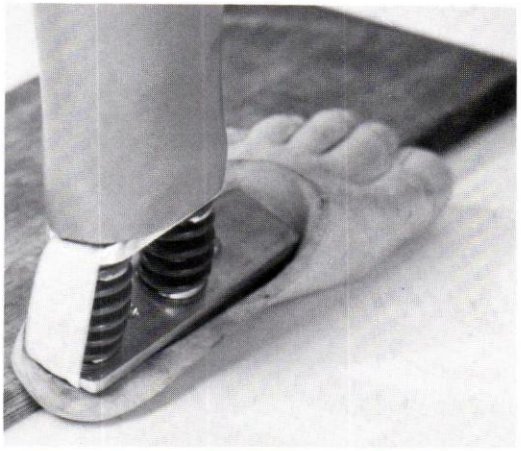


Figure 9. Eversion and view of the Achilles band.

draulic ones. Since its introduction to patient use and field testing 11 months ago, 41 patients have been fitted with the D.A.S. foot. This group is composed of above-knee, knee disarticulation, and below-knee amputees. The D.A.S. foot-ankle system has also been submitted to the Veterans Administration for approval.

FUNCTION

The primary advantages of this system over previously used prosthetic feet are its ability to absorb, store, and return all forces generated in the medial-lateral and anterior-posterior axes. Maximum energy absorption, storage, and return is achieved with the rigid carbon fiber foot that also incorporates a leaf spring system at the toe break section (Figure 6). The smoothest heel-strike to toe-off gait is obtained with the soft foam foot (Figures 6 and 14).

During inversion-eversion (Figures 1-B and 1-C) this system allows anterior spring and posterior spring to work in unison (Figures 1-A, 8, and 9). The main function of all previous multi-axial feet was to conform to irregular walking surfaces. The energy absorbed, stored, and released during inversion-eversion and plantar-dorsi flexion in the D.A.S. foot-ankle is uniformly controlled. This controlled inversion-eversion and plantar-dorsi flexion, with energy absorbed, stored, and returned, negates jerks, abrupt bumps, and inclines which would normally be instantly transmitted from the artificial foot to the residual limb.

The amputee is aided when inversion-eversion, plantar-dorsi flexion occurs because this absorbed, stored, and released

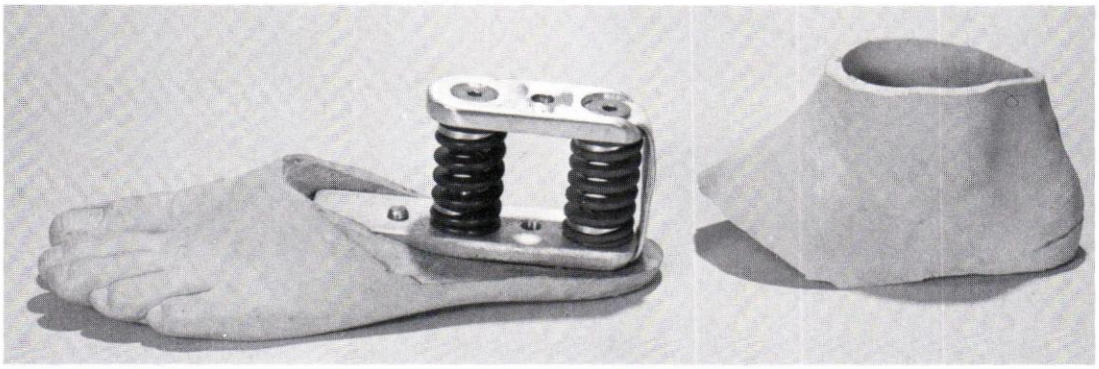


Figure 10. D.A.S. Foot-ankle with the cover removed.

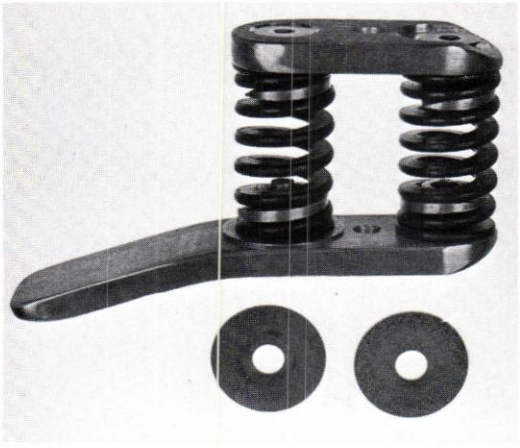


Figure 11. D.A.S. System, for soft foam foot with flat washers for plantar flexion adjustment.

Figure 13. Various compression strength springs for the foot with helical nuts and 3/8" flat head screws socket type.

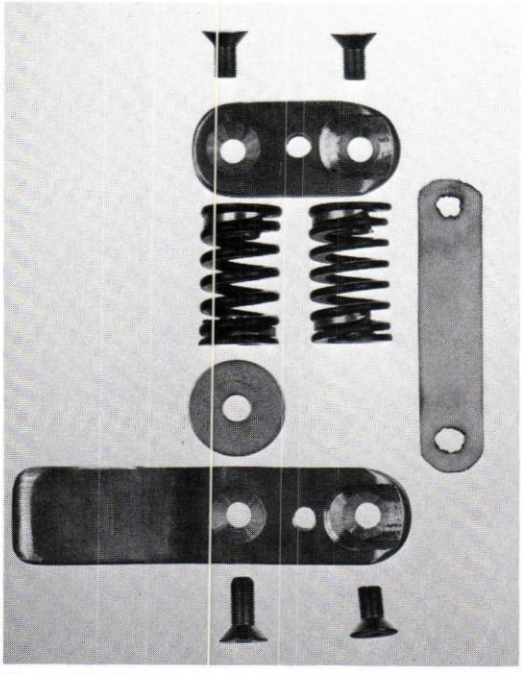


Figure 12. Exploded view of the D.A.S. foot-ankle system.

energy occurs on the prosthetic side (Figures 7, 8, and 9). This allows the amputee to more easily recover his balance with the prosthesis instead of depending solely on the sound limb.

During the dynamic gait cycle of heel-strike to foot-flat (Figures 2-A and 2-B) energy is absorbed and stored while the posterior spring is being compressed (Figure 2-A). Simultaneously, the anterior spring is bowing and compression of its posterior aspect with elongation of its anterior aspect may be seen (Figure 2-B).

This absorbed and stored energy is released from foot-flat to midstance as the weight bearing line moves progressively anterior along the foot (Figures 3-A and 3-B). At mid-stance, the Achilles band prevents further elongation of the posterior spring (Figure 3-B).

From mid-stance to heel-off, there is compression of the anterior spring generating the greatest amount of energy absorption and storage (Figures 4-A and 4-B).

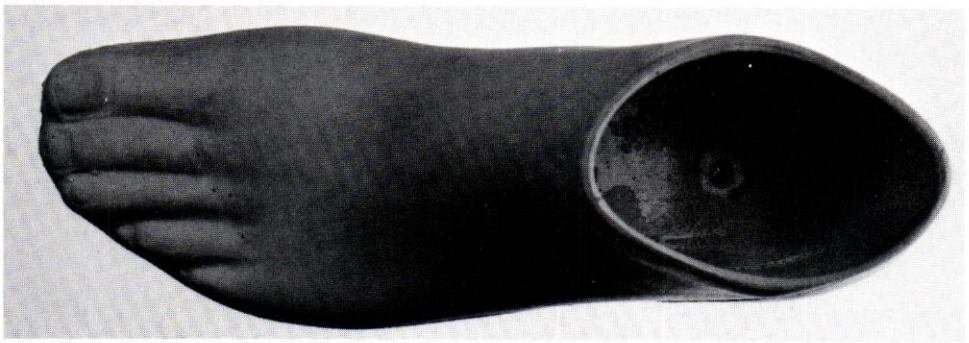
At heal-off to toe-off, this amount of absorbed and stored energy is released from the anterior spring, propelling the amputee forward (Figures 5-A and 5-B).

ALIGNMENT METHOD

When a new prosthesis is being dynamically aligned, a standard S.A.C.H. or similar foot should be used with the adjustable device. This allows the prosthetist the ability to determine a better medial-lateral placement of the foot, as well as the abduction/adduction angle of the socket. Subsequently, the D.A.S. foot-ankle can

Figure 14-A. Soft foam foot: medial view.

Figure 14-B (below). Soft foam foot: top view.



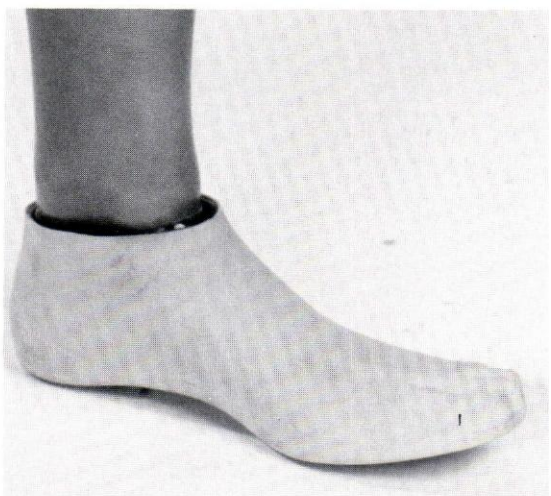


Figure 15. Foot ankle block interface.

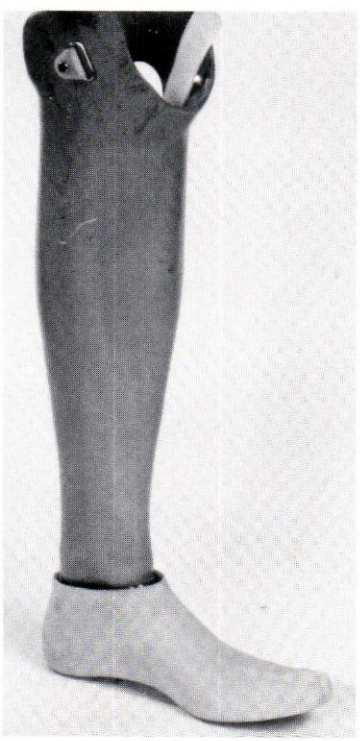


Figure 16. Completed below-knee prosthesis.

be used to determine the correct plantar-dorsi-flexion and anterior-posterior placement of the foot. Plantar flexion may be adjusted on an existing prosthesis by simply adding 1/16" flat washers between the distal end of the anterior spring and the proximal surface of the plantar plate (Figures 11 and 12).

Transferring these alignments from the adjustment device to the finished prosthesis follows standard procedures used in the field today. On exoskeletal prostheses, the ankle block should be shaped to fit inside the soft foam flat ankle section (Figures 15 and 16).

CONCLUSION

Some comparisons can be made between the D.A.S. foot and the standard S.A.C.H. foot. In weight, the S.A.C.H. foot for a size 11 is 1.4 pounds, compared to a 2.2 pound D.A.S. foot. The weight of a prosthetic foot is always of concern to the prosthetist as well as the amputee. Equally important is the degree of function and response of the prosthetic foot. The S.A.C.H. foot is adequate for normal walking conditions on flat surfaces, as is the D.A.S. foot. However, on uneven terrain, the D.A.S. foot excels in its multi-axial capacity to adjust and absorb the impact forces generated during the walking cycle.

The Copes Biomechanical Ankle® is another prosthetic foot which incorporates a singe helical spring and a ball and socket ankle joint. The D.A.S. system has two helical springs which work in unison for maximum energy efficiency throughout the heel-strike to toe-off gait cycle, as well as during inversion/eversion. A major difference between the D.A.S. system and all other helical spring-type feet is the method in which the springs are attached to the plates. Spring steel, once tempered, should not be heated above 750°F. With high heat, as in welding, the spring steel loses memory and weakens, causing early failure either at the weld sight or of the spring itself. This is not a problem for the D.A.S. foot, unlike for the Copes Biomechanical foot.® The helical nut method of attachment bypasses this integral flaw.

With this new multi-axial stored energy prosthetic foot, the amputee may enjoy all outside activities with minimal concern about ramps, inclines, broken sidewalks, or any other obstacles previously avoided.

ADDENDUM

The following set of illustrations depict prosthetic feet from the late 1800s to the mid-1900s which encompass helical springs. The point of showing these is to demonstrate that the use of helical springs in prosthetic feet is by no means new to the field.

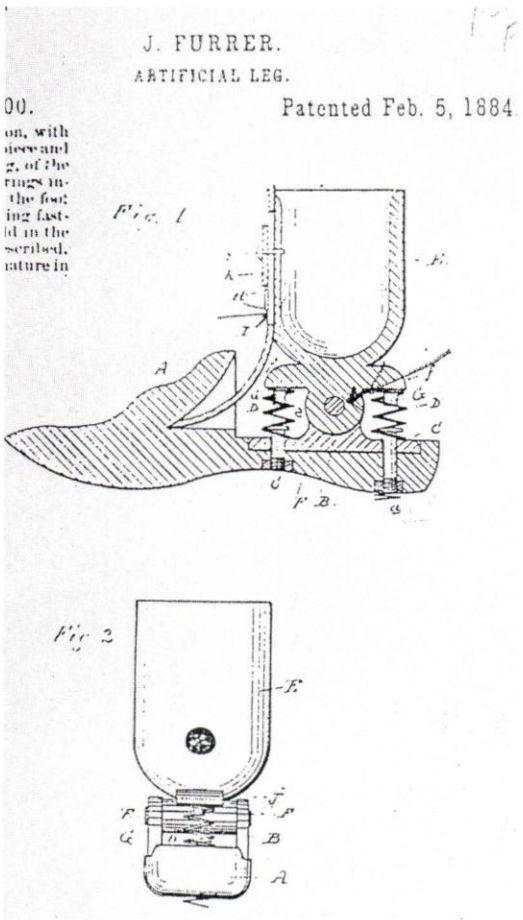

J. FURRER.
ARTIFICIAL LEG.
Patented Feb. 5, 1884.

Figure 17. The J. Furrer Artificial leg, patented February, 1984.

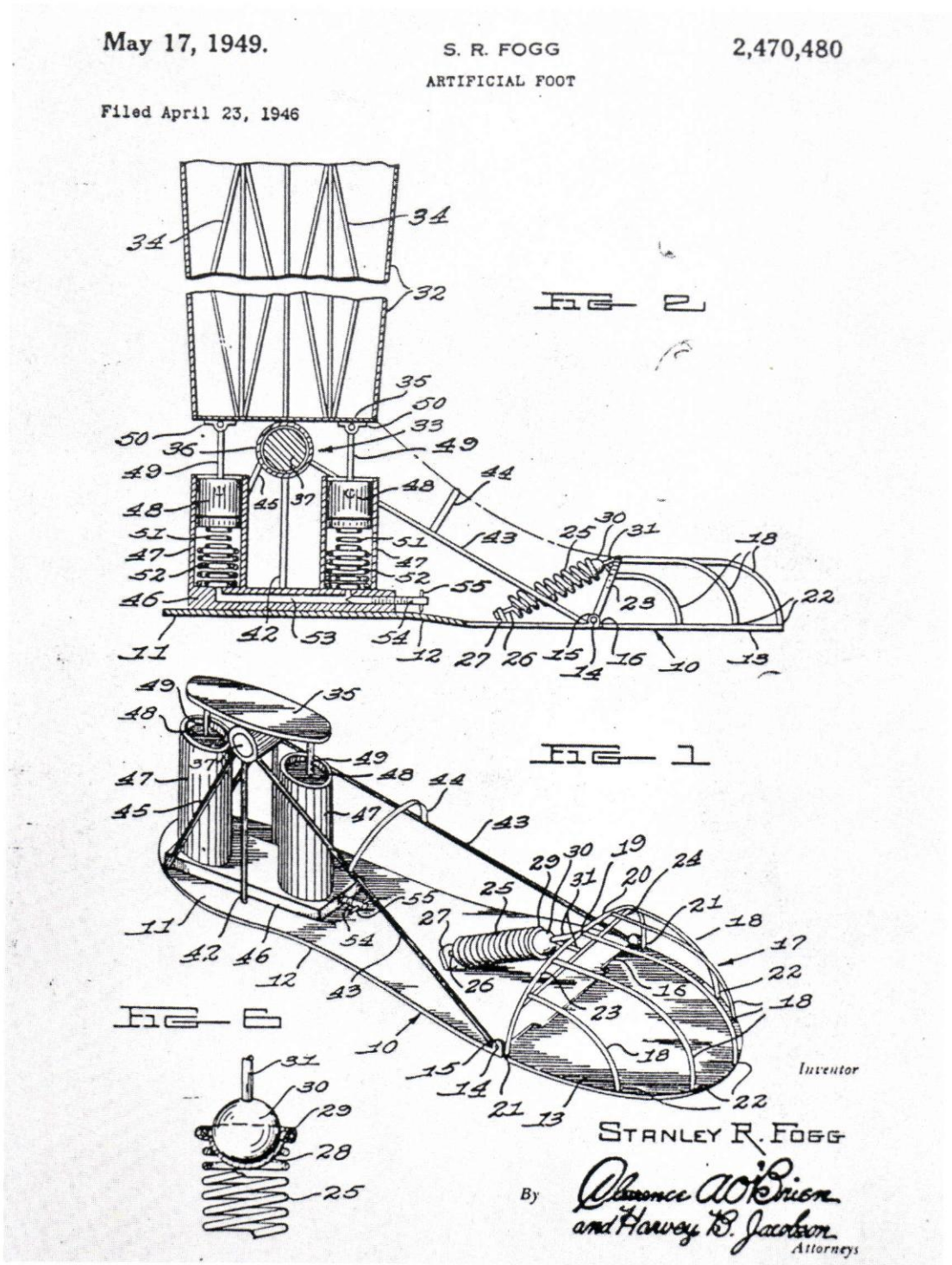


Figure 18. The S.R. Fogg prosthetic foot, patented in May, 1949.

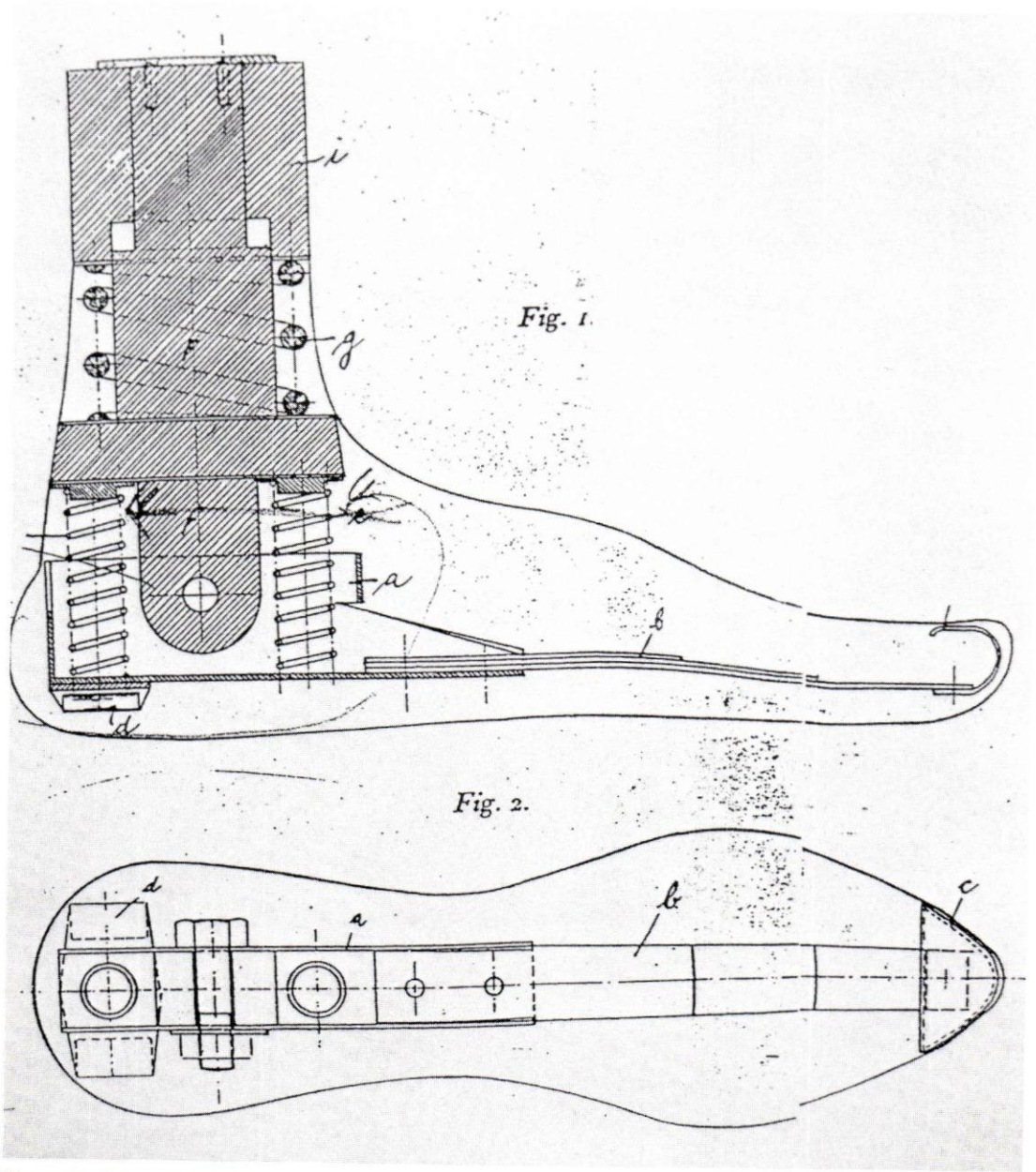


Figure 19. Origin unknown.

AUTHOR

Jerome P. Voisin, C.P. is President of Acadian Prosthetics and Orthopedic Aids Inc., 145 Agnes Street, Houma, Louisiana 70363.

Orthotics and Prosthetics, Vol. 40, No. 1, pp. 37–40.

Editor's Introduction

Orthotics (musculoskeletal supports) and prosthetics (musculoskeletal replacements) have in common their affect on the skeletal system. To understand better the laws of biomechanics as related to orthotics and prosthetics, a look at the structure and function of the components of the skeletal system is warranted. This article will explore components of the skeletal system affected by our field. Perhaps by a better understanding of the human body, enhanced patient care is possible.

With this article, I would like to extend an invitation to potential authors to submit similar "Tutorial" articles for publication in *Orthotics and Prosthetics*, thereby providing a solid base of continuing education for our readers.

Lawrence R. Lange, C.P.O.

Bone and Cartilage: Structure and Biomechanics

H.R. Lehneis, Ph.D., C.P.O.

BONE

Histology

Unlike other connective tissue, the extracellular components of bone are calcified to produce a relatively unyielding substance constituting the major characteristic in the evolution of vertebrate animals. The function of bone is to support, provide protection for vital organs, and to serve as a lever system in the locomotor and manipulative apparatus. Furthermore, it plays a metabolic role in enclosing the blood-forming elements of the bone marrow and to serve as a store for calcium for homeostatic regulation of the calcium concentration in the blood and other fluids.

Macroscopic Structure

Spongy bone consists of trabeculae which delimit inter-communicating spaces, which are occupied by bone marrow. Compact bone appears as a solid mass and blends into the spongy bone without any sharp boundary. Long bones such as the femur and humerus consist of a diaphysis (shaft) which encloses the medullary cavity, and epiphyses at the ends of the shaft, which consist mainly of spongy bone. The trabecular spaces in the epiphyses are directly continuous with the medullary cavity. In the growing individual, the epiphyses and diaphysis are separated by the epiphyseal plate containing cartilagenous material, which constitutes the growth zone. Nearly all bone is covered by periosteum, which is a layer of specialized connective tissue possessing osteogenic properties (i.e., the property to form bone).

Microscopic Structure

Under microscopic examination, it is found that the cellular elements of the

bone contribute to the total mass of the bone to only a small extent.

Compact bone is composed of bone matrix or lamellae. These are arranged concentrically around a longitudinal channel, or Haversian canals. Haversian canals contain blood vessels, and are interconnected with the marrow cavity by transverse, Volkmann's canals. The interstitial substance contains lacunae, which contain osteocytes.

Spongy bone is also composed of lamellae with lacunae in the interstitial substance. The whole makes up the trabeculae of the spongy bone.

Periosteum contains the inner layer of bone-forming osteoblasts in the embryonic and post-natal stage. In the adult, they assume their bone-forming function only when bone is injured, but otherwise remain in their resting form. The outer layer is mostly acellular and contains blood vessels.

Interstitial substance consists of an organic matrix and inorganic salts. Organic matrix consists of collagenous fibers of protein polypeptides. The inorganic matter is composed of submicroscopic crystals of an apatite of calcium and phosphate resembling hydroxy apatite.

Bone cells are three kinds (osteoblast, osteocyte, and osteclast) in actively growing bones. Osteoblasts are associated with the formation of bony tissue found in growing bones and are located at the inner layers of the periosteum and in direct contact with the bone.

Osteocytes are the main cells of the fully formed bone located in the lacunae of the calcified interstitial substance. They are believed to be transformed osteoblasts which in the adult bone are surrounded by a bony matrix.

Osteoclasts are transformed osteocytes. They are believed to play an active role in the reformation of the trabeculae of spongy bone in reponse to stresses applied to the bone and consequent remodeling.

STRUCTURE AND BIOMECHANICS

The structure and biomechanical requirements placed on bone are remarkably interrelated. The architecture of bone, both internal and external, reflects to a great degree an adaptation to stresses applied by external mechanical forces, which may be gravitational, locomotive, or due to functional activities.

The biological response to the stresses placed on bone is explained by Wolff's law, which states that the spongiosa of bone is able to reorient itself through modification of the trabecular system in response to mechanical stresses. This is true both under normal and pathological conditions, while in the development of bone other factors play an important role, such as heredity. It is still believed that the normal geometric configuration of bone is primarily a biological response to the stresses due to forces transmitted through the bone. In recent years, evidence has been accumulating to indicate that the biological structures, including bone, exhibit piezoelectric effects when stressed. For example, a beam which is vertically loaded, and as a result of the load begins to bow, will exhibit an accumulation of positive charges on the convex side and negative charges on the concave side. It has been experimentally shown that bone stressed in the manner described above will remodel itself by resorbtion of bone on the convex side and accretion on the concave side. More recently, the healing of fractures has been promoted by passing an electric current in the order of two to five microamperes, simulating piezoelectric magnitudes, to promote and accelerate healing of the fracture site. Although the total mechanism by which piezoelectricity affects bone remodeling is not yet known, it is believed that a possible mechanism may be that the osteocytes, with their many long dendrites acting as stress sensors, mobilize the cell and may transform it into an osteoblast or osteoclast, but the mechanism at the cellular level is not known or understood. Nevertheless, piezoelectric phenomena seem to play a crucial role in the modeling of bone.

In the growing child, for example, it is consistently observed that from a bow-legged position which, of course, represents the embryonic position, the child develops a knock-knee position after he begins to walk, reaching its maximum at the age of about four or five, at which time the leg becomes relatively straight. This clearly indicates a response to the abnormal stresses applied when the leg is not straight. Of course, in the growing child the knock-knee represents an over-compensation which is not found in the adult with a reduced metabolic rate. In the spine, it is observed that the relative size of the vertebrae increases from the first cervical to the fifth lumbar, again in response to the stresses imposed by the superincumbent weight. Another good example of this is seen in the relative size of the medial and lateral condyles of the knee, the medial condyle being considerably larger than the lateral condyle. This is so because the supporting structures (i.e., the limbs) are lateral to the center of gravity. Thus, during weight bearing, a moment is generated on the knee joint, resulting in relative compression of the medial condyle and tension on the lateral collateral ligaments (cantelever). During locomotion, this moment is further exaggerated in single stance due to the lateral thrust produced by the action of the gluteus medius. It can also be seen that bony protuberances, in general, are due to the tension produced by the insertion of tendons from powerful muscles (e.g., the greater trochanter).

The internal structure of bone represents, with almost mathematical precision, a structural arrangement of the trabeculae along the stress trajectories with orthogonal supporting geometry. The orientation of joint axes is also influenced by locomotive patterns, as for example the ankle axis which is externally rotated due to tibial torsion and represents an adaptation to bipedal locomotion.

In the upper limb, the scapula has evolved from a relatively short vertebral border and lateral placement in primative primates to long proportions of the vertebral border, typical of the hominidae, necessary for and to provide a longer lever arm for the serratus and rhomboid muscles. Thus, in the hominidae the combination of a very well-developed "S" shaped clavicle and a scapula, which has reached its longest dimension of the vertebral border and is placed dorsally, permit the powerful and great range of arm movement necessary for brachiation. These features, in general, have been retained in man.

It can, therefore, be seen that bone modeling occurs in nearly direct response to the biomechanical demands placed on the skeletal system due to a particular mode of locomotion and functional activity.

CARTILAGE

There are five types of cartilage of which only two are considered here because of their biomechanical relevance. These are white fibro cartilage (fibrous cartilage) and articular cartilage.

Histology

The cells are contained within lacunae in mature cartilage. There may be as many as four cells in each lacuna. The cells have a prominent nucleous and clear cytoplasm. The matrix is permeated by felt-like structures of fine collagenous fibers. In fibrous cartilage, the cells are widely separated and arranged in rows, while in articular cartilage, one row of cells near the surface is greatly flattened.

Structure and Biomechanics

White fibro cartilage exhibits a great deal of flexibility, but practically no elasticity in tension. This makes it an ideal tissue for attachment of tendons of muscles to the bony lever. Thus, the motor can be most efficiently used in transmitting its force to the lever without the undesirable energy absorbing effects of a material which is highly elastic in tension. The same cartilage is used in ligaments to stabilize the joints, as well as in controlling joint range of motion.

Articular cartilage of all structures in the

locomotor system is more severely exposed to stresses not only due to weight bearing, but also to those produced by muscle tension. In contrast to fibrous cartilage, articular cartilage is highly extensible and compressible. It also exhibits a great degree of functional adaptability in that its modulus of elasticity increases with increasing load. However, the longer the cartilage is loaded, the slower and less complete the rebound. In other words, its elasticity is impaired by excessive and prolonged loading. This is of biomechanical significance in that joint positions should not be maintained fixed over a long period of time, whether this is due to standing position or in functional activities, for this would lead to permanent changes in the elasticity of the cartilage. Even though the load may not need to be decreased, changes in joint position will alleviate this problem, for one of the primary functions of cartilage is to provide joint mobility. The co-efficient of friction of cartilage is three times lower than ice on ice. This is probably due to the fact that water is found between the matrix of cartilage, thus water is compressed out of the matrix, providing joint lubrication, and sucked back into the matrix on removal of weight bearing.

Menisci, which are composed of cartilage, accommodate for the incongruency of mating surfaces in joints. Incongruency of joint surfaces is needed for recoil of collagen fibers on motion and weight bearing. If the mating surfaces of joints were perfectly matched, the joint would lock with the slightest degree of compression.

SUMMARY

Contrary to the static appearance of bone, it is an extremely lively tissue of the body capable of regenerating itself and modeling and adapting itself to stresses imposed either during growth or due to biomechanical demands.

To a somewhat lesser degree, but still remarkably well, articular cartilage is a lively tissue capable of adapting itself to the varying stresses during locomotion and biomechanical activities. Fibrous cartilage serves its function best by being inelastic in tension to provide for stability of joints without muscular exertion.

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An Above-Knee Prosthesis for Rock Climbing

by Claude Lévesque, C.P.(C)
Christiane Gauthier-Gagnon, M.Sc.(A)

INTRODUCTION

Rock climbing is a dangerous, but challenging activity in which ascents of vertical cliffs are attempted. It is considered a truly challenging activity where danger is a constant element. Very often, the alpinist can balance on a mere inch or two of rock with his feet, while his hands explore a still more precarious hold. For the rock climber, the challenge is not the height of the ascent, but the degree of difficulty of the climb, which can range from easy to very severe. Physical endurance, powerful leg and arm muscles, as well as efficient footgrips and handholds are required to deal with chimneys and crevices, particularly in the case of very steep rocky surfaces.[1]

A small number of lower limb amputees have taken up rock climbing and find it to be a positive experience. In general, they report that this sport provides an opportunity to develop their courage, patience, and presence of mind, and more importantly, a way to overcome fears, prove their ability, and heighten self-esteem through the pursuit of an unusual and challenging activity.[2]

The literature relating to the development of special prosthetic and orthotic devices for rock climbing is scarce. For the below-knee amputee, ice climbing crampons have been adapted to clip to the prosthetic shank.[2] An ankle-foot assembly which provides motion in all planes was also found to be helpful, especially when climbing over typically rough terrain.[3] Above-knee amputees generally prefer to climb without their prosthesis and to rely on specially adapted forearm crutches for added grip and stability.[3] The disadvantage of this method of rock climbing resides in the limited use of the hands for handholds and the necessity for the amputee to carry his prosthesis on his back for use on level surfaces.

When rock climbing with their prostheses, certain problems were brought forward by above-knee amputees. In summary, these are: the ineffectiveness of the footgrip when using an above-knee prosthesis; the forefoot of the prosthesis catching in crevices; the inability to use knee grips; the relative knee instability in certain situations; and movement restrictions due to limited outward rotation of the leg and foot. The bulk of the exoskeletal knee joint assembly and shank also hampers movements and close contact of the body with the rocky surface. For the person with a very short above-knee residual limb, the use of a pelvic band and single axis hip joint further limits performance because of hip movement limitation. In addition, the weight of the prosthesis, due to certain components and reinforcements, imposes upon the amputee extra energy expenditure when lifting the prosthesis and excessive friction between the residual limb and the prosthesis, thereby causing residual limb irritation and breakdown. Consequently the

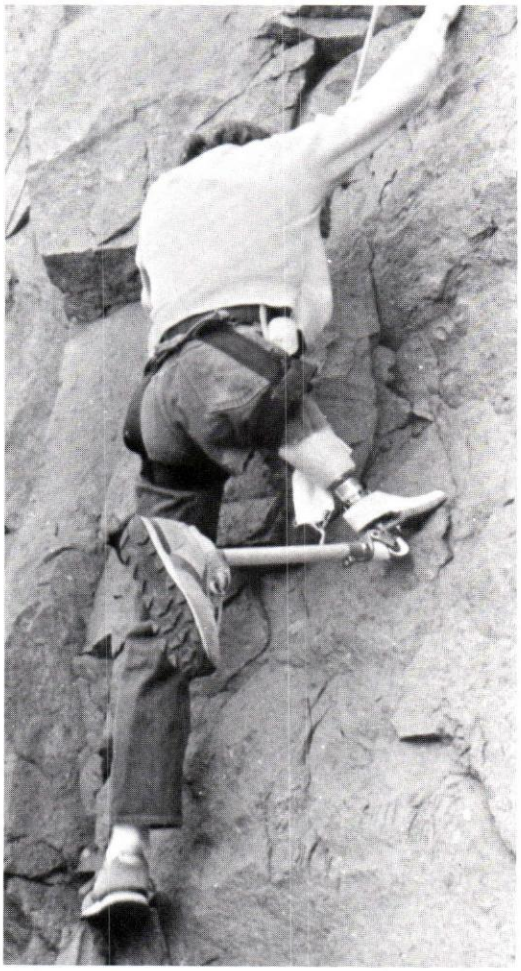

Figure 1. The above-knee prosthesis for rock climbing provides grip close to the residual limb.

above-knee amputee may climb only easy to moderately difficult rocky surfaces. In order to surmount these problems, a rock climbing prosthesis (RCP) was designed specifically for the above-knee amputee.

Modifications were made to an above-knee prosthesis for a very short residual limb previously equipped with a pelvic band, single axis hip joint, exoskeletal single axis, constant friction knee unit, and SACH foot. The rock climbing prosthesis allows greater mobility, is less bulky and lighter, provides grip close to the residual limb (Figure 1), improves stability and footgrips, and avoids hooking of the forefoot in crevices.

FABRICATION OF THE RCP

The RCP prototype includes a conventional socket, a modified pelvic band, a thigh rotation system, a foot assembly close to the knee (upper foot), a modular polycentric knee, a titanium shank, and a SACH foot (lower foot).

Socket and Suspension

A conventional polyester resin socket was used. To allow greater hip flexion, the anterior wall of the socket was lowered by 2.5 cm (one inch). Due to the shortness of the residual limb (length of 17.5 cm or seven inches) initial flexion of the socket of ten degrees and abduction of five degrees were provided.

For added strength and more efficient suspension, a stainless steel pelvic band was preferred to the silesian band (Figure 2). It was fit with a four-way hip joint (ACME #3J-7704-00). Hence, hip movements in the frontal and saggital planes were permitted. Adjustable elastic bands were anchored anteriorly and posteriorly on the socket and band in order to avoid protrusion of the residual limb out of the socket when climbing. The anterior strap extended from the midline of the anterior wall of the socket at the level of the ischial seat, up to the pelvic band (Figure 2). To counter-balance the initial abduction of the socket, the posterior strap was anchored 2.5 cm (one inch) medial to the midline of the posterior wall and 2.5 cm (one inch) below the proximal brim of the socket. All attachments were reinforced with fiberglass.

Thigh Rotation System

In certain rock climbing conditions, the climber must bear weight on the medial border of the shoe. This maneuver involves, to varying degrees, movements at the hip, knee, and ankle joint. The lower limb amputee fitted with an above-knee prosthesis, has limited range of motion in the horizontal plane since no rotation is possible at the knee and ankle joints. Further limitation is introduced by the use of a pelvic band. Hence, to obtain a medial

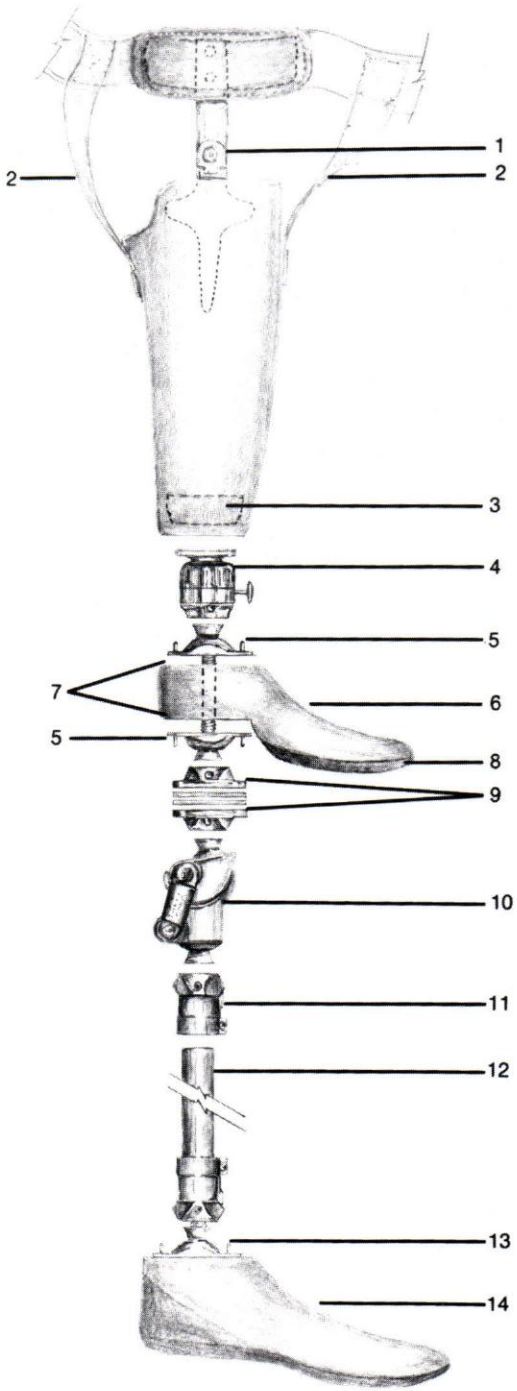

Figure 2. Exploded view of the components of the RCP:

1. **Multi-axial hip joint**
2. **Elastic bands**
3. **Plastic adaptor plate**
4. **Thigh rotation system**
5. **Titanium SACH foot adaptor**
6. **SACH foot with denuded keel (upper foot)**
7. **Fiberglass reinforcements**
8. **Anti-skid rubber sole**
9. **Titanium rotatable socket adaptors**
10. **Modular two-bar linkage knee unit**
11. **Tube clamp adaptor**
12. **Titanium modular shank**
13. **SACH foot adaptor**
14. **SACH foot**

footgrip, the amputee rock climber must twist his trunk away from the rocky wall, increasing risk of a fall. As illustrated in Figure 2, a manually controlled thigh rotation system (Otto Bock #4R45) was fit under the socket with a plastic adaptor plate (Otto Bock #5R1). It allows up to 110 degrees of external rotation of the limb and locks in the neutral position (Figure 3). The release lever is incorporated into the thigh rotation system. For amputees with longer residual limbs, this lever can be extended proximally close to the hip, so that trunk flexion is not necesary to reach it.

Grip Close to the Residual Limb: The Upper Foot

Grip close to the residual limb is made possible through the insertion, at a 90 degree angle, of a SACH foot (Otto Bock #1S10) between the thigh rotation system and the knee unit. Modifications were made to the ankle-foot unit (Figure 1). The rubber of the posterior part of the foot was stripped off and the wooden keel was denuded (Figure 2). The wooden keel was then reinforced with two layers of fiberglass (Figure 2). Two titanium modular SACH foot adaptors (Otto Bock #2R31=M10) were molded in the fiberglass coating and screwed to the keel above and below the keel of the upper foot, thereby eliminating any possibility of torsion at that level (Figure 2). A 0.6 cm (¼

Figure 3. The thigh rotation system allows up to 110 degrees of external rotation.

inch) rubber anti-skid sole was glued under the anterior part of the foot (Figure 2).

Knee Unit

Two titanium rotatable socket adaptors (Otto Bock #4R51) were superimposed and screwed under the upper foot to provide anchorage for the knee unit. A stainless steel two bar linkage modular knee joint (Otto Bock #3R19) was selected (Figure 2). This knee joint unit allows up to five degrees of knee hyperextension for improved knee stability in stance and is provided with an extension aid. Moreover, when the knee is brought into full flexion, it may be maintained in this position, against gravity (Figure 1). Thus, accidental hooking of the lower foot in crevices is avoided.

Shank and Foot

The lower part of the RCP consists of a titanium long tube (Otto Bock #2R38), attached to the knee unit with a titanium tube clamp adaptor (Otto Bock #4R52) and to the SACH foot by a titanium SACH foot adaptor (Otto Bock #2R31=M10). Altogether, the use of titanium reduces considerably the weight of the prosthesis and compensates for the added weight of the pelvic band.

FUTURE PLANS

The rock climbing prosthesis was clinically tested with a 25 year old above-knee amputee, and was found to improve his rock climbing capabilities. With the RCP, the above-knee amputee rock climber is provided with greater mobility and with foot and knee grips acting in different planes. Therefore, the climber has full use of his hands and ascents of steeper walls can be attempted. On more even ground, normal gait is possible with no special adjustment required (Figure 4). Yet certain problems still have to be resolved, one being that of cosmesis and social acceptance of the RCP, since the upper foot is

Figure 4. With the RCP, normal stance and gait are possible.

permanently fixed to the prosthesis and protrudes anteriorly. Ideally this upper foot should be removable and could take the shape of an incurved anti-skid metallic blade which can be attached when needed. A second problem relates to the protection of the knee unit. Since the knee is not covered, it is liable to rub on the rocky surface and be damaged. In addition, it is not protected against rain and water running off the rock.

CONCLUSION

An above-knee prosthesis for rock climbing was developed. It provides two important features: grip close to the knee and full outward rotation of the leg for grip on the medial border of the shoe. It consists of a conventional socket, multiaxial pelvic band and thigh rotation system placed under the socket to increase mobility, a protruding foot above the knee axis for grip close to the knee, a modular polycentric knee, and a SACH foot. Titanium components were used in order to reduce the overall weight of the prosthesis.

ACKNOWLEDGMENTS

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AUTHORS

Claude Lévesque, CP(C), is with the Prosthetics and Orthotics division of the Montréal Rehabilitation Institute, 6300 Darlington Avenue, Montréal (Québec), Canada H3S 2J4.

Christiane Gauthier-Gagnon, M.Sc. (A) is with the Ecole de Réadaptation, Université de Montréal, C.P. 6128, succursale A, Montréal (Québec), Canada H3C 3J7.

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Advanced Prosthetic Techniques for Below-Knee Amputations

Timothy B. Staats, MA, C.P.

INTRODUCTION

The below-knee amputation is the prevalent level of choice in the estimated 50,000 amputations done in the United States each year. The successful prosthetic rehabilitation of the below-knee amputee has been greatly advanced in the last five years not only by technical improvements in the materials and the manner in which they are used to fabricate prostheses, but also by clinical evaluation techniques and procedures that now assist the prosthetist in enhancing the comfort and biomechanical function of the prosthesis. In the early 1960s the term "patellar tendon bearing" (PTB) was introduced by Radcliffe and Foort[1] to describe what was to become the dominantly prescribed prosthesis for the next two decades. More recently, the term "total socket bearing" (TSB) has been more correctly used to describe the weight bearing characteristics of the below-knee prosthesis.[2] This change in terminology and philosophy, along with numerous developments in below-knee prosthetics, will be discussed in this monograph.

EVALUATION TECHNIQUES

The use of xeroradiography in prosthetic evaluations is rapidly becoming not only common but mandatory as an evaluation and fitting tool, particularly in below-knee amputations. The xeroradiograph offers both soft and bony detail not as easily seen in standard x-rays (Figure 1). The prosthetist can directly evaluate the shape of the cut ends of the tibia and fibula, and accurately envision the angle at which these bones have been resected. The amount of bone tailoring performed by the surgeon can be seen and planned for in the socket interface. The evaluation and occurrence of osteophytes, which have been found to be very common, can also be better accommodated for in the design of the socket.

Prosthetists generally requesting xeroradiographs will want true anteroposterior and mediolateral views taken in the negative mode, so that as much detail as possible is visible. Xeroradiographs may be taken after initial prosthetic fittings have been completed. Exposures are taken through the prosthesis with full weight bearing and with the prosthesis suspended off the ground to confirm that total contact and suspension has been achieved (Figure 2). The relative locations of bones with respect to socket shapes are carefully examined to confirm that the weight bearing design of the socket has been achieved. The socket design has also been greatly affected by the use of xerographs. The weight distribution characteristics throughout the socket are now designed to relate physiologically as well as biomechanically to the individual shapes of a particular amputation, rather than to classic patellar tendon bearing-like shapes, which were common until the last five years. In particular, the patellar ligament area is now generally flattened from just under the patella all the way down to the tibial tubercle. This shape takes advantage of this wide surface for weight distribution rather than with the narrow patellar tendon bars common in the

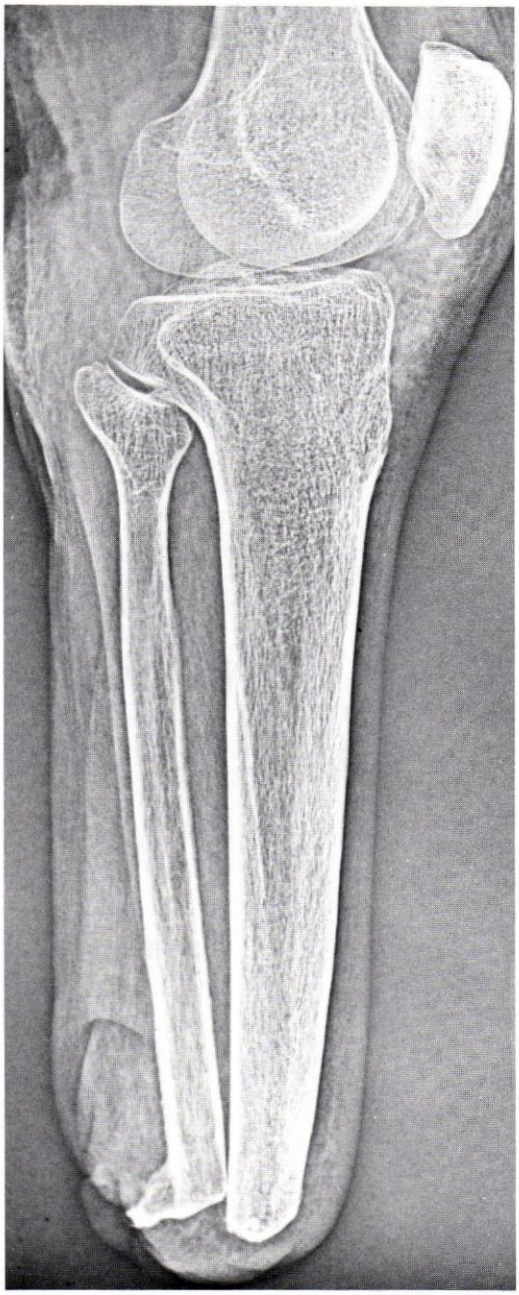

Figure 1. Xeroradiograph of a below-knee amputation.

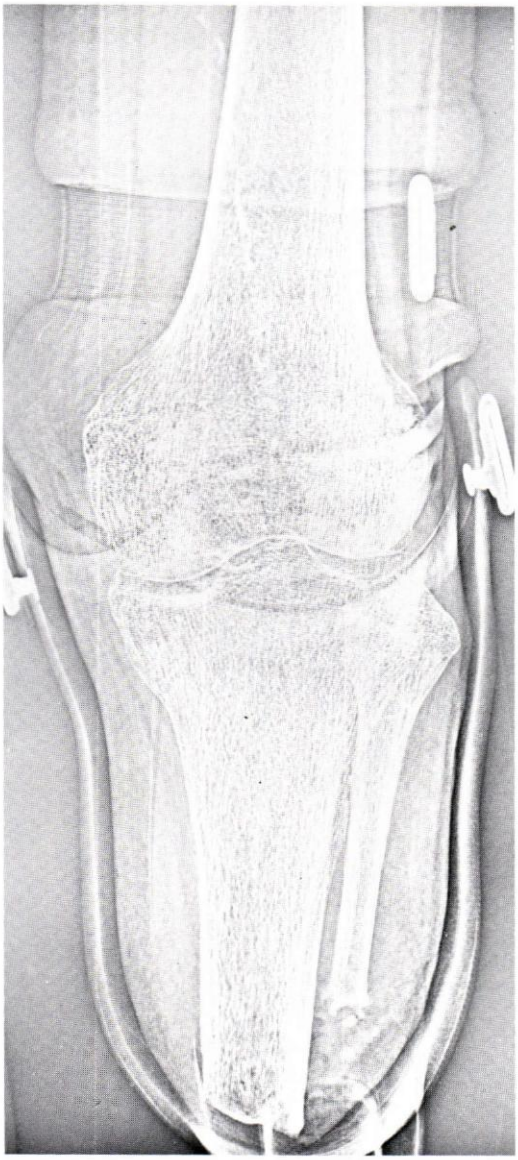

Figure 2. Xeroradiograph of a below-knee weight bearing in a prosthesis.

patellar tendon bearing sockets. This change of shape is a direct result of the use of xeroradiography in the evaluation of the residual limb. Other areas of the socket interface have also undergone evolutionary shape changes as a result of xeroradiographic studies of the residual limb in the socket.

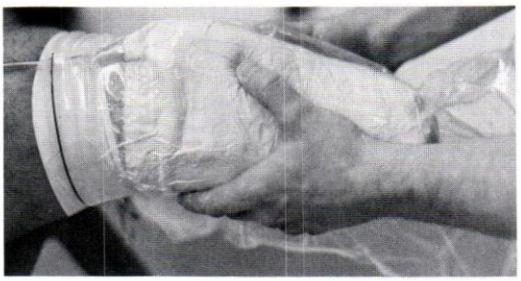

Figure 3. The Hittenberger vacuum casting procedure.

Figure 4. Elastic plaster bandage is used in the second stage of the wrap.

PRECISION PLASTER CASTING TECHNIQUES

The mold or cast impressions taken from the residual limb have changed drastically in the past five years. The recent use of stage casting and the application of controlled pressure[3] or vacuum over the plaster once it has been applied to the residual limb has resulted in improved accuracy.

The Diagonal Four Stage Casting technique[4] is an example of staged casting used not only for weight bearing and suspension, but also for the simultaneous establishment of knee flexion trimlines. The anterior and primarily bony structures of the residual limb are covered with about five layers of regular fast setting plaster bandage. Extreme care is taken in this application procedure to avoid any wrinkles and to assure that all bony structures are encased. Vacuum may be applied by placing a plastic sleeve over this initial stage in what is called the Hittenberger procedure[5] (Figure 3). The

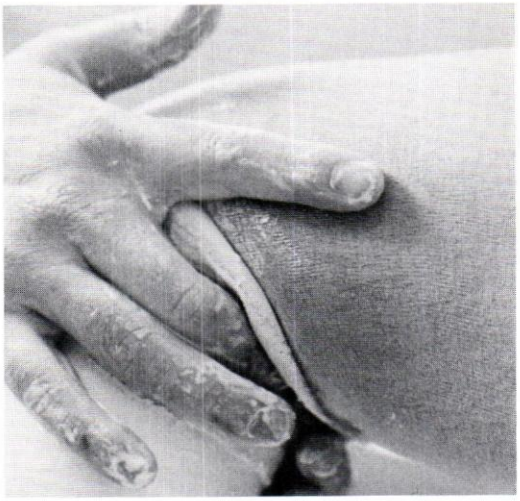

Figure 5. The third stage creates the hamstring tendon reliefs.

Figure 6. The Otto Bock below-knee casting stand.

vacuum source draws the plaster against the tissues and will reflect accurately most of the bony structures. Some prosthetists apply small clay build ups over bony prominences to premodify sensitive areas. These clay buildups are removed from the mold when the residual limb is withdrawn from the cast.

A second stage (Figure 4) using elastic plaster bandage encapsulates the posterior compartment tissues and draws these tissues forward into the anterior shell. A third stage (Figure 5) creates the posterior proximal trimline in the mold, as well as the shapes needed for comfort in the hamstring tendon region of the socket. The cast must be taken in flexion during this stage, and care is taken to maintain total contact distally while also compressing the plaster wrap as high into the popliteal fossa as possible. The reason for this high trimline is to again attempt to distribute as much weight as possible over the greatest area.

The fourth and final stage of the wrap cast creates the supracondylar suspension through careful molding over the femoral condyles to conduct pressure to areas of the femur that can tolerate the downward force of the weight of a completed prosthesis. This final stage is removable so that the residual limb can be readily withdrawn from the cast. In the past, the plaster wrap cast was taken with one or more casting socks placed over the amputation prior to cast application. It is now more common to use no sock barrier or only a sheer nylon stocking so that as tight a cast as is possible can be obtained. Barrier creams are used on the skin when no stocking is used in casting.

In the diagonal four stage casting technique, the wrap cast is carefully mounted into a gimble mounted ring stand[6] (Figure 6). The inner surface of the wrap cast is coated with alginate, and the patient reenters the wrap cast to apply full weight into the liquid alginate. The pressure of the residual limb into the gelling alginate more accurately defines the shapes and volume of the residual limb. After the wrap cast is removed from the stump, it is immediately filled with plaster and will become the master model. The outer plaster mold and alginate is removed, leaving a very accurate model of the residual limb. The prosthetist must rectify this master model to measurements previously taken from the amputation to further enhance the weight distribution throughout what will become the entire socket surface. It has been found that the extra effort taken during casting not only defines more accurately the amputation tissues, but also results in more comfortable and repeatable socket shapes.

Figure 7. Molten transparent thermoplastic is vacuum-formed over the residual limb model.

TRANSPARENT CHECK SOCKETS

The general use of transparent sockets was introduced in clinical practice in the early 1970s.[7] A variety of plastics have been used for this purpose, including polycarbonate, polypropylene, acrylics, and Surlyn.™ The method of production generally involves heating the plastic material to a near molten state, at which time it is drawn over the plaster model (Figure 7). External air pressure resulting from inner vacuum forces hot plastic intimately against the model. The plastic is then allowed to cool

prior to removal of the plaster model. The socket is trimmed to the shape of the prosthetic socket and mounted on an alignment pylon for the purpose of initial fit evaluation and, in some cases, dynamic walking trials.

The transparent check sockets are now fitted to the [residual limb] without fitting socks to permit careful visual examination of the skin. Generally, blanching of the skin indicates excess pressure, while redness denotes lack of contact or looseness. Holes may be drilled through the socket wall to permit probing for skin contact against the socket wall. A more recent technique of checking socket fit in transparent sockets involves injecting small amounts of glycerin into the regions of the socket that are perceived as being loose.[8] If improvement of fit is indicated by change of skin color, the glycerin is then removed from the socket and alginate introduced into the same region of the socket. Some prosthetists will, as a rule, apply alginate to the entire inner surface of the check socket and again pressure fit the check socket in a manner similar to that previously described during the wrap cast procedures.[9] The check socket is immediately filled with plaster to create a master model over which the definitive socket will be fabricated. It is becoming increasingly common for serial check socket fittings to be performed in problem cases or in cases where patients can afford the extra expense of this time consuming procedure, in order to achieve the superior results of the socket algination process.

PROSTHETIC SOCKETS AND SOCKET INTERFACES

A variety of new socket materials and socket types have recently been introduced into clinical prosthetics practices. In certain cases the materials are not actually new, but the more effective methods in fabrication have made their usage practical.

A socket interface material that increased in popularity in 1984 is the silicone laminate socket liner.[10, 11] Fabricated from nylon impregnated with silicone elastomer (Figure 8), the silicone liner provides a soft interface material capable of absorbing more shear forces than other interface materials. The objections to this material are its weight and limitations facing the prosthetist in making socket shape and size changes once the liner and socket have been fitted. These objections are generally overcome through more accurate fittings made possible by improved casting and check socket use. The weight problem has also been largely minimized through the use of ultra-light carbon graphite laminates for the rigid outer socket, which encases the silicone liner. An alternative silicone material in the form of a gel-like cloth introduced over ten years ago[12] is regaining popularity since previous problems with gel migration have been solved through the improved fabrication. It has also been discovered that both

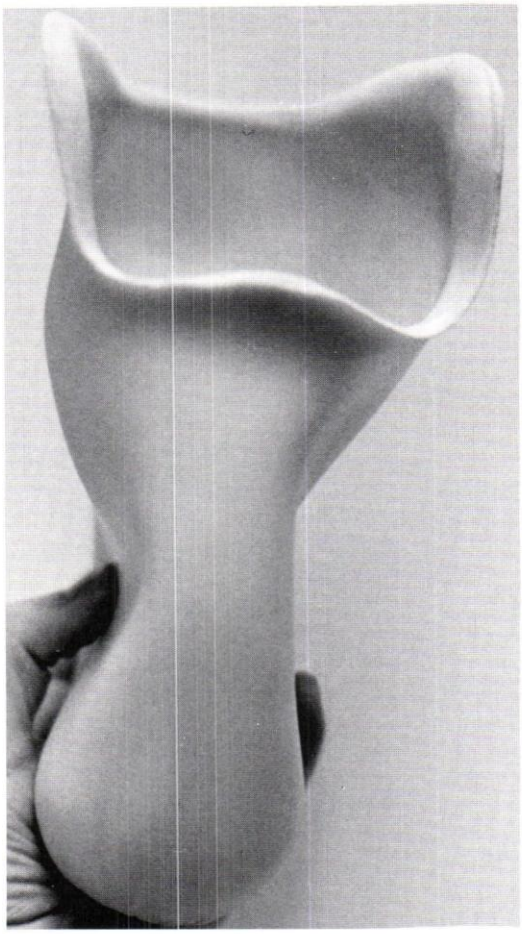

Figure 8. The laminated silicone elastomer socket liner.

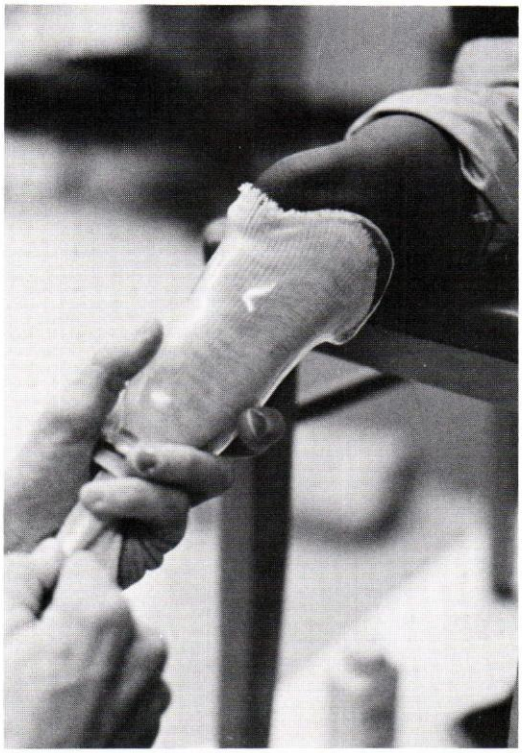

Figure 9. The suction below-knee socket is donned using a stockinette pull sock.

Figure 10. The inner shell of the suction below-knee socket fits into a rigid outer socket.

types of silicone liners can, when properly fabricated, be fitted with only thin nylon sheaths or no covering over the stump at all. The traditional use of thick stump socks is now in question, as techniques using only precision socket fit gain acceptance.

One such technique is the suction below-knee socket. The suction socket is not new. Prosthetists in San Francisco have fitted soft liner suction sockets for at least 20 years.[13] Recently, however, in Uppsala, Sweden, Friestadt[14] and Grevsten[15] have fitted numerous below-knee patients using hard sockets with distal valves similar to those used in above-knee suction socket prostheses. This process is accomplished through the use of a thin inner socket of polyethylene or Surlyn® thermoplastic. A rigid outer shell of laminated acrylic or polyester plastic then reinforces and supports the thin inner shell. The inner socket is donned by pulling the socket on with a length of stockinette (Figure 9). Some patients prefer to slide into the inner shell using a small amount of lubricant, which easily permits the residual limb to enter the socket (referred to as UCLA "wet fit"). When the stump has settled into the socket, the suction valve is inserted into the valve seat, ensuring complete suction. The thin shell inner liner is then inserted into the more rigid outer structure (Figure 10). This interesting technique can be enhanced by a process in which air spaces are created opposite bony prominences outside of the thin inner shell. The thin and flexible inner shell only exerts tolerable pressure on the sensitive bony structures. The air space between the outer shell and the inner shell further protects any potentially sensitive areas.

In more conventional techniques for making socket liners the pressure transmission of forces can be controlled through the use of multiple durameter liners.[16, 17] Materials of different density and firmness are laminated together in such a way as to provide support on the one hand and pressure

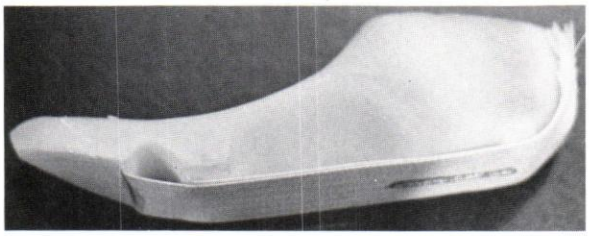

Figure 11. The SAFE™ foot keel is flexible and has a strong plantar band which stimulates the normal foot.

Figure 12. The Seattle™ foot keel design.

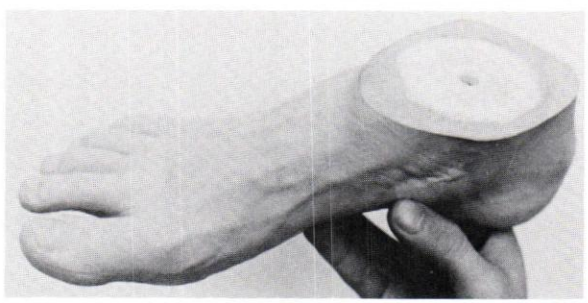

Figure 13. Life-like appearance of the Seattle™ foot.

relief where it is necessary. In particular, materials such as Pelite,™ a resilient thermoplastic foam, is used in conjunction with a super-soft polyethylene foam called Aliplast.™ The softer material is used over bony prominences, while the firmer material is used over tissue that is more pressure tolerant. When the multiple durameter socket liner was first used, it was thought that the softer foam would pack out and be virtually useless. It was found, however, that the soft foam only packed out the amount needed to relieve pressure and provide comfort. It appears that the use of suction fit and better suspension methods has also contributed to reducing friction between the stump and the socket interface.

PROSTHETIC FEET AND OTHER COMPONENTS

The recent introduction of several new prosthetic feet has sparked interest in the possibilities of increased activities for the below-knee amputee. There are also many benefits that less active patients can derive from these new foot variations.

The SAFE™ foot developed by Campbell and Childs[18] represents a major advance in

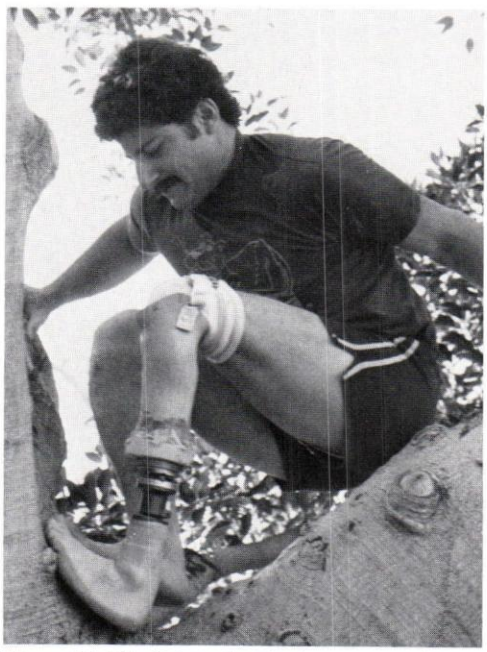

Figure 14. The Jaipur foot is demonstrated in a tree climbing exercise.

Figure 15. Below-knee pylon systems.

design of artificial feet. The SAFE™ foot has gained wide acceptance in a relatively short period of time due to its physiologic design. It is manufactured with a flexible inner skeleton keel with a strong plantar surface band, which acts in much the same manner as a normal foot (Figure 11). As the amputee rolls over the toe of the SAFE™ foot, the forefoot portion becomes more rigid. The flexible keel permits the patient to easily adapt to uneven surfaces and rugged terrain. The flexibility of the foot has had one interesting side effect in that the general alignment rules used by most prosthetists cannot be used with the SAFE™ foot.

The Seattle™ foot,[19] developed at the Prosthetic Research Study in Seattle, Washington, under the direction of Dr. Ernest Burgess, is now in the final developmental stages and is planned to be in production for commercial distribution in the near future. At present, the Seattle™ foot is still being tested. The principal feature of the Seattle™ foot is a unique keel design (Figure 12) that stores energy through compression. This stored energy is transmitted back to the amputee at toe off. Original designs consisted of a multiply laminated plastic leaf spring. Later designs tested carbon graphite leaf designs, and presently the keel is being tested with a special high strength nylon called Delrin. The outer covering of the Seattle™ foot is pleasingly realistic as it is manufactured using molds taken from human feet (Figure 13).

The Jaipur foot[20] (Figure 14) from India is another example of lifelike design and functional response. In this case a very flexible foot was designed for use by patients in conditions typical of rural India, and generally for barefoot usage. Interest in the Jaipur foot in the United States is related to use as a recreational prosthesis. Laboratory testing of the Jaipur foot has not proven it to be safe for usage in the United States, where patients are generally much heavier than the average Indian.

ALIGNMENT SYSTEMS

Numerous pylon alignment systems are now available for use during dynamic alignment of the below-knee prosthesis (Figure 15). Some of these alignment pylons are removed from the prosthesis during finishing, and others such as the popular Otto Bock Endoskeletal pylon system[21] (Figure 16) become integral to the finished prosthesis when covered with a soft foam cover. The alignment systems are divided into vertical and nonvertical systems, but all are used to perform essentially the same functions of establishing the optimum angular and linear relationship of the foot and socket.

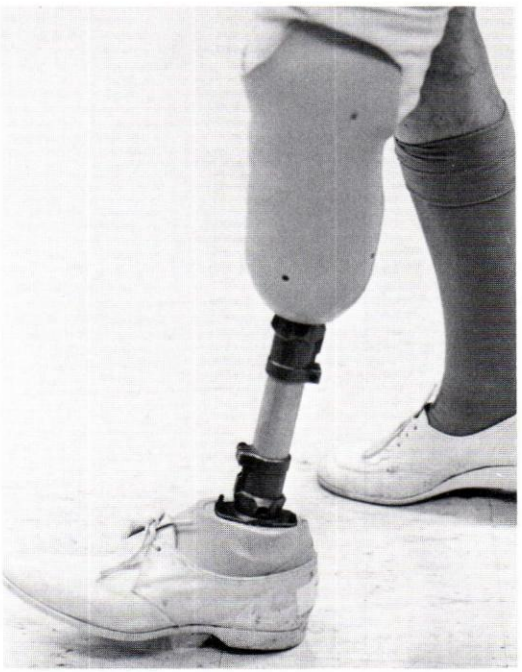

Figure 16. The Otto Bock below-knee pylon.

One unusual development in the area of pylon systems and feet is called the "Flex-Foot™"[22] prosthesis (Figure 17). This prosthesis consists of a series of carbon graphite struts that can be aligned very much like other pylon systems. The one major difference in the Flex-Foot™ is that the entire structure can flex when weight is applied during walking and running. The carbon graphite strut's size and strength is calculated in relation to the patient's body weight and expected use requirements. While the full implication of this system is not known in relation to normal and sedentary use, its use in high performance athletic activities has shown

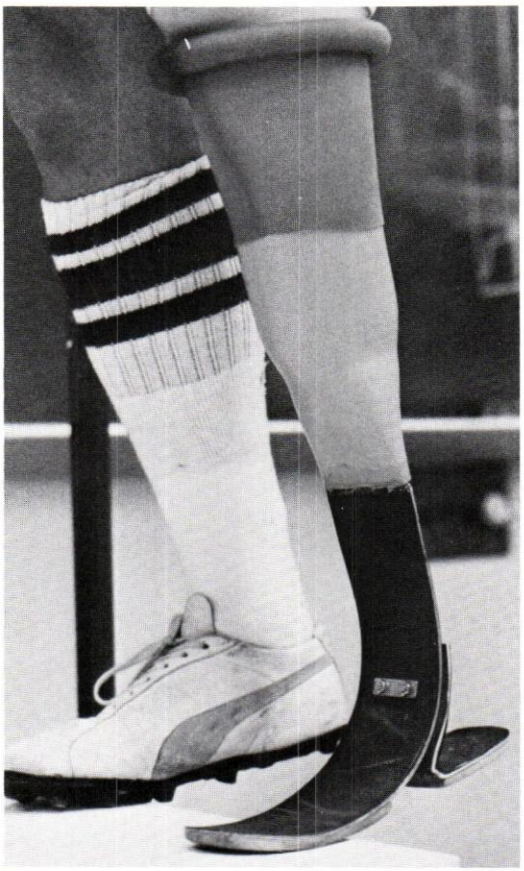

Figure 17. The Flex-Foot™ prosthesis.

Figure 18. Videotaping walking trials of a below-knee amputee.

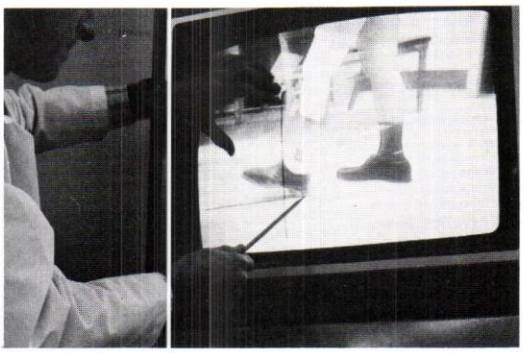

Figure 19. Slow motion analysis of videotaped walking trials are used to enhance dynamic alignment.

marvelous results. At present it is being used for below-knee amputee patients who want to run. The Flex-Foot™ is shown without its cosmetic covering.

DYNAMIC ALIGNMENT AND GAIT ANALYSIS

Beyond socket fit, gait analysis and dynamic alignment have always been regarded as the most difficult area of below-knee prosthetics. The use of video recording and slow motion analysis of the patient walking with the prosthesis (Figure 18) has been a great help to both the patient and the prosthetist doing the alignment. Careful observation of walking trials using closeup views of the foot, pylon system, and stump-socket system, as well as wide angle views of the patient during locomotion, are possible without exhausting repetitions by the patient (Figure 19). It is possible to precisely analyze piston action, socket displacement, and trunk bending gait deviations, which are normally quite difficult to judge accurately during walking trials.

FINISHING TECHNIQUES

Cosmetic restoration is as important to some below-knee amputees as functional replacement. Two advances are noteworthy in the area of finishing techniques: the mirror image finishing technique[22] and cosmetic skin coverings.[24]

The mirror image finishing technique involves taking a careful impression of the sound leg of the patient, creating a master model from this mold, and laminating a shell over this model. Before the laminate becomes rigid it is removed from the model and quickly reversed, creating a mirror

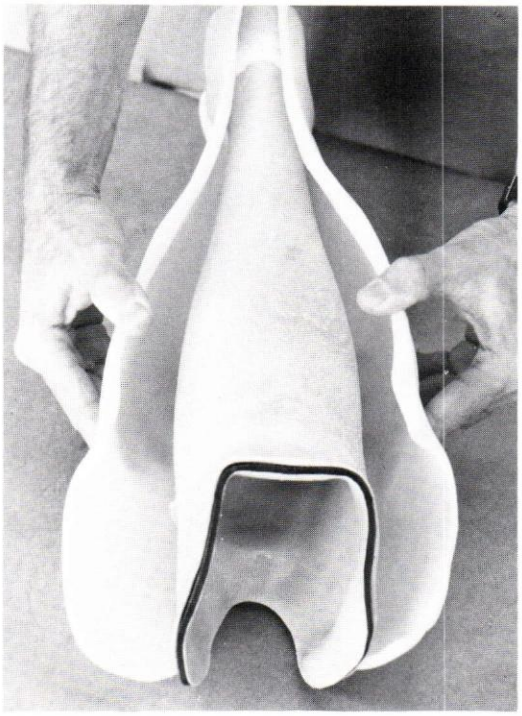

Figure 20. The mirror image finishing technique.

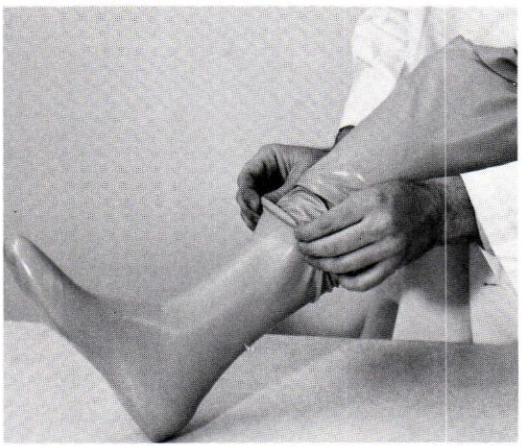

Figure 21. Prosthetic skin is carefully donned over the prosthesis to create cosmesis.

image of the opposite side. This mirror image shell is then placed over the aligned prosthetic pylon stem. A flexible urethane foam is injected into the cavity. When the foam has cured, the outer shell is removed (Figure 20), leaving a dimensionally accurate replica of the sound side.

The finish of the prosthesis can be further enhanced through the use of prosthetic

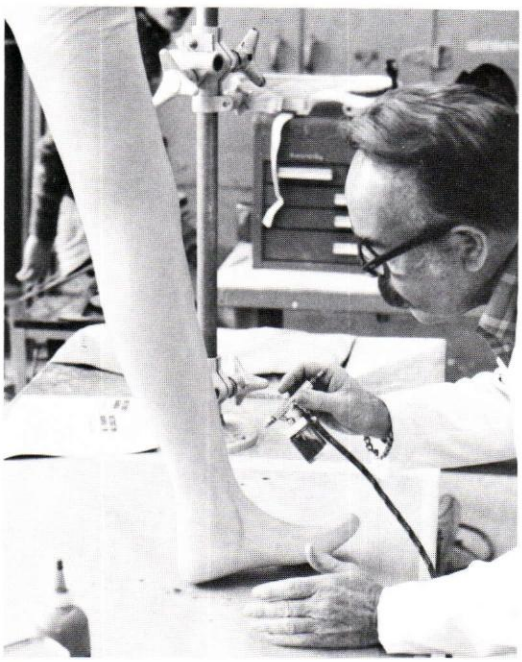

Figure 22. The prosthetic skin covers may be colored using an airbrush system/coloring.

skin covers, which are pulled over the shaped prosthesis (Figure 21). Prosthetic skin covers are available in copolymer vinyls, silicones, and acrylic latex materials. It is possible to air brush colors (Figure 22) on the skin covers with the use of special coloring systems.[25] Patients must expect to pay as much for these advanced finishing and cosmetic techniques as for the cost of the prosthesis itself. True cosmetic restoration is time consuming and artistic (Figure 23). It is not available from all prosthetists, and any patient who has great expectations for the cosmetics of the prosthesis should be warned to seek consultation in advance of beginning work on a prosthesis. It often is not possible to cosmetically convert a prosthesis that is made in a conventional manner.

COMPUTER AIDED SOCKET DESIGN AND MANUFACTURING

Research and clinical applications in the area of computer aided socket design[26] and computer aided manufacturing[27] of be-

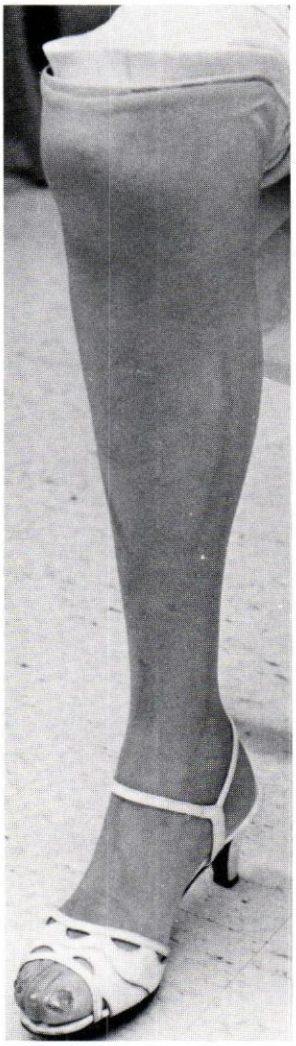

Figure 23. The "Massey" prosthetic skin.

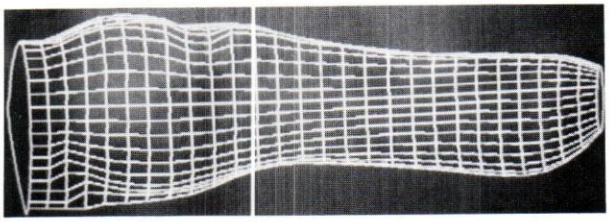

Figure 24. Computer aided socket design, as demonstrated at the Medical Engineering Research Unit in British Columbia, Canada.

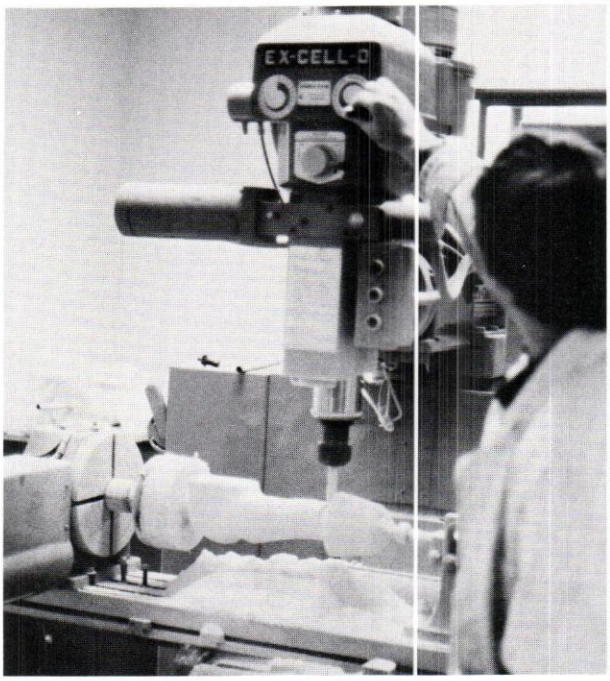

Figure 25. Computerized stump measurements are sent to a computer-driven milling machine to create the master stump model.

low-knee prostheses is underway in Canada and in the United Kingdom. With the aid of computers, the below-knee socket is designed on the monitor screen of the computer (Figure 24) using measurements taken from the patient. These measurements and the socket, which is shown on the screen, may be modified in much the same manner as a cast. When the model modification is completed, the digital information is transmitted to a computer driven milling machine, which in turn shapes a solid blank into a stump model (Figure 25). The model is then used to fabricate the below-knee socket in a more or less conventional manner.

Research is also being done in the area of shape sensing of amputation stumps, so that measurement information can be entered into the computer directly. It would appear that these approaches to prosthetics hold great promise and could unravel many of the mysteries regarding socket fit and alignment. It is unfortunate that these computer systems are becoming available during a period of limitation of medical services through cost containment. The systems are presently very expensive initially, but appear to offer cost benefit if they can be proven to be reliable. The actual acceptance of computer aided socket design and manufacturing systems by prosthetists will de-

pend greatly on the design flexibility and freedom built into the software of the system. Initial reaction of prosthetists using the computer screen to shape sockets has been favorable. If the screen and computer can accurately reflect socket shapes, and these shapes can be easily moved and changed, it is no problem to make a prosthetic socket. Development of the computer programming needed to achieve this end is no small task, and those in research are commended for their efforts to this point in time.

Significant advances in below knee prosthetics philosophy and clinical practice have been achieved over the past 15 years. This monograph has pointed out many of the newer developments that will shape the prostheses to be used in the next decades. Many of the techniques have only recently been introduced into clinical practice and will take a number of years to spread to all prosthetists. Not all prosthetists will share in the author's enthusiasm for these new developments, and they will continue to practice using techniques that they have found successful. Prosthetics students are being taught these new techniques and can be expected to include them selectively in their practices.

AUTHOR

Timothy B. Staats, M.A., C.P. is adjunct professor of orthopedic surgery and director of Orthotics and Prosthetics Education of the University of California at Los Angeles School of Medicine, 1000 Veteran Avenue, Rehabilitation Center, Room 22-56, Los Angeles, California 90024.

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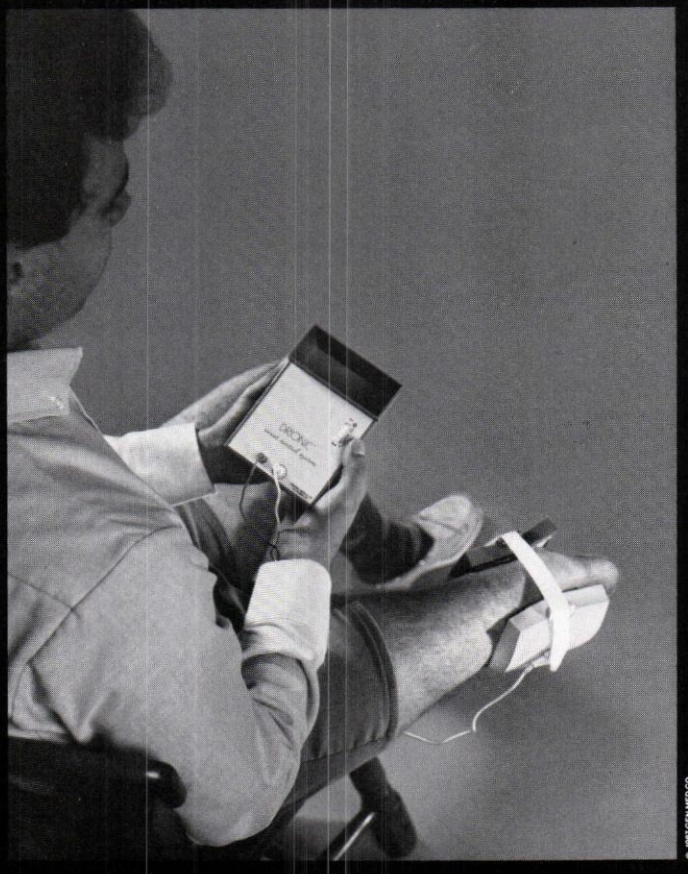

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Book Reviews

On Stump Socket Lamination, Wieland Kaphingst and Sepp Heim. Published by Freidr. Vieweg and Sohn. Available in the U.S. from IPS, P.O. Box 230, Accord, MA 02018, $7.50, 43 pages.

This book describes work done by the authors in Tanzania under the sponsorship of the West German Relief Agency, Gesellschaff fur Technische Zusammenasbeit (GTZ) Gmbh. Fundamentally, it details the method of direct forming and lamination of a below-knee socket directly on the patient's limb complete with liner and PVA bags. Resort to such an expedient may strike most in the USA as bizarre. As the authors point out, however, it is intended not as an alternative to conventional fabrication procedures, but as a means of overcoming the unavailability of plaster of Paris in some third world nations.

While it may not be particularly relevant to the American scene, this book is very interesting and very well done. The text is quite clear and illustrated with a comprehensive series of excellent line drawings. Most American practitioners will enjoy reading it and, in the process, gain some appreciation for the problems encountered in the third world.

Physical Therapy Management of Lower Extremity Amputations, Gertrude Mensch, Patricial M. Ellis. Aspen Publishers, Inc., 1600 Research Boulevard, Rockville, Maryland 20850. 365 pages. Index. $42.50, 1986.

The title aptly and precisely describes the purpose of the book. It covers for physical therapists the physical therapy management of lower limb amputees in a comprehensive and thorough fashion. It focuses principally on the central topic and addresses side issues only insofar as they are relevant to the main subject. As such, therefore, it does not pretend to cover the entire subject of lower extremity amputees for all professionals of all disciplines involved. A prosthetist may not find much of personal interest in the book but I believe he would be well advised to have the book available so as to familiarize himself with the therapists's function and to have it available when therapists with whom he comes into contact with ask for a reference book.

The book deals primarily with adults and below-knee and above-knee amputees. Some prosthetists may object to the fact that the book contains an extensive section on trouble shooting gait deviations, feeling that the listing of prosthetic considerations is an infringement on the prosthetists' prerogatives. However, the listing of prosthetic consideration is but one class of possible causes among many and it is difficult to see how the topic could be dealt with without including reference to prosthetic causes.

Orthotics Excetera, John B. Redford, Editor, Williams and Wilkins, 428 East Preston Street, Baltimore, Maryland 21202. Third Edition, 1986. 836 pages. Index.

This book is a member of the Rehabilitation Medicine Library and was originally published as a part of the Physical Medicine Library, edited by Sidney Licht. As the third edition it continues the format of the preceding editions and continues much of the same material.

It offers an extensive and comprehensive overview of the subjects of orthotics, durable medical equipment and adaptive devices and clothing. This fact is probably the book's greatest weakness. It is unwieldy in size and it is difficult to find specific material due to the size. One volume devoted

solely to orthotics and another to deal with the rest of the material would doubtlessly be more manageable and allow expansion of sections that deserve it.

The book contains much material that is useful but it should be born in mind that it is written by physiatrists for physiatrists and covers the topic of orthotics from their perspective. An orthotist is likely to find himself not totally in sympathy with this point of view and must also bear in mind that it differs from the orthopedists perspective.

Orthotic Principles and Practices, G.K. Rose, Distributed in the U.S. by Sheridan House, Inc., 145 Palisade Street, Dobbs Ferry, New York 10522. 237 pages. Index.

This book contains a comprehensive overview of the subject of orthotics from the viewpoint of a British Orthopedic Surgeon and thus an American Orthotist will find much that is familiar yet strange. The combination is interesting and instructive. Of specific interest are the sections on treating the foot and the section describing the Swivel Walker and Hip Guidance Orthosis.

While the book is well written and interesting it is doubtful if an American orthotist would find it clinically useful. Perhaps it should best be considered by those interested in a review of the subject of orthotics and a different perspective.

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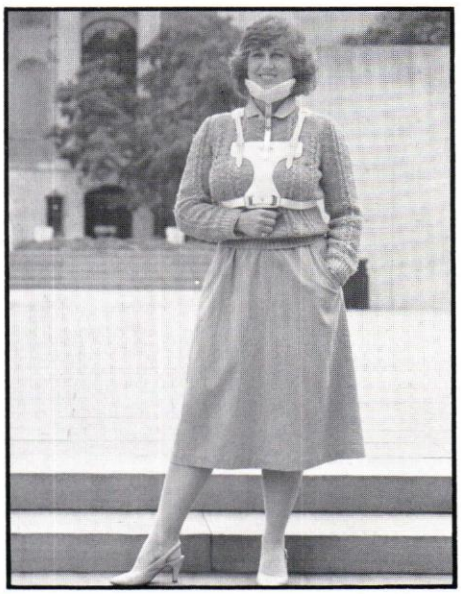

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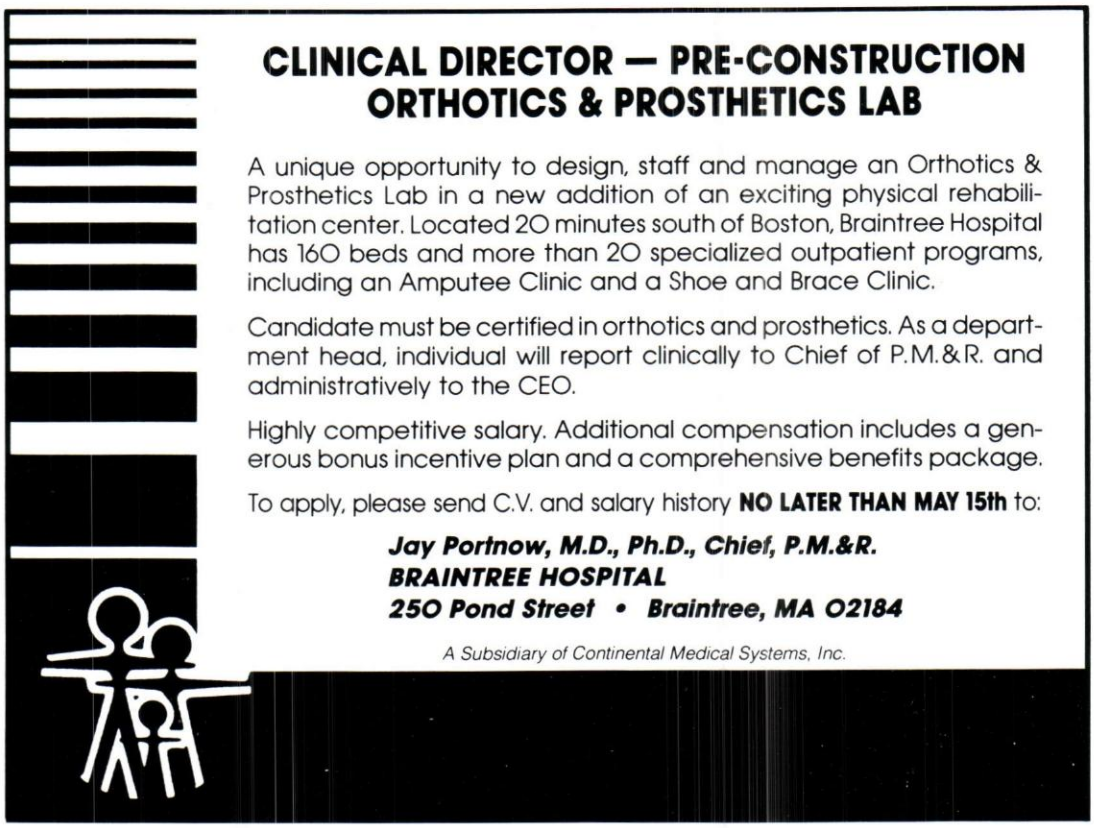

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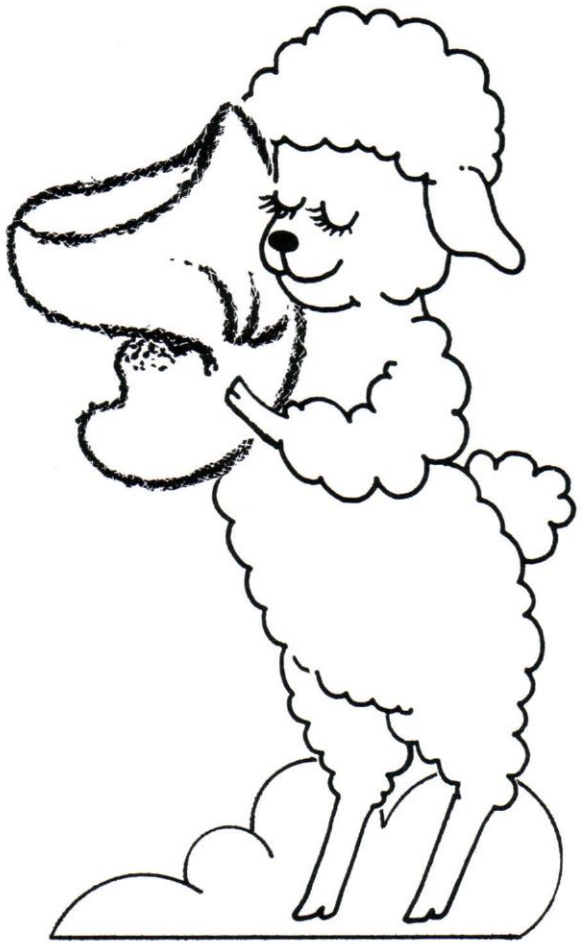

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