Fall 1987
Volume 41
Number 3

Orthotics and Prosthetics

Journal of the American Orthotic and Prosthetic Association

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Orthotics and Prosthetics

Fall 1987 **Volume 41, Number 3**

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.

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Calendar of 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 date to avoid conflicts in scheduling.

1987

November 21, Southern Chapter of the Academy meeting, Anaheim Marriott, Anaheim, California. Contact: Sandy Hargrave (714) 839-9304.

November 26–29, Medical/Hospitech 87, Bangkok International Exposition Center, Bangkok, Thailand. Contact: SKA 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 Elliot 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.

March 5, Academy Midwest Chapter Spring Scientific Seminar/Social Event. Contact: Mark Edwards, CP, (312) 908-8006.

March 12, Academy Northern California Chapter Seminar, Oakland, California. Contact: Robert A. Bangham, CO, c/o Hittenbergers, 1117 Market Street, San Francisco, California 94103.

April 11–15, 10th Congress of the International Federation of Physical Medicine and Rehabilitation, Sheraton Hotel, Toronto, Ontario. Contact: Secretary, 545 Jarvis Street, Toronto, Ontario M4Y 2H8, Canada.

April 28–29, Region IV Meeting, Hyatt Regency Hotel, Memphis, Tennessee.

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

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

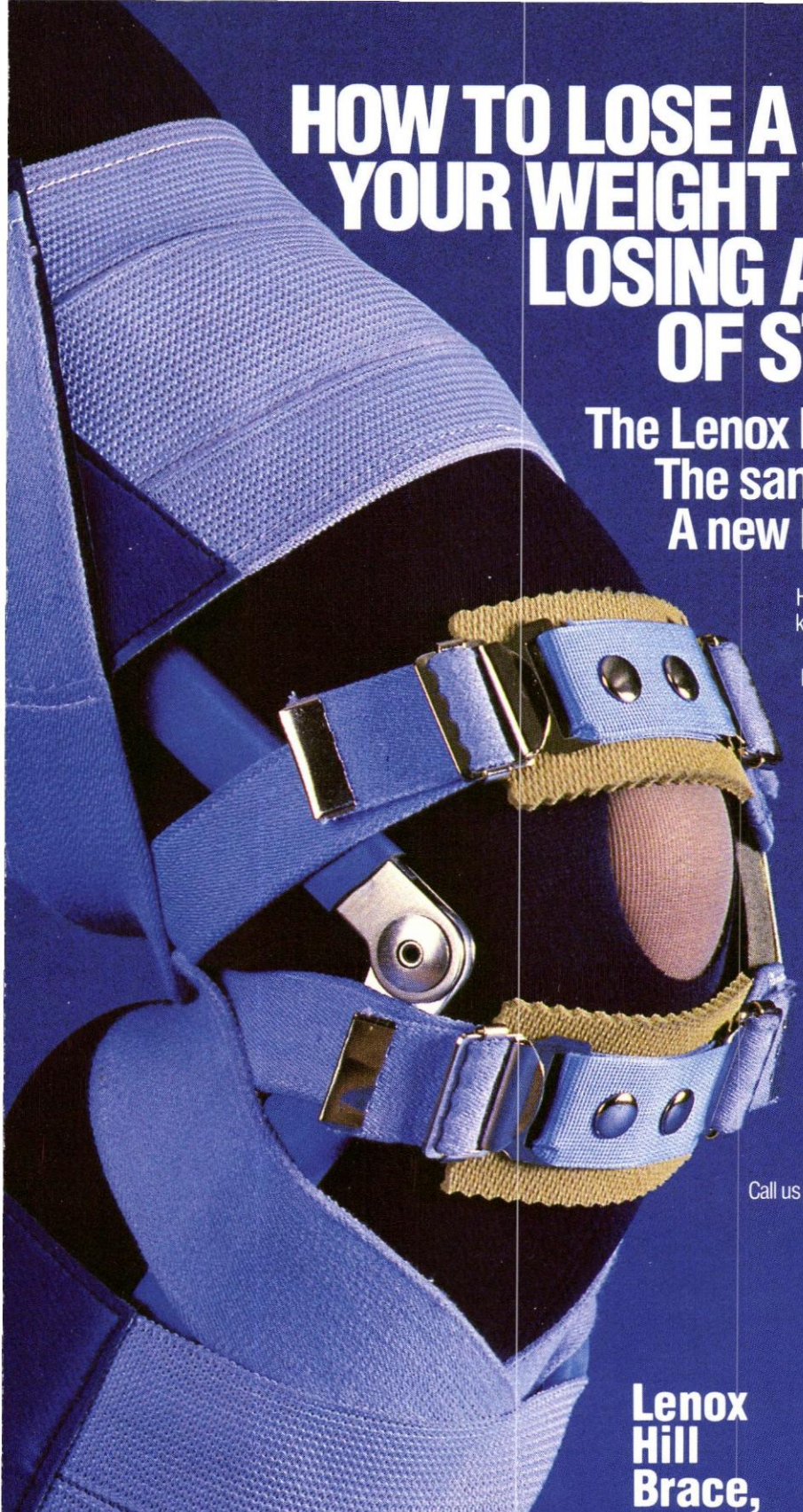
June 8–11, AOPA Regions II and III Combined Annual Meeting, Trump Plaza Hotel and Casino on the Boardwalk, Atlantic City, New Jersey.

June 15–18, AOPA Regions VII, VIII, X, and XI Combined Annual Meeting, Seattle, Washington.

June 23–25, AOPA Region VI and the Academy Midwest Chapter Joint Educational Seminar, Pheasant Run, St. Charles, Illinois. Contact: Phil Tirimacco, CP, (312) 342-7200, ext. 2828, or Charles Grantham, CP, (219) 836-2251.

July 16–18,, AFI-ENDOLITE Prosthetic Certificate Course, "Endolite High Technology Prosthesis," Miami Lakes Inn & Country Club, Miami, Florida. Contact: Karen Hewitts, Registrar, AFI-ENDOLITE, 2400 West 82 Street, Hialeah, Florida 33016; (305) 823-8300.

August 13–15, AFI-ENDOLITE Prosthetic Certificate Course, "Endolite High Technology Prosthesis," Miami Lakes Inn & Country Club, Miami, Florida. Contact: Karen Hewitts, Registrar, AFI-ENDOLITE, 2400 West 82 Street, Hialeah, Florida 33016; (305) 823-8300.



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September 3–5, AFI-ENDOLITE Prosthetic Certificate Course, "Endolite High Technology Prosthesis," Miami Lakes Inn & Country Club, Miami, Florida. Contact: Karen Hewitts, Registrar, AFI-ENDOLITE, 2400 West 82 Street, Hialeah, Florida 33016; (305) 823-8300.

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.

September 24, Academy Northern California Chapter Seminar, San Francisco, California. Contact: Robert A. Bangham, CO, c/o Hittenbergers, 1117 Market Street, San Francisco, California 94103.

October 15–17, AFI-ENDOLITE Prosthetic Certificate Course, "Endolite High Technology Prosthesis," Miami Lakes Inn & Country Club, Miami, Florida. Contact: Karen Hewitts, Registrar, AFI-ENDOLITE, 2400 West 82 Street, Hialeah, Florida 33016; (305) 823-8300.

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

November 12–14, AFI-ENDOLITE Prosthetic Certificate Course, "Endolite High Technology Prosthesis," Miami Lakes Inn & Country Club, Miami, Florida. Contact: Karen Hewitts, Registrar, AFI-ENDOLITE, 2400 West 82 Street, Hialeah, Florida 33016; (305) 823-8300.

November 21, Southern California Chapter of the Academy Fall Seminar, Marriott Hotel, Anaheim, California. Contact: Marmaduke Loke, 7910 Frost Street, San Diego, California 92123.

1989

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

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

May 10–13, International Trade Fair and Congress for Orthopaedics and Rehabilitation Technology. Contact: NMA Nurnberg Messe- und, Ausstellungsgesellschaft mbH, Objektleitung, Messezentrum, D-8500 Nurnberg 50, West Germany.

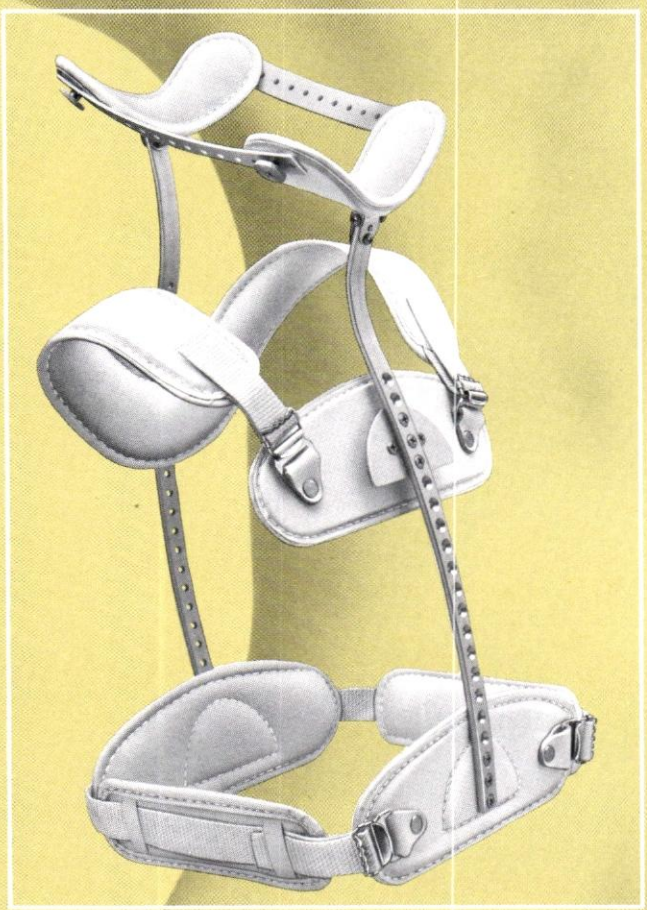
May 12–14, AOPA Region IX, COPA, and the California Chapters of the Academy Combined Annual Meeting.

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

May 18–20, The Second S.M. Dinsdale International Conference in Rehabilitation, "Visions and Controversies in Rehabilitation," hosted by the Royal Ottawa Regional Rehabilitation Centre, Ottawa, Ontario. Contact: Information Department, (613) 737-7350, ext. 602.

October 2–8, AOPA Annual National Assembly, Bally's 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.



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1990

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

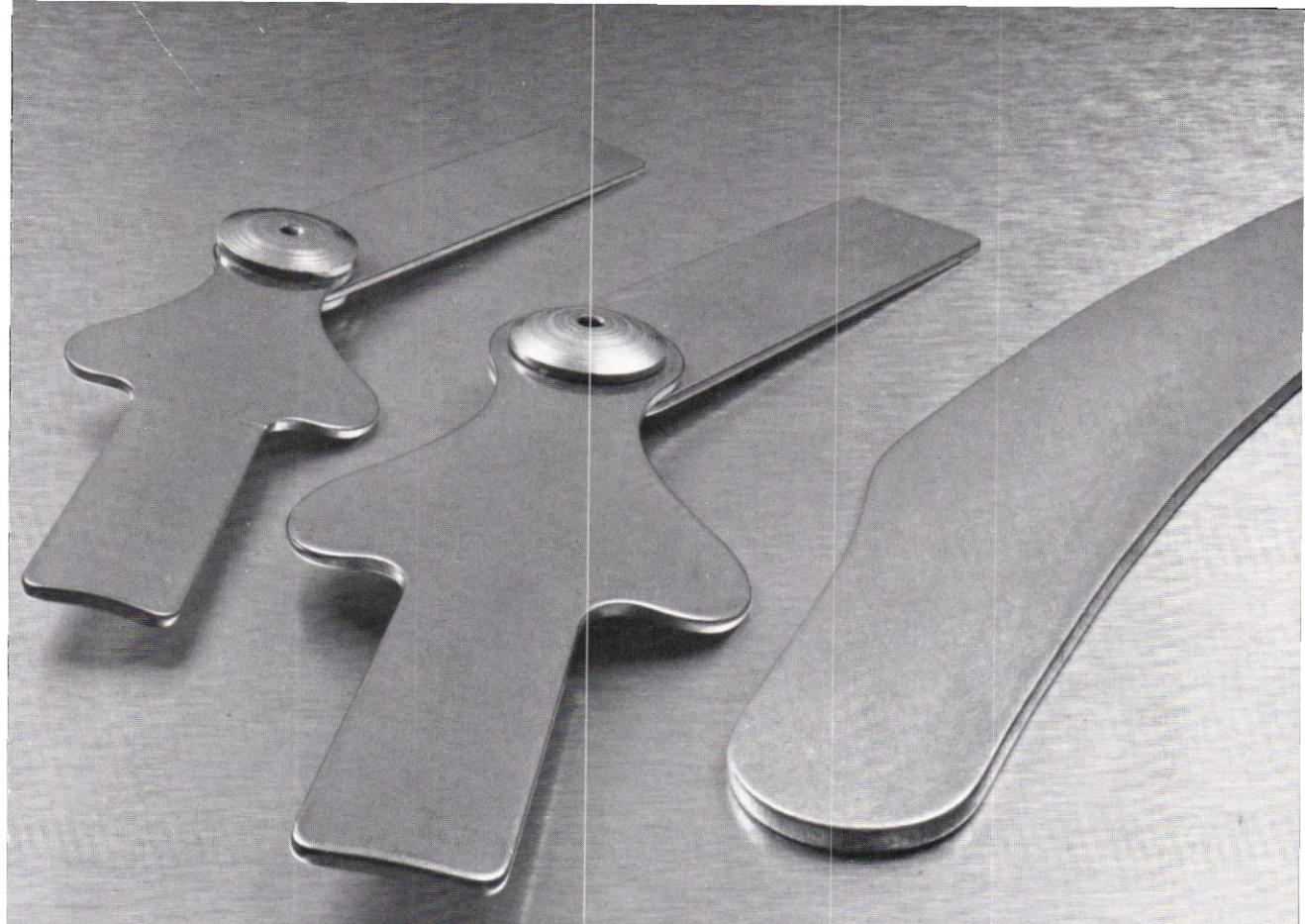
February 8–13, American Academy of Orthopaedic Surgeons Annual Meeting, New Orleans, Louisiana.

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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Pelvic Band—P02-340-0000

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	Weight	Weight
Regular Hip Joint	8.5 oz. (242 gm.)	5.2 oz. (147 gm.)
Small Hip Joint	4.7 oz. (132 gm.)	3.2 oz. (90 gm.)
Hip Band	9.7 oz. (274 gm.)	4.1 oz. (117 gm.)

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Letter to the Editor

To the Editor:

In a recent issue of *Orthotics and Prosthetics*,[1] O'Toole and DeCarteret extolled the virtues of the New England Preparatory Prosthesis (NEPP). Lest anyone get the impression that this prosthesis is the first choice of all New Englanders, we offer the following observations.

Space age technology aside, the NEPP is unnecessarily heavy, bulky and unattractive. Traumatic young amputees might possibly tolerate its extra weight, but for the every increasing number of elderly dysvascular amputees, the weight, which is almost twice that of a plastic modular system, seriously limits their ability to walk.

If the NEPP was an optimally functional prosthesis, then its weight, cosmesis and even its unnecessarily long fabrication time would be only minor drawbacks. But, it is a non-endbearing prosthesis secured only by circumferential pressure applied through lace-up leather corsets, and this is its shortcoming. Without distal endbearing, problems with edema, stump shape, wound healing, pain, and distal migration of the stump are inevitable. Moreover, in a below-knee prosthesis, PTB suspension is difficult to maintain without a socket-end and this often leads to serious skin breakdown from pistoning. In the above-knee prosthesis, ischial weight-bearing is next to impossible to maintain because of the flexibility of the leather ischial shelf and its small area of contact on the tuberosity, leading to distal migration of the stump and impingement. Last, but not least, we find that virtually all patients need help indefinitely in donning this prosthesis, which seriously undermines their capacity to be independent.

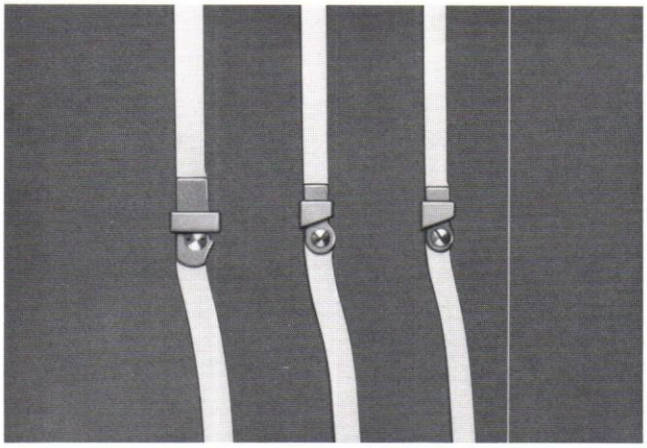
O'Toole and DeCarteret emphasize that the lace-up style of the New England Preparatory Prosthesis allows for easy adjustment in the presence of volume changes, thereby avoiding the need for many stump socks. This may be so, however, we'd like to reassure our fellow practitioners around the country that, yes, end-bearing variable-volume plastic sockets that have alignment adjustment capabilities do exist in New England. And, in our view at least, they do a better, more efficient, more cosmetic, more functional job at addressing the needs of early prosthetic management than do leather corsets.

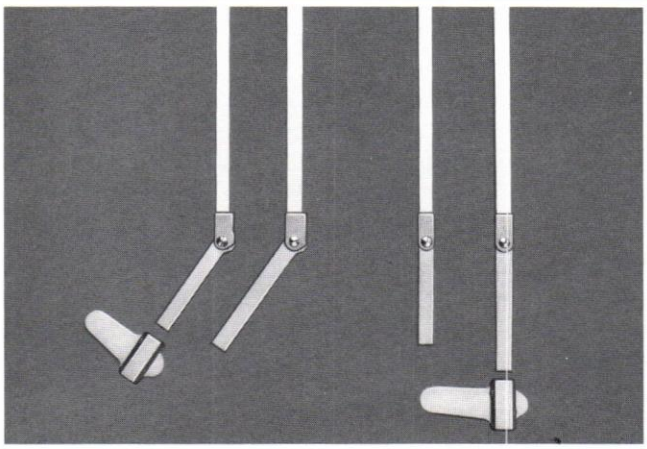
Sincerely yours,

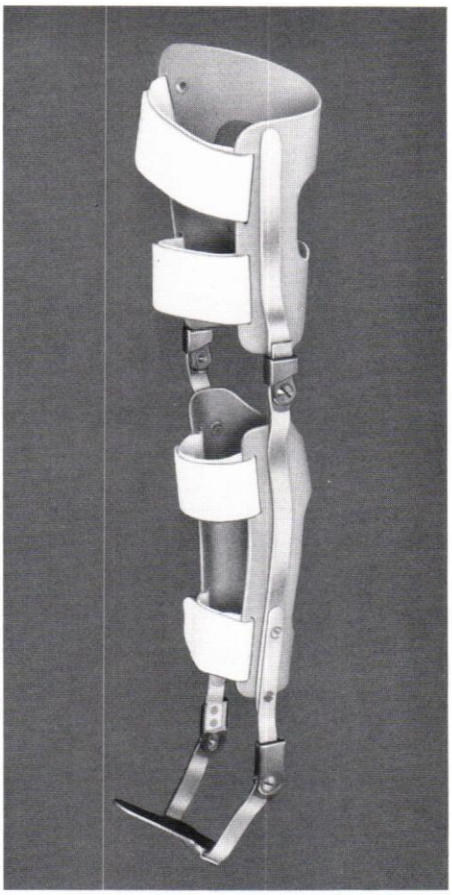
Jay Portnow, M.D., Ph.D.
Chief, Physical Medicine
& Rehabilitation
Braintree Hospital

George Boutross, C.P.O.
Director/Orthotics and
Prosthetics
Braintree Hospital

[1] O'Toole, D.M. and DeCarteret, D.R., "A Commentary on the New England Preparatory Prosthesis," *Orthotics and Prosthetics*, Summer, 1987, pp. 29–31.







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17K35 Caliper Plate, stainless steel, lengths: 90 mm for size 6, 105 mm for size 5

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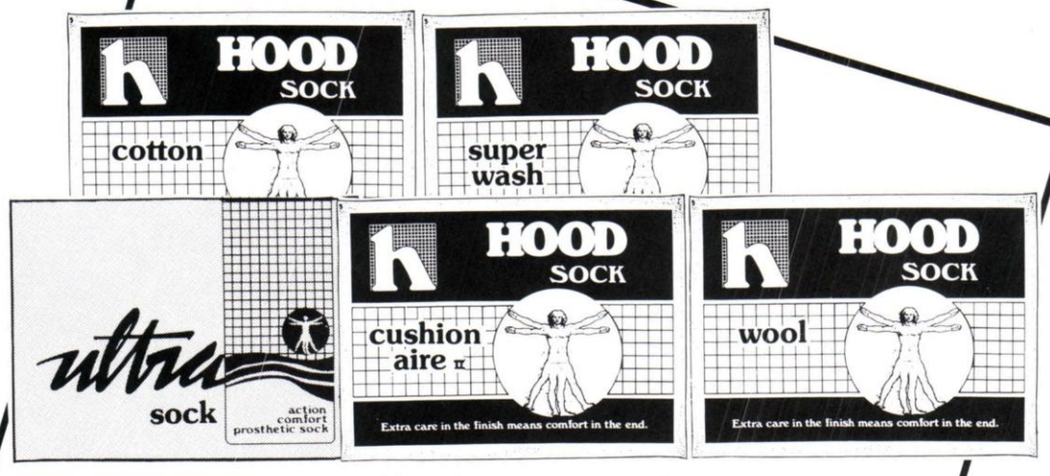

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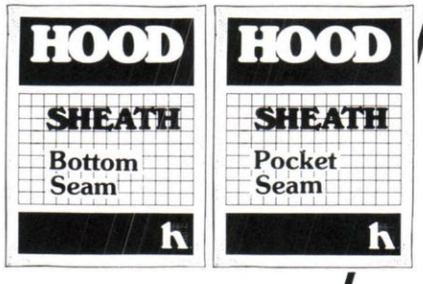

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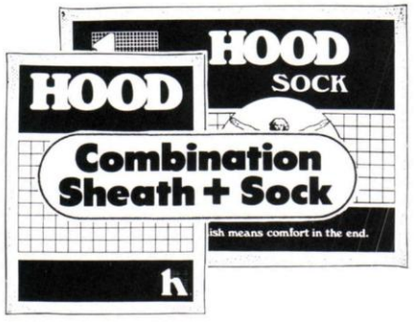

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Time has proven the value of the **C.D. DENISON TWO POSTER CERVICAL COLLAR,** not only as a post-operation support, but also in non-surgical application, when a more positive positioning control is desirable.

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The **C.D. Denison Two Poster Cervical Collar** is available through your local orthotist on request.

Orthotics and Prosthetics, Volume 41, Number 3, pp. 14–21.

Unreasonable Risk

Dale Berry

INTRODUCTION

As in any profession, employees in any O/P laboratory are at a constant risk to injury in one way or another every day. Be it slipping on a wet floor or cutting a finger with a knife, these risks are accepted because they are remote, and the cause and effect of the risks are obvious.

Unreasonable risk is yet another matter. Unreasonable risk without knowing it can lead to possible and probable injury. Therefore, it is important to recognize and understand the potential risks to which the O/P profession is exposed and to learn to avoid them through safe practices and work habits.

This presentation is not an editorial or opinion of the author, it is an accumulation of government† occupational health and safety documentation and safety data sheets from specific manufacturers. Whenever possible, direct quotes are used from the documents listed in the references.

An important factor to consider is that all the materials and chemicals reviewed present virtually no health risks if handled properly. This guideline is intended as a source of information. It does not attempt to present all data; rather, it presents pertinent information and data in summary form.

†Geneva, Switzerland, International Labor Office. Washington, D.C., NIOSH/OSHA Office.
Hamilton, Canada, Canadian Center for Occupational Health & Safety.

FIBERGLASS

Fiberglass is available in many forms. The composition and physical properties depend upon the application. For reinforcing plastics, the fibers are usually 6 to 9 micrometers in diameter. A common binder used in fiberglass weaving techniques is phenal-formaldehyde. Fiberglass is flexible, resistant to heat and chemicals, and not soluble in any solvent.

Health Hazards

Skin "Fiberglass dust and filaments can cause considerable skin irritation characterized by itching, redness and swelling. The larger, more rigid, the fiber, the greater the irritation. There is apparently no allergic reaction to fiberglass. Adverse dermatitis effects are reversible if exposure ceases."[1]

Lungs "Inhalation of fibrous glass dust does not appear to have caused major health problems in workers. Long exposure to dust *did not* cause harmful effects as measured by x-ray examination of lungs, tests of lung function, mortality (death rates) or cancer incidence."[1]

"In some studies, workers had excessive rate of chronic bronchitis and emphysema. The adverse health effects were said to be non-disabling and reversible if exposure ceased."[1] Inhalation of fibrous glass dust by experimental animals did not cause fibrosis (growth of scar tissue in the lungs) or cancer.[1] Fibrosis is not regarded as a human hazard of these fibers.[2]

Eyes Loose airborne filaments may cause a potential hazard and subsequent eye injury. "Needle sharp fragments of unattended fiber may cause penetration and eye injury hazard so eye protection is necessary."[2]

Cancer "There is considerable evidence that *inhalation* of fibrous glass dust does not cause cancer in workers or experimental animals."[1]

Protective Equipment

- Eye Glasses
- Particle Dust Mask
- Clean Lab Coat
- Latex Gloves

Storage and Handling Use a well ventilated room with good lighting. It is recommended to cover fibrous glass with plastic to prevent filaments from becoming air borne.[2]

First Aid and Emergency Procedures Upon development of a rash or skin irritation, discontinue handling of fiberglass and seek medical attention. In event of a loose filament entering the eye, do not attempt to wash away. Seek immediate medical attention.[2]

Fire Fighting Fiberglass is a non-combustible and does not pose a fire hazard.[2]

CARBON (GRAPHITE)

Carbon is derived from two sources: natural and synthetic. Whereas natural carbon can cause the disabling lung disease "pneumoconiosis," synthetic carbon, a petroleum product, is considerably safer. Synthetic graphite is the choice used in the orthopaedic industry.

Health Hazards

Skin Dust and filaments may cause minor skin irritation. The adverse conditions are reversible if exposure ceases.[3]

Lungs Synthetic carbon produces minor irritation of the respiratory tract, but no lasting tissue damage.[3]

Eyes Loose airborne filaments may cause a potential health hazard and subsequent eye injury.[3]

Cancer No data was obtained discussing the relation of cancer and synthetic graphite.

Protective Equipment

- Eye Glasses
- Particle Dusk Mask
- Latex Gloves
- Clean Lab Coat

Storage and Handling Use a well ventilated room with good lighting. It is recommended to cover carbon fabrics with plastic to prevent airborne filaments.[3]

First Aid and Emergency Procedures Upon development of a rash or skin irritation, discontinue handling of synthetic graphite and seek medical attention. In the event of loose filaments entering the eye, do not attempt to remove. Seek immediate medical attention.[3]

Fire Fighting Carbon poses no significant fire or explosion hazard unless airborne concentrations are extremely high.[3]

KEVLAR®

Kevlar® is a Du Pont trade name for a class of aromatic polyamide fibers.

Health Hazards

Skin "In human patch tests, no skin irritation was observed after 48 hours of continuous contact."[4]

Lungs "Based on animal insufflation tests, respirable dust from Kevlar® produces what would be considered a typical lung reaction to a nuisance dust particulate."[4]

Eyes Loose airborne filaments may cause a potential health hazard and subsequent eye injury.[4]

Cancer No material was obtained by the author discussing the relationship of Kevlar® and cancer.

Protective Equipment

- Eye Glasses
- Particle Dust Mask
- Latex Gloves
- Clean Lab Coat

Storage and Handling Use in a well ventilated and well lit room. Kevlar® should be stored under a plastic cover to discourage any airborne filaments.[5]

First Aid and Emergency Procedures In the event of airborne filaments entering the eye, do not attempt to wash away; seek immediate medical attention.[4]

Fire Fighting Kevlar® is a fire retardant and does not support combustion.[5]

ACRYLIC (Methyl-Methacrylate) (CH_2 OCH_3 $COOCH_3$)

Acrylics encompass a large variety of resins and plastics that are slightly soluble in water, very soluble in organic solvents, and classed as a colorless liquid with a fruity smell. Although there are many blends and brands of acrylic resins and plastics, they are all based as a methyl-methacrylate and can be treated equally with concern to health and safety.

Health Hazards

Skin Methyl-methacrylate is allergenic and can cause dermatitis on prolonged exposure to the skin.[6]

Lungs Overexposure to methyl-methacrylate may cause irritation to the nose, throat, skin, and eyes. It is considered a narcotic and may also cause drowsiness and at very high levels, unconsciousness.[7]

Eyes Extreme care should be taken to ensure no contact is made with liquid acrylic and the eyes. Dust generated from polymerized acrylic should be avoided.[6]

Cancer "No data are thus far available for the evaluation of carcinogenic power to humans of acrylic resins."[6]

Protective Equipment

- Eye Glasses
- Latex Gloves
- Lab Jacket (long sleeve)
- Dust Mask

Storage and Handling Liquids should be stored in a no smoking room at room temperature and not exposed to sunlight. A well ventilated room should be maintained.[7]

"Since its (acrylic) odor threshold is below the permissible exposure limit, and since irritation occurs within three times the permissible exposure limit, methyl-methacrylate is treated as a material with good warning properties."[7]

In the event of a spill of excessive amounts of acrylic, "Persons not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed."

1. Remove all ignition sources.
2. Ventilate area of spill or leak.
3. "For small quantities, absorb on paper towels. Evaporate in a safe place (such as a fume hood). Allow sufficient time for evaporating vapors to completely clear the hood duct work. Burn the paper in a suitable location away from combustible materials. Large quantities can be collected and atomized in a suitable location away from a combustible chamber. Methyl-methacrylate should not be allowed to enter a confined space, such as a sewer, because of the possibility of an explosion."[7]

First Aid and Emergency Procedures

Eye Exposure "Wash eyes immediately with large amounts of water, lifting the

lower and upper lids occasionally. Get medical attention as soon as possible."[7]

Skin Exposure "Promptly flush the contaminated skin with water. If clothing is soaked, remove immediately and flush the skin with water. Clothing should not be re-worn until all the acrylic is removed. If there is any skin irritation, seek immediate medical attention."[7]

Overexposure If large amounts are inhaled, remove the person to fresh air at once.[7]

Swallowing In the unlikely event of swallowing liquid acrylic, get medical attention immediately. If it is not available, get the afflicted person to vomit. Do not induce vomiting to an unconscious person.[7]

Fire Fighting "Methyl-methacrylate will ignite at 421°C (790°F). It can be extinguished with dry chemical foam or carbon dioxide. During decomposition toxic gases and vapors (such as carbon monoxide) may be released."[7]

POLYESTER

There are many different types, brands, qualities, and materials referred to as polyester (e.g., resin, tape, Mylor, Dacron, Acylid paint).

For use in orthopaedics, the material technically is polyester resin in styrene solution. Styrene is a reactive monomer, clear and colorless, oily liquid. It has a sharp sweet odor and is a necessary consideration when evaluating the hazards and safety of polyeser resin as used in laminating.

Health Hazards

Skin Contact with the skin can cause dermatitis and dissolve skin oils.[13]

Lungs "Brief exposure to high concentrations of styrene vapor can cause irritation of the nose, throat, and lungs. Prolonged exposure to high concentrations of vapor (10,000 ppm for ½ hour or 2,500 ppm for 8 hours) can cause paralysis of the central nervous system and result in unconsciousness and death. Lower concentrations of vapor can cause mild to moderate irritation."[12]

"The most common health effects of mixing, shaping, and curing styrene-modified polyester resins relate to carcosis (headache, dizziness, drowsiness, anorexia, vomiting) and mucosal irritation (burning of eyes, sneezing, coughing) from styrene vapor and to the dermatitis potential of the components. Odor and irritation help to discourage extended exposure."[11]

Eyes Liquids and vapors are irritating to the eyes and contact and exposure should be avoided.[13]

Cancer "Styrene produced lung tumors in mice following oral administration. Death from leukemia and lymphoma (cancers of the white blood cells) have been reported in workers exposed to mixtures of styrene, benzene, and butadiene. The cancers cannot be attributed to styrene alone. As well, there is evidence that styrene has caused chromosome aberrations and other genetic damage in workers: Genetic damage may indicate an increased risk of cancer. These results are cause for concern that styrene may increase the risk of cancer in humans."[12]

Reproductive Effects "There is one report of an increased incidence of birth defects among women working in plastic boat factories. The women were exposed to styrene, polyester resins, organic peroxides, and solvents."[12]

Protective Equipment[13]

- Eye Glasses
- Clean Lab Coats (long sleeve)
- Latex Gloves

Storage and Handling Polyester resin and styrene solutions should be stored in a dry, cool place away from strong oxidizing agents. Good housekeeping should be

maintained in a no smoking room with good ventilation.[13]

First Aid and Emergency Procedures

Eye Contact Flush eyes immediately with water; seek immediate medical attention.[13]

Skin Contact Clean skin with nonirritating agents such as waterless hand cleaners or an equal mixture of acetone and sulphonated oil cleaner. Never use req solvents to clean the skin. If a rash develops, seek medical counsel.[13]

Fire Fighting Polyester resin in styrene solution will burn if heated strongly or exposed to flame or sparks. It emits acrid, toxic fumes when burning or decomposing.[12]

DIMETHYLANILINE ($C_6 H_5 N(CH_3)_2$

This is a straw to brown colored liquid with a characteristic ammonia-like odor used to promote the curing of thermosetting polyester resin.

Health Hazards

Skin Dimethylaniline affects the body by contact with the skin. "Overexposure to Dimethylaniline may affect the ability of the blood to carry oxygen. Dimethylaniline has been shown to cause methemoglobinemia."[14]

Lungs "Dimethylaniline absorption, whether from inhalation of the vapor or by skin absorption of the liquid, causes anoxia due to the formation of methemoglobin. It is said to be less toxic than aniline as regards to methemoglobin formation, but more of a central nervous system depressant."[14]

Eyes Avoid eye contact with liquid.[14]

Cancer No data was obtained discussing the relationship of Dimethylaniline and cancer.

Protective Equipment

- Eye Glasses (splash proof)
- Latex Gloves
- Clean Lab Coat (long sleeve)

Storage and Handling Store in a cool well ventilated area away from sparks and heat. Ensure containers are well sealed and contamination is not possible. Store Dimethylaniline in its original container.[14]

First Aid and Emergency Procedures

Eye Exposure Wash eyes immediately with large amounts of water; seek immediate medical attention.[14]

Skin Exposure Wash contaminated skin immediately with soap or mild detergent. If soaked into clothing, remove and do not re-wear until properly laundered. If rash or irritation occurs, seek medical attention.[14]

Breathing In event of overexposure to fumes, expose the person to fresh air and seek medical attention.[14]

Swallowing In this unlikely event, have the person drink large amounts of water, then try to make the person vomit. Do not make an unconscious person vomit. Seek medical attention.[14]

Fire Fighting Ignition temperature is 371°C (700°F).[14]

Contact with strong oxidizers (Benzoyl peroxide) may cause explosion or fire. Contact with strong acids may cause violent splattering. During decomposition, hazardous products of toxic gases and vapors may be released. Extinguish any fire with foam, dry chemical or carbon dioxide.[14]

BENZOYL PEROXIDE ($C_6 H_5 (CO_2)_2$)

Benzoyl peroxide is used as a paste to catalyze thermosetting polyester resins and as a powder to cure acrylic resins. The major hazards are fire and explosion; health hazards are uncommon but not negligible.

Health Hazards

Skin Benzoyl peroxide is used in medicine for treatment of acne. It may cause dermatitis and skin irritation to more sensitive skin.[9]

Lungs Fumes may cause nose and throat irritation.[9]

Eyes Avoid any contact of Benzoyl peroxide or fumes with the eyes.[8]

Cancer "(Benzoyl Peroxide) when repeatedly applied to the skin of mice, was not a carcinogenic."[8]

Protective Equipment

- Eye Glasses
- Latex Gloves
- Clean Lab Coat (long sleeve)

Storage and Handling Benzoyl peroxide should be stored in its original containers in a cool, ventilated place apart from other flammable or reactive materials. It should be protected from flame, static electricity sparks or sources of heat such as steam pipes, radiators, or direct sunlight. Care must be taken not to contaminate Benzoyl peroxide. Empty Benzoyl peroxide containers should be destroyed. Keep the lid tightly on the container at all times.[8]

First Aid and Emergency Procedures

Eye Exposure Wash eyes immediately with large amounts of water. If irritation persists after washing, seek medical attention.[8]

Skin Exposure Wash contaminated skin immediately using soap or mild detergent. If irritation persists after washing, seek medical attention.[9]

Swallowing In this unlikely event, have the person drink large amounts of water, then try to get the person to vomit. If the afflicted person is unconscious, seek immediate medical attention.[8]

Fire Fighting Benzoyl peroxide ignites at 103°C (217°F). "It is a powerful oxidizer and contact with wood, paper, and other combustible substances may cause fire."[9]

Hazardous decomposition products of toxic gases and vapors may be released in a fire involving Benzoyl peroxide. "In case of a fire where amounts of Benzoyl peroxide are stored, water should be applied by sprinkler system or by a hose at a safe distance, preferably with a fog nozzle. Portable extinguishers should not be used."[8]

POLYURETHANE (TWO PARTS: A & B)

Polyurethane foams are a wide class of industrial chemicals in many forms and qualities. Polyurethane foams are formed by the reaction of polyals and isocyanates. Isocyanates are a family of highly reactive chemicals and are the key ingredient and backbone to polyurethane foam. The most common isocyanate is TD1; others in wide use are MD1 and PAP1.

When determining the safety and health hazards of polyurethane foams, an evaluation of isocyanates is imperative. This data refers to flexible foams in liquid, solid or cured states.

Health Hazards

Skin Polyurethane chemicals can cause dermatitis. Avoid contact with skin at all times. Polyurethane dust is very irritating to the eyes. Avoid contact at all times. Isocyanate vapor, liquid and dust will react with the moisture of your skin and dry out the cutamion tissue.[18]

Lungs The greatest potential risk to you when you use polyurethane chemicals comes from breathing fumes, mist, or dust. You must avoid breathing these chemicals.

Eyes Isocyanate vapor, liquid, or dust will react with the moisture of your eyes.[15]

Cancer "In 1978, Thyssen et al., of Germany published the paper, 'Inhalation Studies with Polyurethane Foam Dust in

Relation to Respiratory Tract Carcinogenesis.' Male and female Sprague-Dawlwy rats were exposed to freshly generated polyurethane foam dust, in concentrations averaging 8.65 mg/m3 air, for 6 hours daily, 5 days a week, over a period of 12 weeks. No indication of a carcinogenic effect of the inhaled dust on the respiratory tract could be established. However, any dust particles that enter the lungs can cause some risk."[15]

Protective Equipment

- Eye Glasses
- Clean Lab Jacket (long sleeve)
- Latex Gloves
- Respirator or Well Ventilated Room

Storage and Handling Store indoors in a well ventilated no smoking room away from heat sources and sunlight. Containers should be kept well sealed, because the chemicals react adversely to water and moisture in the air to produce carbon dioxide gas. If trapped in a closed container, the gas can build pressure to explode or spray chemicals upon opening. If a polyurethane container is bulging, wear proper safety equipment and slowly unscrew the cap to allow the gases to escape. Cured foams are to be handled with equal care. Dust particles should not be exposed to skin, eyes or lungs, and dust should not be allowed to accumulate in any quantity. Cured foam should only be used in non-smoking areas.[19]

First Aid and Emergency Procedures

Eye Exposure Flush eyes immediately with large amounts of water for 15 minutes; seek immediate medical attention.[19]

Inhalation Leave the area, breathe pure oxygen if possible; seek medical attention immediately.[19]

Skin Exposure Clean contaminated area with clean towels and mild detergent or soap. Then wipe with rubbing alcohol, do not use solvents or acetone. If a rash develops, seek medical attention.[19]

Prevent foam dust from skin contact, body moisture will be absorbed and dry the skin.[19]

Swallowing Isocyanates are not very poisonous, but they will react with the lining of your throat and stomach and can cause damage to these tissues.[16]

In this unlikely event, have the affected person drink large amounts of water and then induce vomiting, repeat vomiting two or three times, seek immediate medical treatment.[19]

Cured Foam or Dust The foam will absorb and react with the mucous membrane in the throat and trachea, and will adversely react with the stomach lining. Never eat or drink in areas where polyurethane dust or vapors are present.[18]

Fire Fighting Polyurethane is extremely flammable in all forms and states. "Flexible polyurethane foams are more hazardous than rigid polyurethane or polyisocyanurate foams. Unlike rigid foams, flexible foams, once ignited, may degrade rapidly and melt to a combustible liquid which may add to the fire involvement. Rigid foam, if ignited, burns dry and in place."[15] Heat, friction and flame will ignite polyurethane. Upon decomposition, a thick smoke containing a *very* toxic gas and vapors is released.[18]

CONCLUSION

As with most industrial chemicals and materials, perhaps the greatest factor which contributes to potential risk is ignorance or willful disregard of suppliers' recommendations and/or regulatory agencies' requirements. Understand the potential risks—learn to avoid them.[††]

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The Talus Control Ankle Foot Orthosis

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Lynne Logan, M.A., P.T.

INTRODUCTION

Ankle/foot management in orthotics has had a variety of health care professionals concerned for many years. The development and use of polypropylene altered the direction of orthotics. Further realization of the capabilities of thermoplastics is leading to more advanced systems in orthotics. The orthosis presented in this article is an example of cooperation between practitioners in related medical fields, adaptation of available materials to the management of ankle/foot disorders, and the development of a system of design and fabrication to accommodate the diagnostic and treatment methods used under the direction of Franziska Racker, M.D., Physiatrist and Medical Director for The Special Children's Center, Ithaca, New York.

Review of the anatomy and physiology of the foot, evaluation, short leg cast boots and orthotic treatment of the unstable ankle/foot will be discussed. X-ray and gait studies of this new type of orthosis will document its feasibility.

ANKLE/FOOT EVALUATION

Physical evaluation of a vast number of so called flat feet, toe walkers, and other anomalies have revealed a stable medial longitudinal arch component, in most cases, when the talus and calcaneus are secured in neutral alignment. Furthermore, when the talus and calcaneus are in the neutral position, the arch is maintained without displacing the muscular and ligamentous structures of the foot and without additional plantar surface support.[5] Neutral foot position is determined by grasping the talus, at the talocrural joint, between the thumb and the index finger. The prominences should feel equal on either side of the dorsum of the foot. If hand pressure or weight bearing do not result in collapse of the arch until the talus is allowed to deviate from neutral, it is our contention that some support other than plantar surface pressure should maintain neutral foot position.

USE OF POSTERIOR AND PLANTAR SURFACE CONTROL

The posterior solid ankle foot orthosis (PSA) has been typically used for various ankle and foot deformities which require additional stabilization of the lower leg (i.e., the equinus or calcaneal foot). When this stabilization is not necessary (i.e., excessive pronation, supination, metatarsus adductus), foot appliances such as the supramal-

leolar orthosis (SMO),[7] low profile orthosis or UCBL orthosis have traditionally been used (Figure 1). These orthoses rely primarily on plantar surface pressure to realign the structures of the foot and ankle. Clinically it has been noted that the patient often complains of pressure on the medial border with a pronated foot or on the lateral border with a supinated foot. Subjective evaluation can often detect little correction of the deformity as the patient actually continues to malalign his foot inside the orthosis. Another measure of poor foot position is the "dirty heel syndrome" in which the inside heel area of the orthosis is dirty and dusty suggesting that the calcaneus is not maintained inside the appliance and indicates that the inferior aspect is not a weight bearing surface. Additions of ankle straps or tightly laced high topped shoes do not seem to alleviate this problem although they make the problem less obvious by obscuring the view. Extra padding and supports often increase pressure or merely disperse it over a greater area. X-ray studies of the calcaneus inside a PSA show that it easily slips into varus or valgus and thus does not maintain that very important structural component of the ankle.[5] Also, due to the bulk of the PSA, the patient often must wear a shoe at least one size larger than his actual foot. If then, the foot has not

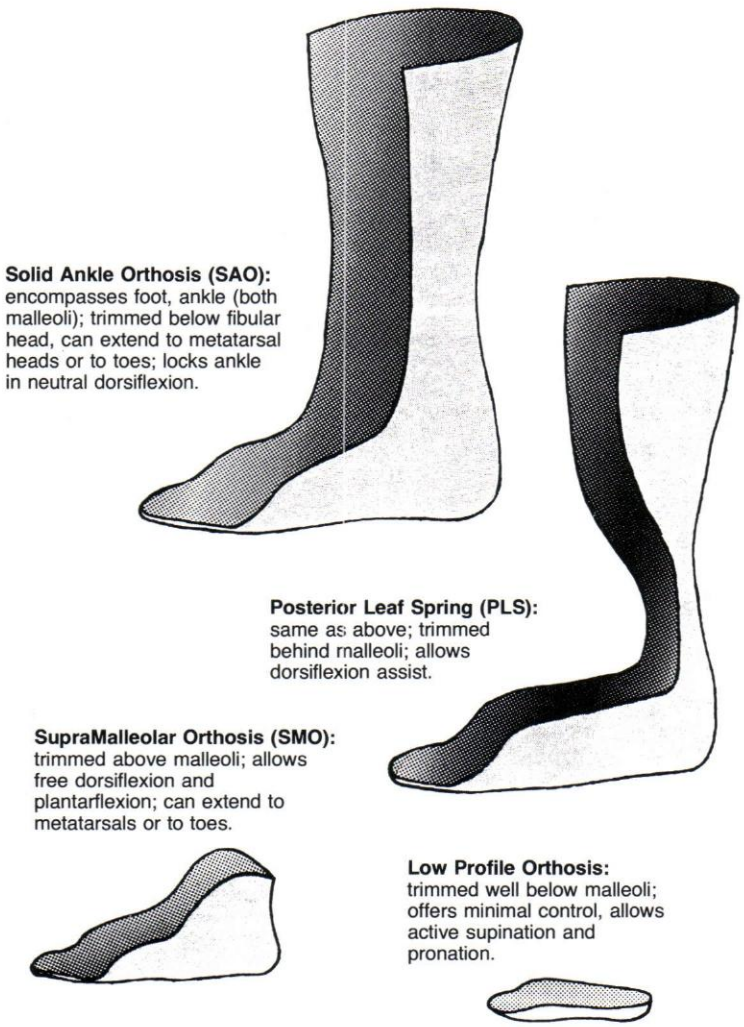


Figure 1.

been well corrected in the orthosis, the musculature surrounding the joints continues to have poor biomechanical advantages. They must follow the laws of physics and their intended action over a part is often changed to a different action, which reinforces the cycle of abnormal joint position and motion.[6] An example would be the extensor hallucis longus slipping laterally (toward the midline of the foot) over the great toe when the foot is in excessive medial weight bearing causing this muscle to become a toe adductor rather than extensor. Hallux adductus is a common side effect of pronated feet in both young and old patients. The earlier these symptoms are addressed, the better the chances of preventing more serious foot disorders.

USE OF SHORT LEG CAST BOOTS AND DEVELOPMENT OF THE T.C.-A.F.O.

The use of short leg cast boots has been an adjunct to the management of poor foot position in children demonstrating varying degrees of abnormal tone.[1,2] These casts attempt to provide control of the talus and calcaneus, maintenance of neutral ankle/foot alignment, and approximately normal sensory feedback during stance. Securing the ankle/foot in neutral alignment places the muscles in their best biomechanical advantage, essentially reprogramming the child's kinesthetic awareness.[3] Unfortunately cast boots are bulky, heavy, and unattractive.

The orthotist, although sought out for advice and evaluation, is essentially excluded from the fabrication of cast boots. This provided an opportunity for the orthotist author to observe the effects of cast boots on foot control and ambulation. These observations led to research and the development of an orthosis which augments the positive features of cast boots while incorporating the light weight and cosmetic features more commonly associated with thermoplastic ankle foot orthoses.

When evaluating the foot to determine the possibility of fabricating short leg cast boots, the clinician (therapist, orthotist, etc.) should note muscle tone, range of motion, tendency toward varus or valgus at the subtalar joint, what happens to the forefoot when the hindfoot is corrected and associated reactions of the foot and body as a whole. In both weight bearing and non-weight bearing conditions, the foot is positioned as closely to neutral as possible. A neutral talus is achieved as previously described and the calcaneus is aligned under the tibia. The cast boots maintain this position by total foot contact.[7] Frequently, the next step in lower extremity management is the use of polypropylene ankle foot orthoses. As has been previously noted, the use of plantar surface correction does not appear to maintain subtalar control. At the Special Children's Center, the talus control ankle foot orthosis (TCAFO) or talus control foot orthosis (TCFO) has been a promising adjunct to the total therapeutic management.

The TCAFO was designed to augment the results of cast boot management. It is a posterior donning orthosis (Figure 2) which does not require the wearer to have the ankle/foot in a neutral position before the shoe is applied. However it is desirable to mobilize the ankle/foot prior to donning the orthosis. The anterior design allows the orthosis to serve as a dynamic device gradually pulling the foot into the desired ankle/foot alignment (neutral dorsiflexion). The talus is secured in neutral alignment and deviation of the calcaneus is resisted by an extension of plastic in that specific area. The support mechanisms within the shoe are essential to provide resistance against deviation of this plastic extension. Pads may be applied to increase the control of the calcaneus medially or laterally as needed. This extension is wedged between the counter of the shoe and the soft tissue of the foot. The orthosis should not be worn without a shoe for ambulating. However as a night time treatment, to augment the effects of day time wear, the orthosis may be effective. A laced shoe or good low cut sneaker or tennis shoe is adequate for weight bearing conditions.

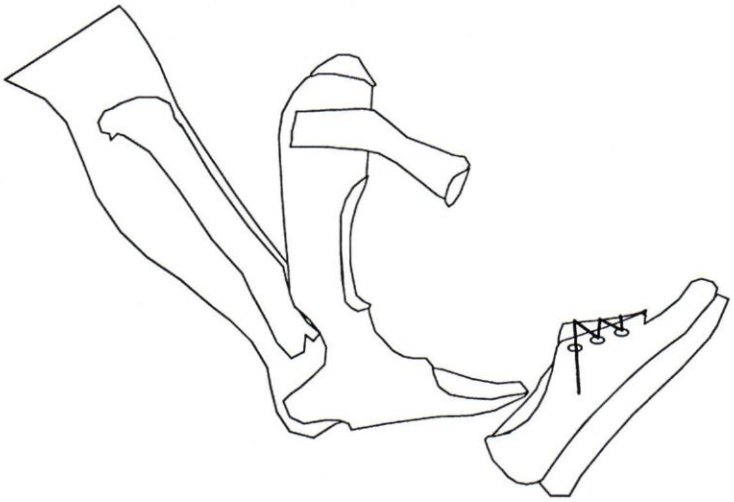


Figure 2.
1. Apply orthosis to foot only.
2. Apply shoe tied securely.
3. Slowly draw the tibial section of the orthosis to the leg and attach strap.

Follow-up visits are minimal after the first month. During the first month, if the patient is wearing the orthosis regularly, the medial malleolus or navicular area may show signs of excessive pressure. This is resolved by applying a firm pelite pad to the distal lateral calcaneus. The objective of this pad is to re-establish control of the calcaneus following dissipation or repositioning of fatty tissue in that area.

The talus control AFO has thus far proven effective in stabilizing the talus, the talocrural joint and the calcaneus. It is, however, not the only method of management used by our clinic team. To determine whether a patient is a candidate for the TCAFO or not he/she should:

- exhibit a stable arch when the talus and calcaneus are secured in neutral normal alignment.
- have an active, supportive family.
- be monitored by a team of persons knowledgeable in the fitting and followup of the TCAFO.

Many patients have been fitted successfully with the talus control ankle foot orthosis. Several have been fitted and refitted to achieve the desired results. Initially it was thought that the original trim lines would be adequate, to provide floor reaction, but we soon found it necessary to encapsulate the malleoli, and add channels or composite in order to meet this requirement. In all cases the achievement and maintenance of neutral leg, ankle, and foot alignment is the goal. Our team realized that we were trying a new approach in foot management and that failures were inevitable. It was necessary to develop a system of measuring and modifying to minimize the chances for technical or mechanical failure.

THE CASTING AND MODIFICATION PROCEDURES

The casting procedure for the TCAFO is preceeded by hands on mobilization of the foot to achieve the desired alignment. Neutral alignment is essential as plantar flexion will result in exaggerated knee extension. Similarly dorsiflexion will result in a crouch gait. Neutral position, in this procedure, is achieved with the patient seated and supported so that minimal weight is on the foot. The desired alignment of the foot should not deviate because of the weight of the foot/leg.

Meticulous care is taken to conform to all measurements taken during the measuring and casting session. The "rule of thumb" had been to follow the negative impression when in doubt but that method simply will not work when fabricating the TCAFO. When care is taken in the measurement session, these measurements should be and have been used to correct a poor positive model with excellent results. It is not always possible to get an ideal impression,

but, in our experience, it is almost always possible to obtain good measurements.

GAIT ANALYSIS

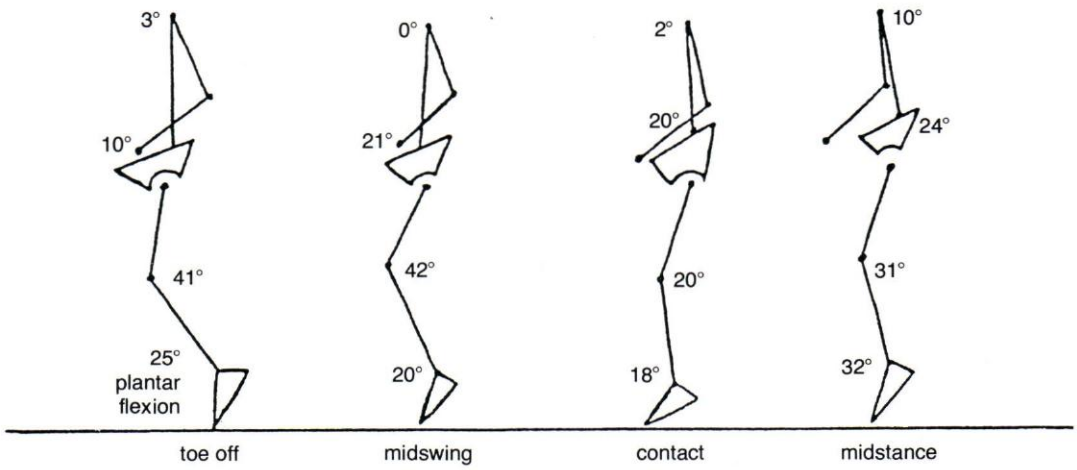
In order to fully evaluate the effects of the TCAFO in quantitative terms, an analysis of gait cycle is indicated. Studies have shown that the parameters of ambulation can be more fully appreciated by recording and analyzing data obtained through high speed photography, electromyography, dynamic peizoelectric force plate, and foot switches.[8,9]

The authors, in conjunction with the Ithaca College School of Physical Therapy, developed a pilot study to research the complex pattern of movement that occurs during ambulation. This was done by comparing gait cycles and using two different types of lower extremity orthoses. Two children were fitted with both PSA's and TCAFO's. The positive models used to fabricate the PSA's were also used to fabricate the TCAFO's. This was done to preserve identical alignment characteristics. The patients' ages are three and four years and both have a diagnosis of cerebral palsy. One ambulates with a walker and has spastic quadraplegia. The other child ambulates independently and has spastic diplegia. Neither of the children has had any orthopedic surgery.

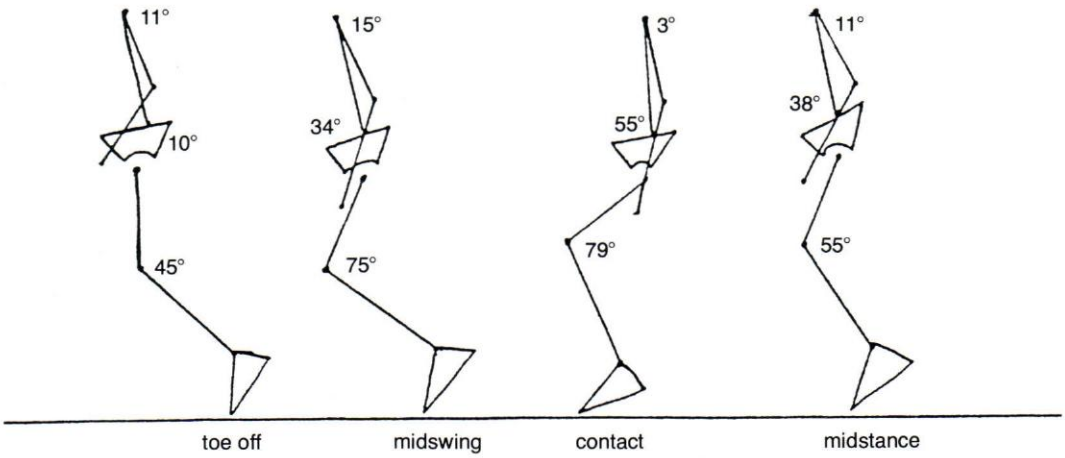
The patients were filmed, using high speed photography (60 frames per second), during barefoot, PSA and TCAFO ambulation. This information was then viewed on a Vanguard Motion Analyzer and from this, data was collected on upper body positioning, foot strike, joint angles, and changes occurring in these different phases of the gait cycle. The first subject, S., (the independent ambulator) showed remarkable improvement in general when using the TCAFO's. S. was usually a toe walker when walking barefoot (Figure 3-A). He held his arms in "high guard" with his elbows flexed and behind his trunk during most of his gait cycle. His trunk was relatively upright, but he took many small, quick steps and his gait and body appeared stiff.

With the PSA's, there was more forward trunk lean, and the elbows stayed behind the trunk. Hip and knee flexion angles increased in all phases, and the heel almost never contacted the floor during any stance phase (Figure 3-B). With TCAFO's, S. was able to stand more upright, his arms were more relaxed and down. He was able to swing his arms forward of the trunk during same leg mid-swing phase in a nice reciprocal arm motion (Figure 3-C). There was, most surprisingly, hip extension during toe off and heel-to-toe strike during the foot contact phases. Dorsiflexion of the ankle was also observed as the leg moved over the weighted foot because the TCAFO allows some movement in the ankle area. Subjectively, viewing the film, it could be noted that S.'s gait appeared more relaxed and "normal." Differences in knee, hip, and trunk angles were interesting in that the gait cycles using an orthosis followed a specific curve while the barefoot cycles were much different (Figure 4-B). Generally, there was a 15° to 40° increase towards extension in the hip and knee angles when using the TCAFO's as opposed to the PSA's. Although hip and knee flexion were more extended during the initial contact phase of the barefoot cycle, it must be remembered that S. was also walking on his toes and his arms were in back of his trunk, and therefore functionally useless in maintaining an upright position. In addition to high speed photography, a pressure sensitive electrode was placed on the heel of subject S. while walking with the PSA's and the TCAFO's. It was attached to a buzzer which was activated by heel contact. Out of ten steps, S. was unable to activate the buzzer with the PSA on. He was, however, able to do so 80 percent of the time with the TCAFO.

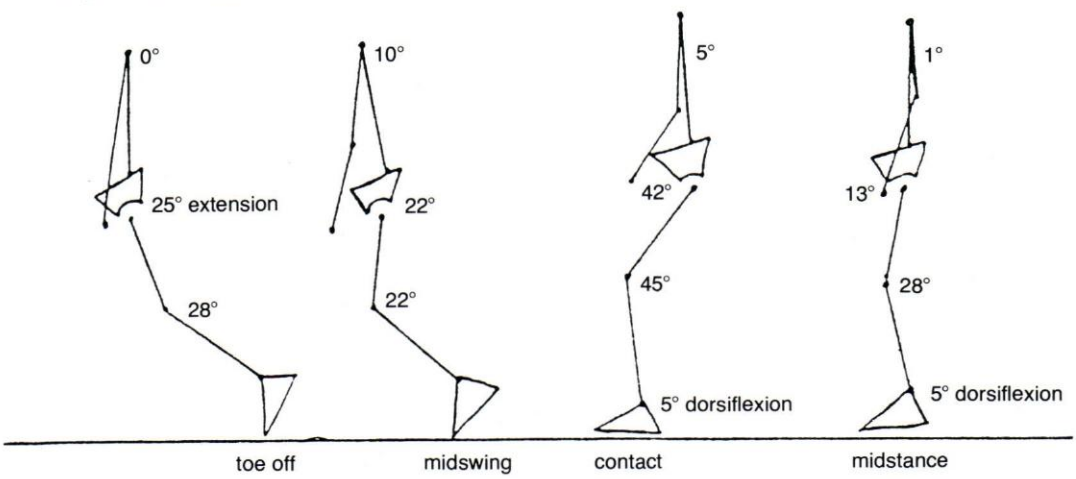
Although the changes in S.'s gait were dramatic, P.'s changes were less so, and most possibly due to overuse of his upper extremities on the walker; thus perhaps masking more pronounced gait differences with less actual lower extremity weight bearing. Again, there is a difference between curves developed with and without an orthosis (Figure 4-A). Generally, there is



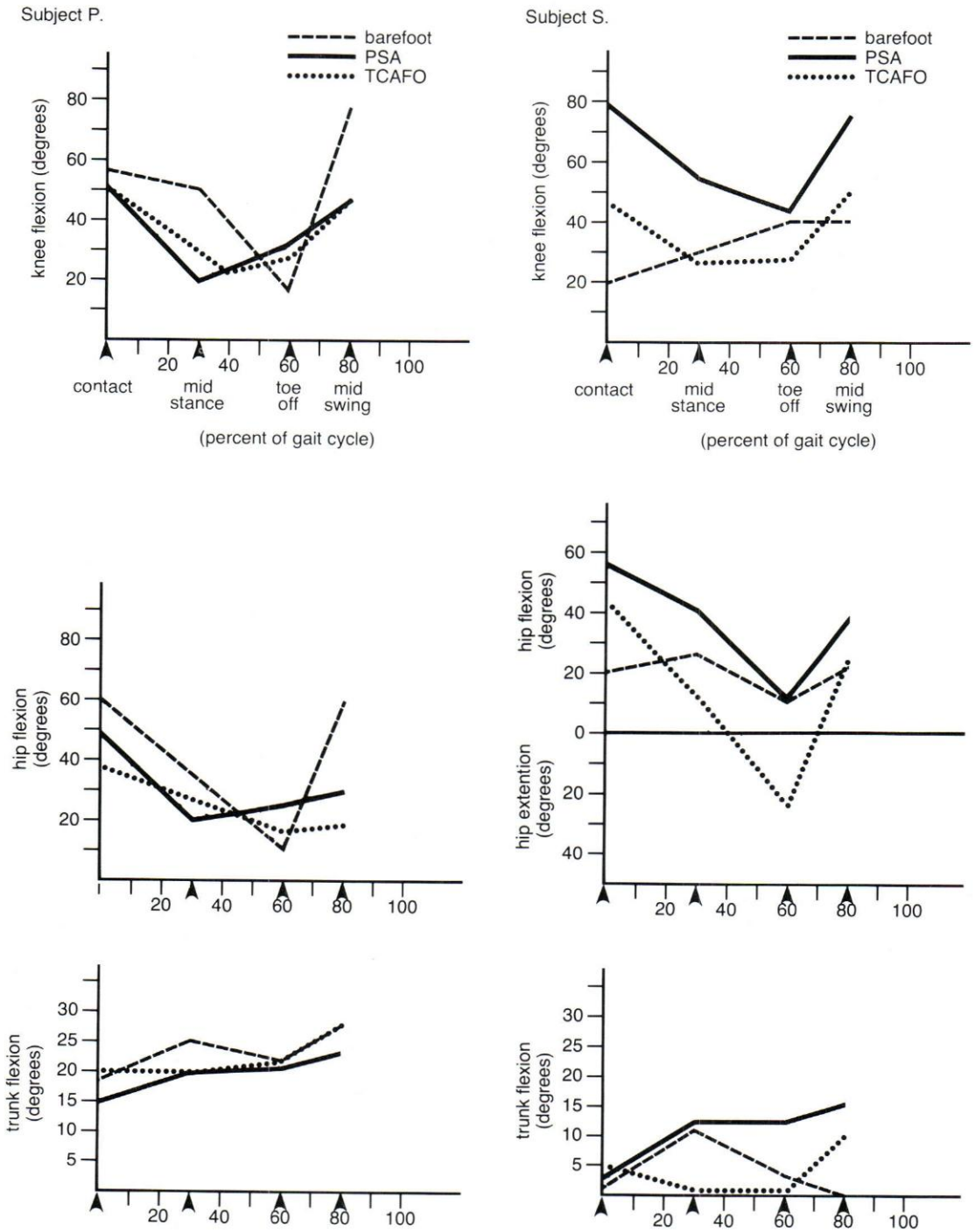
3-A. Subject S barefoot.



3-B. Subject S with PSA.



3-C. Subject S with TKAFO.



Figures 4-A and 4-B. Gait curves developed for patients P. and S.

more hip and knee extension with orthotic treatment during the gait cycle as the subject is in less of a crouched position with exception of toe off, in which the barefoot subject is seen on film to literally lurch forward to push himself through. Trunk angles change very little as P. is very dependent on the support of his walker and this does not change with or without the orthosis.

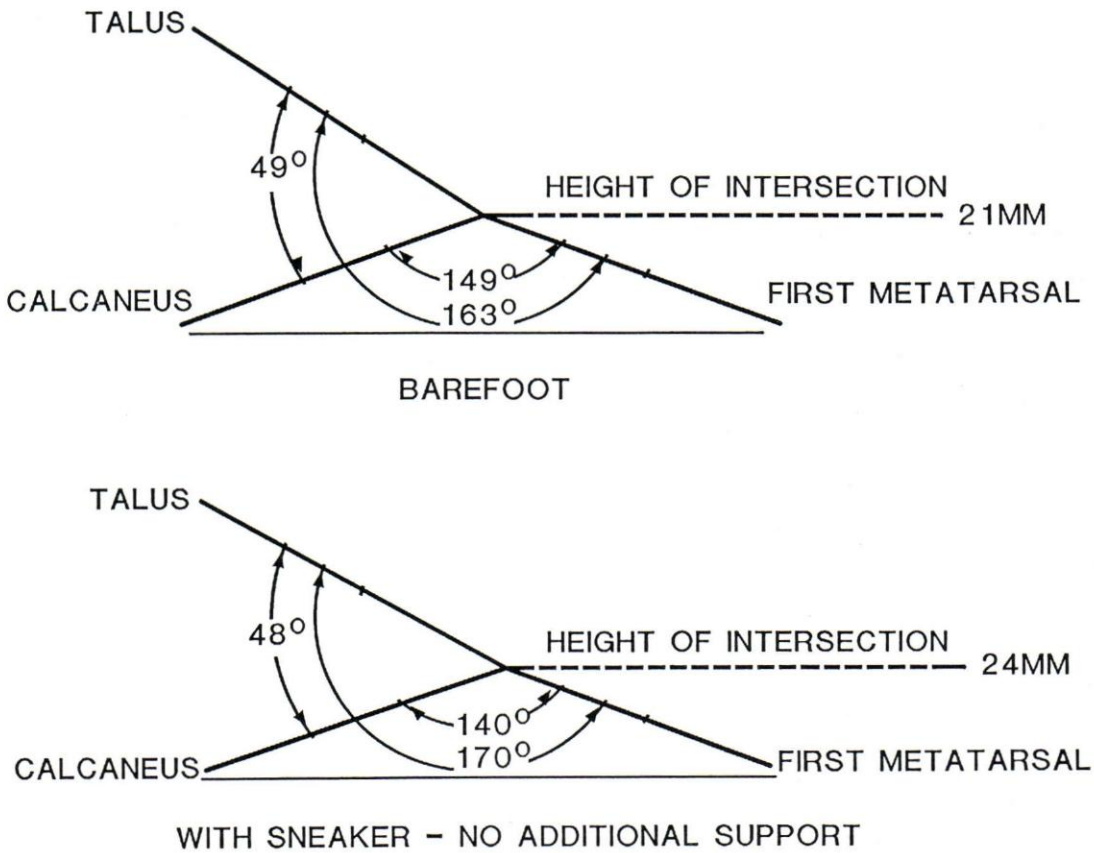
X-RAY STUDIES

In an attempt to verify that support other than plantar surface pressure should maintain neutral foot position, one patient was fitted with TCFO's and her feet were x-rayed:

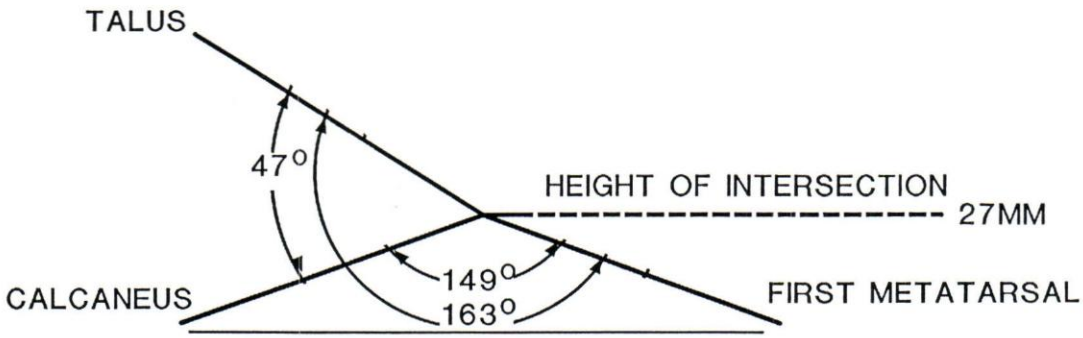
- barefoot,
- in sneakers without the use of any additional supports,
- with plantar surface (arch) supports,
- and finally with TCFO's.

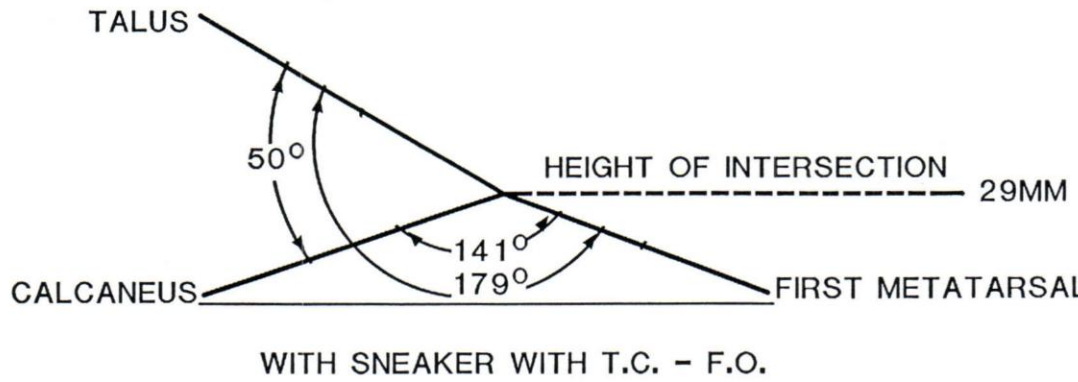
The height of the arch is measured from a point where a line representing the angular relationship of the talus to the shaft of the first metatarsal (angle T) intersects with a line denoting the comparative angle of the calcaneus and the shaft of the first metatarsal (angle C). The ideal data for a patient of this size and weight is: height approximately 30mm, angle T approximately 180°, and angle C approximately 140°.[11]

The barefoot view is represented in graph form showing a height of 21mm with an angle T of 163° and angle C of 147° (Figure 5-A). Each of the following comparatives provided change, some positive (closer to the desired heights and angles) and some negative (farther from



Figures 5-A and 5-B.





Figures 5-C (top) and 5-D (bottom).

the approximate normal height and angular measurements).

The same patient wearing a running type sneaker without additional support produced a height of 24mm, an improvement of 6mm, with no measurable change in angle T and a negative value of 3° to 150° at angle C (Figure 5-B).

The next graph highlights data taken with sneakers and plantar surface arch supports featuring a height of 27mm, an improvement of 6mm, an improvement in angle T of 5° to 168° and an improvement in angle C of 2° to 145° (Figure 5-C).

Finally, and most dramatically, the information collected from the x-ray of this patient wearing the same sneaker with the talus control foot orthosis (TCFO) revealed a height of 29mm, a positive result of 8mm, an improvement of 16° in angle T to 179°, and an improvement of 6° in angle C to 141° (Figure 5-D).

CONCLUSION

Through open and frank discussion by the entire therapeutic and orthotic management team, meetings on a regular basis, and a respect for each discipline, continued growth can be assured. Research is time consuming and costly, but the benefits can be enormous. The implications of these pilot and comparative studies are that traditional plantar surface control may often be contraindicated, or may not provide the intended support and alignment. Further research is indicated, possibly including EMG and forceplate studies, on a larger patient population. By using the myriad of modern technical advances available to us, better methods of orthotic management may be realized. Indications or contraindications for surgery may be more thoroughly explored and developed, and treatment applications may

be more representative of the growing knowledge of kinesiological and biomechanical movement parameters.

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The Dynamic Rotating Functional Knee Orthosis Concept

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James B. Montgomery, M.D.

INTRODUCTION

The human knee is a masterpiece of engineering. As the largest and most complex joint, it is one of the most vulnerable for injury. Any disruption in the structures, in or around the knee, has been shown to create a functional loss or change in the mechanics of the knee joint. Motion of the knee occurs simultaneously in three planes: frontal (coronal or longitudinal), sagittal, and transverse (horizontal). However, the motion in the sagittal plane is so significant that it accounts for most of the knee motion.

Knee orthoses have, historically, been primarily designed to impart rigidity to the knee and to restrict motion in order to provide stability. Many orthoses are fabricated either from cast impressions, tracings of the leg, or both, implying that an intimate fit with the extremity and functional stability are obtained by the custom fabrication. The external hinge joints used today follow kinematic pathways, which are considered simpler than that of the anatomic knee. Orthotic joints may be grouped into three categories as follows. First, the fixed axis type that allows for a single axis of motion. Second, the polycentric systems provide for the natural posterior motion of the femur relative to the tibia producing equal motions on each side of the joint. Third are the "anatomical" systems that attempt to duplicate the asymmetrical knee motion during flexion.[10,17]

These joints are combined with various designs of cuff configurations to produce an orthosis that will attempt to generate the relative motion that resembles that of the normal knee. However, the mismatch between the orthotic and anatomic knee joint motions still exists, causing restriction of normal range of motion, distal migration of the orthosis, and condylar separation. Even with the "Anatomical" systems, placement and maintenance of proper position are critical to function.

This paper will review the scientific basis for the development of a completely new concept in functional orthotics which allows dynamic stabilization. It will also review the kinematics of the knee during the gait cycle and outline the role of the proprioceptive reflex arc in causing disabling subluxation episodes in unstable knees.

Anatomy

In the normal gait cycle, the foot/ankle complex is supinated at heel strike and the knee is extended with the tibia in an externally rotated position.[2,12] The collateral

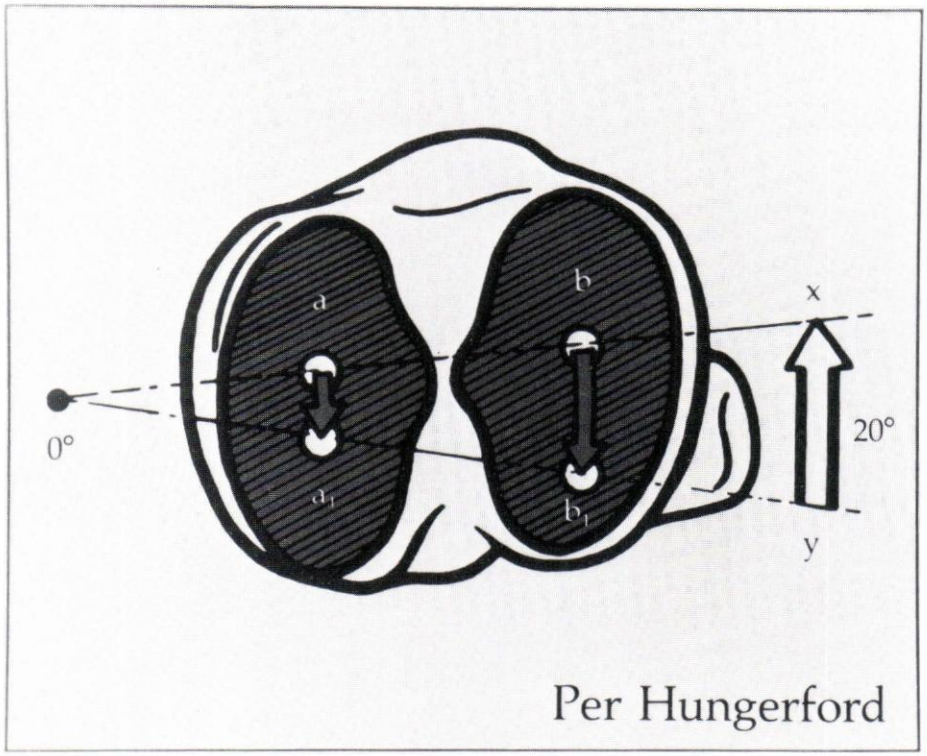

Figure 1. Automatic rotation tibial-femoral points of contact in extension (a, b) and flexion (a_1, b_1).

ligaments tighten and inhibit excessive rotation by becoming crossed in space. The foot is quickly lowered to a flat position by an eccentric contracture of the Tibialis Anterior muscle and the knee progressively flexes and undergoes internal rotation. The collateral ligaments become more vertical and so are lax, while the cruciate ligaments become coiled around each other and begin to come under strong tension. At midstance phase, maximum pronation of the foot/ankle complex is achieved and maximum internal rotation of the knee is produced. The beginning of toe off starts with the progressive supination of the foot/ankle complex and the accompanying external rotation of the tibia to push off phase.

While the amount of tibial rotation can vary between individuals, tibial rotation must always be present for the knee to function in an anatomic way. The anatomic structures of the femoral condyles, the tibial plateau, and the menisci have been well documented by Muller.[12] The lateral femoral condyle undergoes two to three times the amount of relative anterior/posterior excursion as the medial femoral condyle.[17] In fact, for the internal and external rotation aspects of the normal gait cycle of the knee to occur, the axis of rotation is actually somewhat medial to the medial tibial plateau for this excursion process (Figure 1).[7,8,16] In the last 20° to 30° of extension, the "screw home mechanism" occurs with progressive internal rotation of the femur, leading to external rotation of the tibia. Therefore, for the tibia to approach its normal degree of rotation in extension, any external orthosis applied must allow for this anatomic rotation to occur. To accommodate this, the axis of rotation of the orthosis or of the tibial component of the orthosis must be medial to the medial tibial plateau at the normal axis of rotation of the knee. Only in this location can the lateral plateau move in greater anterior/posterior distance than the medial plateau.

Discussion

It now seems evident that any form of external support, no matter how rigid, will generally be doomed to failure if judged by static testing. Two recent studies[1,4] in the *American Journal of Sports Medicine* draw two seemingly conflicting conclusions. First, no external orthosis can either replace or approach the static resistance provided by the normal anterior cruciate ligament and, secondly, the majority of patients with symptomatic anterior instability of the knee are improved by wearing any of the various orthoses. Paulos[14] states that in his study he demonstrated anterolateral tibial subluxation in every patient in every functional knee orthosis examined by the Losee test. Nonetheless, "Our subjective results show that most patients like to use the braces despite the fact that we could not mechanically show they were working." Because of the external nature of the orthoses and the large amount of soft tissues in the thigh, all orthoses will allow significant passive movement when tested in a static manner. The fact that body type has been shown to influence orthosis performance further supports this conclusion.

There are several shortcomings in the various orthoses on the market today. The most restrictive of these types are those systems with rigid tibial and femoral components linked by rigid double upright hinges. The benchmark, which most functional orthoses have been judged against, is the Lenox Hill Brace.[13] While the orthosis is totally rigid and totally custom made, it has no rotational mechanism in it, yet it is called a derotational brace. This design is rigidly fixed by double uprights to the thigh and calf. There is either no rotation allowed in the extremity, or the normal rotation takes place between the orthosis and skin interface, or the skin envelope around the leg. While the rigidity imparted by this type of orthosis would certainly increase the resistance to subluxation of the tibia and therefore provide a resistance, at the same time it resists the normal motions that need to occur during functional activity, i.e., flexion and external rotation.[9] On the other hand, the more flexible orthoses with their inherent lack of rigidity do not seem to perform as well subjectively, because less rigidity is imparted to the knee structure.

In prior studies, several key factors have been brought out about knee orthoses:

a. they improve static stiffness at low loads;[1]
b. at high static testing, all orthoses allow tibial subluxation;[4]
c. most episodes of buckling at the knee occur during low load, low force situations;[4]
d. significant forces are required to sublux a loaded knee;[6,11]
e. post injury rehabilitation does not necessarily correlate with subjective improvement of performance and symptoms when the patient is put in an orthosis.[15]

The term "low load" ligament function is defined as when the ligaments keep the correct apposition of the articular surfaces during muscle-generated function, providing for proper joint lubrication and normal contact forces. The term "high load" ligament function is defined as the ligaments providing stability in a traumatic situation where the external load occurs too rapidly for the muscles to equilibrate.

Rationale

With the above information, it is clear that other factors must be present that are responsible for the subjective improvement gained through functional support of the knee. It is our hypothesis that the major factor involved in successful orthotic care is the establishment and maintenance of the proper tibia-femur relationship prior to loading of the knee in the low load situation. All joints have a proprioceptive reflex arc that gives unconscious protection against joint injury if a load is applied in any position other than a conjugated one.[5,12] In knee joints, stretching an interarticular ligament can elicit firing from proprioceptors situated only in the ligament.[3] Therefore, whenever an unstable knee is loaded in a subluxed position, there is an immediate reflex arc that produces a muscle inhibition and subsequent

"giving way" sensation. No matter how strong the muscles are, the reflex inhibition will elicit a "giving way" episode if the joint is not conjugate.[3] However, once a conjugate joint is loaded, extreme forces are required for subluxation.[6,11] For this reason, rehabilitation is most important in the unstable knee. It is our premise that all orthoses function by helping to resist the subluxation in the low force, unloaded position, allowing a proper tibia-femur relationship to exist prior to heavy loading of the knee. This can easily explain the benefits gained from functional orthotics even in the unrehabilitated knee.

While the more rigid orthoses provide for greater rigidity, they have no ability to allow for rotation; therefore, the capability to prevent subluxation is less. During the last 20°-30° of knee extension, the tibia is undergoing a progressive external rotation as the "screw-home" mechanism takes place. Any orthosis which does not allow rotation to occur can prevent or minimize rotational excursion in terminal extension. Therefore, if an orthosis minimizes the external rotation of the tibia in terminal extension, by definition, it would be minimizing the distance of travel required to sublux the knee anterolaterally. Based on this fact, we, in conjunction with 3D Orthopedic, have designed an orthosis that dynamically produces an external rotation force that is greater as the knee extends and allows for the tibia to be held in a more reduced position during terminal extension. This allows for a greater capability in preventing subluxation prior to loading. The orthosis also provides an adjustable rigid stop to block excessive internal rotation beyond a normal degree by its rigid link to the medial upright (Figure 2).

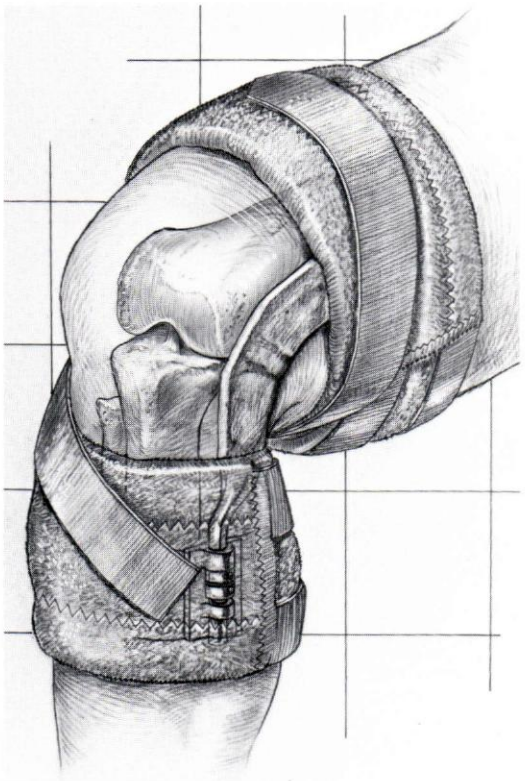

Figure 2. The orthosis provides adjustable rigid stop to block excessive internal rotation beyond a normal degree by its rigid link to the medial upright.

Summary

We feel that all functional orthoses work by eliminating or reducing knee subluxation at low loads, thereby preventing the activation of the proprioceptive arc reflex which causes disabling buckling of the knee. The term "low load" implies either passive or active forces acting upon the tibia prior to taking full body weight on the extremity, during either routine walking or high performance activity. If the proper tibia-femur relationship is maintained, the buckling phenomenon will be eliminated. This concept can adequately explain the following observations made by prior investigators: a) The orthosis is seen to increase relative knee stability, even though maximal laxity remains unchanged; b) Stability is greatly increased by loading a knee; and c) Symptoms of instability seem to be improved by increasing resistance to low forces of displacement. This implies that episodes of subluxation occur during low force, low load situations, giving rise to the clinical "giving way" experienced when the knee is then loaded.

The 3D Dynamic Functional Knee Brace clearly accomplishes the goal of maintaining the conjugated tibia-femur relationship. The medial post and hinge help the

knee track with normal rotation during gait by the true dynamic rotation strap action. Thus, normal knee kinematics are recapitulated actively by this orthosis.

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The Sarasota Swim-Sports Prosthesis, A Technique For Providing A Dual Purpose Prosthesis

William T. Lovegreen, C.P.O.

INTRODUCTION

Originally intended to be used just in the water, with proper alignment and use of the Seattle Foot® made by Model and Instrument Development,† this prosthesis works equally as well on land. The concept of incorporating a chamber for negative buoyancy is not a new one, however the method of fabrication is different. In Florida, there is a great need for a prosthesis that can be used effectively in both environments.

Various types of prostheses have been made for use in the water, however, they all have something in common; they float. Some of these types have been more or less flotation devices. One type is made entirely with rigid foam. Plastic laminate encases the entire limb including the foot. It not only floats, but with such a hard and functionally long external keel, it traumatized the residual limb. The remainder of this type of prosthesis had similar problems. When a conventional SACH foot is used, the trauma to the residual limb is relieved, but not the problem of flotation. Another problem associated with the SACH foot is that the material decomposes after a period of time in water. Fortunately with the advent of the energy storing Seattle Foot® also came the life cast look, the tough external skin, and the non-porous internal parts made of Delrin. So one of my problems was solved, thanks to Model and Instrument Development.

Upon examining the second problem of how to prevent a prosthesis from floating, it was found there was no easy solution. Adding weight to a prosthesis seems easy enough, but having a patient use a 10 to 15 pound prosthesis would not be accepted very well. What was needed was a weight that could be easily added and removed as needed like the way a large ship or submarine takes on water for ballast. With this idea in mind, there was thought put into the ways of creating a chamber inside of the prosthesis. The most economical but sturdy material that could be found was P.V.C. (Poly Vinyl Chloride) pipe. Pipe of 2¼" diameter was used to make the chamber, which was placed between the socket and the ankle block. Then, 2 pieces of ¾" diameter pipe were placed posteriorly, one distally, and one proximally. These allowed for a gradual intake of water as the patient entered the water, thus making the prosthesis less buoyant. When the patient leaves the water, the fluid in the chamber drains out through the distal pipe leaving the prosthesis lighter.

†Model and Instrument Development, Inc., 861 South Poplar Place, South, Seattle, Washington 98144.

PROCEDURE

A P.T.B. socket utilizing supracondylar suspension in conjunction with a latex sleeve to water proof the inside is incorporated into the design. A Pelite™ insert was used in the test cases, but a hard socket could have been used. The socket, made with acrylic resin, is set up on a standard below knee alignment device, and the appropriate sized Seattle Foot® is then attached.

The patient is then fitted and allowed to walk in the parallel bars. However, the patient should walk barefoot to simulate the actual conditions of being on the beach or at the pool. The Seattle Foot® does allow the patient to wear sandals, thongs, or tennis shoes giving him or her a vast choice of shoes to wear.

When the fitting of the prosthesis is complete it is then transferred, using a vertical alignment device. After removing the BK adjustable alignment device a durathane ankle block is used at the distal end. It must be cut down to about two inches in height to allow the longest piece of P.V.C. pipe to be used. The ankle block is then sealed inside so that no moisure can affect the foam and the correct length of 2¼" P.V.C. pipe is selected and cut. The pipe will have to be long enough to fit down inside the ankle block and cradle the socket. However, before permanently bonding the pipe to the ankle block with sealing resin, acrylic sealing resin mixed with a filler should be poured into the center of the ankle block, completely covering the foot bolt. Make sure to lubricate the foot bolt for easy removal after the resin cures. Proceed to bond the socket to the pipe, again with sealing resin, making it completely water tight. Then, using a ¾" hole saw, make two holes, one as far distal on the posterior as you can go on the chamber and the other as far proximal on the posterior.

Two pieces of ¾" diameter P.V.C. pipe, approximately 6" in length, are cut and bonded into the holes. Keep the distal one horizontal but give the proximal one an upward tilt (Figure 1). It is important to seal these well with P.V.C. cement,

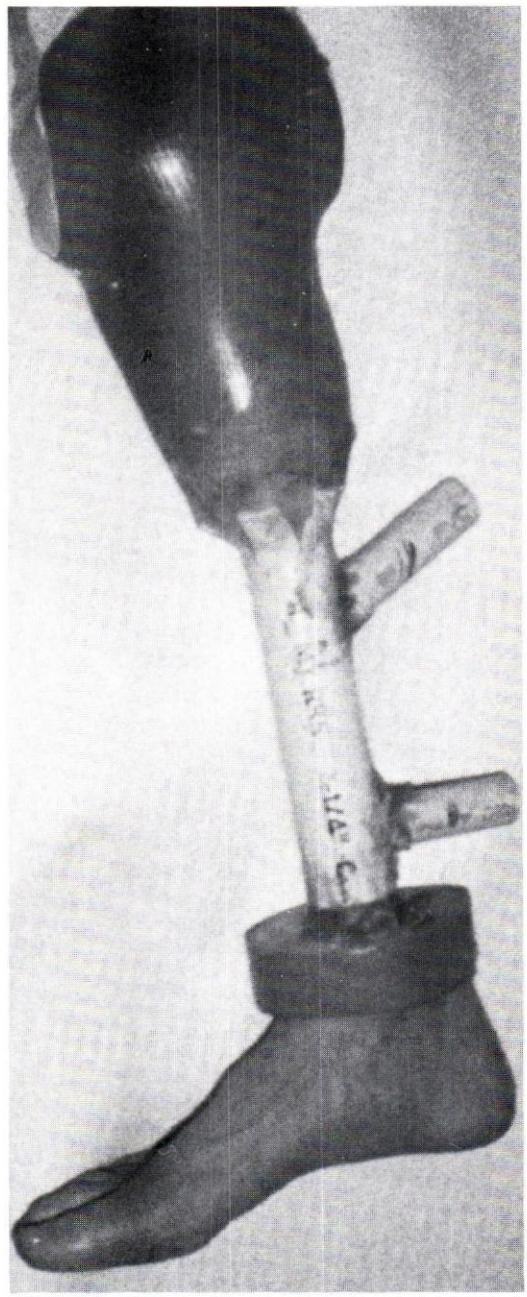

Figure 1. Medial view of transferred prosthesis ready to be foamed up for shaping. Note the upward tilt of proximal tube; distal tube remains horizontal.

Figure 2. Anterior view of completed prosthesis on patient.

Figure 3. Posterior view of prosthesis on patient. Note later sleeve as water barrier, and entry/exit holes for ballast.

as any leakage will cause the surrounding foam to deteriorate. Masking tape is placed over the ends of the ¾" diameter P.V.C. pipe, and the socket is then foamed up and shaped (Figures 2 & 3).

Bonding of the foot to the prosthesis needs careful consideration. The hot glue method that Model and Instrument Development recommends is used. In addition, a bead of glue around the top edge of the foot is used to ensure a perfect seal. The final step after tightening the bolt, provided with the foot, is to fill the bolt hole with hot glue to prevent any corrosion.

CONCLUSION

With this technique, the patient has a prosthesis that can be used equally as well on land as in the water. He/she can walk right from the tennis courts or golf course directly into the pool or ocean using the same limb. This provides the patient with the benefits of two prostheses in one design.

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The Effects of Different Ankle-Foot Orthoses on the Kinematics of Hemiplegic Gait

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James C. Wall, Ph.D.

INTRODUCTION

One of the primary goals in the rehabilitation of a stroke patient is to develop a safe and efficient gait. A common gait problem exhibited by these patients is a dropfoot caused by spasticity of the calf musculature and/or weakness of the pretibial muscles. This problem is frequently corrected by means of an orthotic device, commonly, an ankle-foot orthosis (AFO). Currently, there are several types of AFOs to select from, the most frequently prescribed for the hemiparetic patient being:

- klenzak-AFO (KL-AFO)
- plastic shoehorn AFO (PL-AFO)
- spring wire AFO (SW-AFO).

These AFOs have similar biomechanical functions and contraindications.[1,25] The prescription of an AFO is usually based upon a physical assessment of the patient, including an assessment of gait, and the biomechanical characteristics of the AFO.

Often the initial gait assessment and the evaluation of the effect of the orthotic device during ambulation are by subjective means. The quality of assessment is, to a large degree, dependent upon the experience of the clinician,[9] but at best must be regarded as an unreliable clinical skill.[24] Therefore, it is not surprising that subjective assessment often does not detect subtle changes, due to the orthosis, or resulting from the long rehabilitation process. Nor does subjective assessment allow for accurate comparison, which is essential if the clinician is to determine improvement or deterioration requiring remedial action. It is for these reasons that there has been a trend towards implementing objective measurement of gait to improve subjective assessments in clinical facilities.[29] To quantify the gait pattern of a patient in a clinical setting, the measuring devices must be easy to apply and non-restrictive, and the results must be immediately available and easy to interpret.[31] Two gait variables which have been shown to be useful in the assessment of hemiplegic gait and which are fairly easy to measure are the temporal (T) and distance (D) parameters, such as stride time and step length. One technique that measures the T/D parameters simultaneously is a specialized walkway.[7,30] More commonly, however, these parameters are measured independently. Ink pads, or some similar technique may be used to leave imprints on the floor indicating the positions of foot/floor contact, from which measurements of the spatial parameters of gait can be made.[5] Electrical switches of various forms can be used to determine the duration of foot/floor contact, thereby allowing the temporal pa-

rameters of gait to be calculated.[10] By utilizing a number of switches distributed on the sole of the shoe, footswitches can provide information on the sequencing pattern of foot/floor contact.[33]

Many studies have analyzed hemiparetic gait using different techniques, such as the electromyographic patterns of the muscles of the lower limb and stride kinematics.[11,21,22,28] The results from the stride kinematics indicate that hemiplegic subjects walk significantly slower and take shorter stride lengths than able-bodied persons. The hemiparetic subjects spend less time in stance on the affected limb and thus demonstrate a greater degree of asymmetry in their gait pattern.[29] Gait asymmetries within the various component parts of the support phase have also been shown in patients with residual hemiplegia.[32] The rehabilitation process[18] and the degree of motor recovery[3] have been shown to improve the hemiparetic gait. With rehabilitation and increased motor recovery, using the Brunnstrom method with Fugel-Meyer scoring, hemiparetic subjects have been shown to walk faster with improved symmetry (using single support time as a measure of symmetry). Single support time and stride length increased on the affected side, while double support time (period between heelstrike of the sound leg and toe-off of the paretic leg) decreased.[3] The foot/floor contact patterns for hemiparetic subjects without orthoses have been studied using heel and toe footswitches.[8,11,28] In one of these studies,[28] the subject progressed from making initial contact with the toe only to a flat-footed contact in which both heel and toe made contact with the ground simultaneously. Other studies have shown the foot-floor patterns for hemiparetic subjects using various orthoses.[16,27] Lehmann, et al.[16] found that all the AFO designs they studied restored a normal heel to toe foot contact pattern, although differences were found in the durations of the various temporal phases of the gait cycle. In a comparison of orthoses used by subjects with severe plantarflexion spasticity, it was found that plastic AFO users made initial contact with the heel, whereas those using the BICAAL orthosis made contact with the forefoot, the implication being that, for this type of patient, the use of plastic rigid AFO results in a more normal sequence of foot-floor contact.[27]

Most of the studies that have compared different AFO designs have utilized able-bodied subjects.[13,14,15,23,26] The problem with using able-bodied subjects is that they would be capable of using compensatory patterns that individuals with extensive motor changes would be unable to perform. In a comparison of three different plastic AFOs, using both able-bodied and hemiparetic patients, the relative durations of stance and swing were consistent in both groups.[16] There were significant differences in the duration of midstance (defined as the period from heel-strike to heel-off) and pushoff phase (the period from heel-off to toe-off). The hemiparetic patients spent more time in midstance and less time in push-off. Due to the limited plantarflexion provided by all the PL-AFOs, knee instability occurred during heel-strike, but adequate toe clearance was provided by all the orthoses.[16] At heel strike, with the plastic rigid AFO, normal plantarflexion of the ankle is eliminated and thus restricts the progression of foot flat. This may even occur with the foot locked in slight plantarflexion. In order for the hemiparetic patient to obtain foot flat, while the ankle is locked, compensatory mechanisms, particularly at the knee, have to be utilized. In two studies comparing conventional AFOs (metal and leather orthoses) and plastic AFOs,[6,27] both types improve the walking speed of the hemiparetic. In the first study,[6] there was no significant difference in the oxygen consumption using either orthosis. In the second study[27] using rigid orthoses, the plastic AFO users had heelstrike occurring normally in 15 to 16 patients, while the BICAAL had 9 of 16 normal occurrences. The plastic AFOs demonstrated the normal loading pattern of metatarsal five/metatarsal one, or metatarsal five/metatarsal one/great toe, while the users of the BICAAL orthosis did not consistently demonstrate this characteristic pattern.

The purpose of the study was two fold: to quantify if there were any differences in the temporal sequencing of foot/floor contact or in the temporal stride kinematics of the hemiplegic patients walking with and without an orthosis, and to evaluate the feasibility of utilizing footswitches and a telemetry system as assessment aids in the clinical setting.

METHODOLOGY

Seven hemiparetic patients volunteered to participate in the study, of whom five were male and two female all between the ages of 50 and 75 years. Subject selection was based upon the following criteria:

- a stroke that had occurred more than 18 months prior to the study;
- no limiting soft tissue contractures of the lower limb;
- no severe fixed joint deformities;
- mild to moderate increased tone of the gastrocnemius-soleus;
- no receptive aphasia;
- nonapraxia;
- minimal superficial sensory loss;
- capable of walking eight to ten meters with or without an ambulatory aid;
- had been previously prescribed either the KL-AFO, PL-AFO, or SW-AFO.

Only one subject (C) required an accessory; a lateral T-strap to control a moderate lateral ankle instability (varus) during the weight-bearing stage. A summary of the characteristics of the subjects is presented in Table I.

The KL-AFO consisted of four basic components:

- a steel stirrup, which was attached to the shoe;
- a mechanical joint, which included springs to provide dorsiflexion assist and a 20 degree plantarflexion stop;
- bilateral aluminum uprights;
- an aluminum calf band, covered with leather and a leather strap for the closure, located approximately ¾" below the fibular head.

All the KL-AFOs utilized a conventional ankle alignment, as opposed to the anatomical method, where the mechanical joints are aligned with the malleoli and tibial torsion is accounted for.

The PL-AFO was fabricated from 3/16" polypropylene molded to a plaster positive model of the subject's leg. The PL-AFOs were of the semi-flexible type rather than the flexible type. The flexibility of a given orthosis depends primarily upon the trimlines around the ankle joint. The orthosis was made to fit inside the subject's shoe, and the closure at the proximal end was by means of a Velcro™ fastener. The orthosis was fabricated to hold the foot in approximately 0°-5° of dorsiflexion.

The SW-AFO orthosis was made of spring wire and an aluminum calf band with a leather covering and closure. The dorsiflexion assist was provided by a loop in the wire, located at the point of attachment to the shoes. The spring wire was not firmly attached to the shoe, but allowed easy removal for transfer from one shoe to another.

The footswitch and telemetry system used in this study was a commercially available system designed for clinical use.[†] The footswitches, which were incorporated into an insole, monitored the floor contact times of the following foot regions: heel (HL), metatarsal 5 (M5), metatarsal 1 (M1), and greater toe (GT). The footswitches were attached to the sole of the subject's shoes with tape. Each footswitch produced a different voltage output when closed, and hence a different pen deflection on the polygraph recorder. All combinations of switch contacts were unique.[4] The footswitches were connected to a transmitting box, located around the subject's waist, by thin wires. The footswitch data were picked up by a receiver, the output of which was recorded on a polygraph. This system was initially checked, calibrated, and tested for reliability, using two normal subjects.

The subjects were required to walk a distance of ten meters. Two optical switches were used to detect when the patient entered and left the central six meters of the walkway. Four channels were utilized on

[†]B & L Engineering, Santa Fe Springs, California.

the polygraph. A timing marker confirmed the paper speed (50mm/second) and provided a time component for the measurement of the stride kinematics. Distance markers (output from the optical switches) delineated the data to be analyzed from which to calculate walking speed. The two remaining channels were used to record the footswitch data from both feet independently.

Each subject was required to walk at a self-selected comfortable speed under two conditions (where possible). The first condition was with the orthosis on, and the second condition was without the orthosis. A training period was permitted to allow the subject to become familiar with the experimental setup and to become familiar with the imposed conditions. A minimum of three walks were recorded for each condition. Two subjects (C and E) could not walk without an orthosis.

Two walking trials were analyzed for each condition performed. Four consecutive strides from the central six meters of the walkway were analyzed for each trial. The selection of the strides to be analyzed was based on the consistency of the raw printout. The following points were digitized[††] from the foot/floor output on the polygraph: heel on, off; M5 on, off; M1 on, off; toe on, off; and swing phase foot contact on, off, indicating scuffing during the swing phase. The output from the optical switches, indicating when the subject entered and left the central six meters of the walkway, was also digitized. The X-Y coordinates of these points were input to a mainframe computer[†††] for processing and storage. The temporal gait variables calculated from these data were the walking speed, stance period, swing period, double support periods, symmetry (single support time ratio), and the onset and duration of heel, M5, M1, and toe contact for both feet.

[††] High Precision Co-ordinate Digitizer, Gentian Electronics Ltd., Kanata, Ontario, Canada.

[†††] Cyber 150/580, Control Data Canada, Mississauga, Ontario, Canada.

RESULTS

Table II shows the temporal kinematics for each subject with and without an orthosis. Two subjects (C and E) could not walk without their orthosis (KL-AFO) and therefore, were, only tested under one condition. The measurements included stride time (ST), braking double support (BDS) (defined as the period of double support following initial foot/floor contact), single support (SS), thrusting double support (TDS) (defined as the period of double support immediately preceding the final foot/floor contact), total support (TS), and swing (Sw). These are presented for the paretic limb only; however, with these data, the values for the unaffected side can also be determined. Thus, swing on the paretic side is equal to single support on the contralateral side. Note also that total support for the unaffected side will be longer than that for the affected side if single support is greater than swing on the paretic limb. Also included in this table are data from healthy able-bodied males aged 60 to 65.[19]

Table III shows the results for the with and without orthosis conditions of the onset and duration of floor contact of the various parts of the foot. Only the results from the paretic side are shown. The normative data shown in this table are estimated values obtained from a representative pattern.[4]

DISCUSSION

Stride Kinematics

All of the subjects walked slower than able-bodied individuals for both conditions. The walking speeds ranged from a low of 0.07m/s to a maximum of 0.6m/s, this latter value being less than half that of the speed adopted by an able-bodied elderly man walking at a self-selected normal speed. The differences seen in velocity between the two conditions are no greater than one might expect from two traverses of the walkway even for an able-bodied subject, the exception to this being subject G, who showed a marked increase in walking speed while wearing an orthosis.

When expressed in terms of percentages of stride time, the durations of each of the double support phases, as well as the total support phase, all increase with a decrease in walking speed, whereas single support and swing both decrease. This certainly helps to explain some of the differences noted between the data shown for the hemiplegic subjects and the normal values. However, the most noticeable differences in the temporal kinematics are the patient to patient variability and the asymmetrical nature of the walking pattern. All the subjects, in both conditions, spent more time in total support on the sound leg than on the paretic leg, a finding that is in agreement with a number of other studies on hemiplegic gait.[29,32] The favoring of the paretic limb is also reflected in the shorter single support phase on that side compared to the sound limb (i.e., the swing time of the paretic limb). It has been stated by Brandstatter, et al.[3] that hemiparetic gait is best characterized by single support symmetry. The duration of the two double support phases is very similar in some subjects (A, B, C, and D) and very marked in others (E, F, and G). This variability in asymmetry, both in extent and position within the support phase is a feature that has been discussed by Wall and Turnbull[32] with respect to a group of residual stroke patients.

For all subjects except F, the durations of the phases remain virtually unchanged between the two conditions, even for subject G in whom a marked increase in walking speed was noted while wearing an orthosis. Although there is very little difference in walking speed or stride time between the two conditions for subject F, the duration of the braking double support phase increases as did the total support phase when using an orthosis. Swing time decreases also and the result is a more symmetrical walking pattern.

Sequencing Pattern of the Foot/Floor Contact

Table III shows the normal sequence of foot/floor contact using data from another study.[4] Here initial contact is made with the heel followed by M5, M1, and finally the great toe. A feature commonly seen in hemiplegic gait patterns is a drop foot in which initial contact is made with the forepart of the foot and this is often associated with toe contact during part or all of the swing phase (scuffing). If there is also varus, then initial contact is with the M5 region rather than with the toe. Subjects A and F demonstrated this pattern when walking without an orthosis. The fact that the earliest contact made by subject A in this condition is shown as occurring at 1.6% of the stride, rather than zero, can be accounted for by the data shown: mean values of four strides are for each of two walks. Subject A never had the heel of the paretic foot in contact with the ground, but was still able to clear the ground during the swing phase. However, subject F demonstrated scuffing. The application of an orthosis eliminated this gait problem in both subjects and resulted in a relatively normal sequencing pattern, as characterized by initial HL contact, followed by M5, M1, and finally GT.

The paretic leg exhibited a fairly normal sequencing in both conditions in subjects B, D, and G. There were no major alterations in the gait with the use of an orthosis.

For subject C, the paretic leg only had floor contact by the HL and M5 regions. This strongly suggested that the orthosis maintained the ankle/foot complex in a varus position, indicating that the weight was borne only on the lateral aspect of the foot. The possible reasons for this pattern were either a poor alignment of the mechanical joints, the ankle may have assumed a varus orientation within the orthosis during weight bearing, the knee may have gone into varus, or the sole of the shoe may have been worn on the lateral aspect (which is usually the result of one of the previous factors).

The paretic leg of subject E exhibited a flat-foot gait, with almost simultaneous contact of the HL, M5, and M1 regions. Heel-rise occurred prematurely, and there was a prolonged contact of M5. The flat-foot and premature heel-rise patterns may be related to the angle that the orthosis was set in and to the rigidity of the AFO

Characteristics of Subjects Used In Sample							
Subject	Age	Sex	Height (m)	Paretic Side	Years Post CVA	Orthosis Used	Walking Aid
A	67	M	1.68	R	15	SW-AFO	Regular Cane
B	62	F	1.56	R	6	KL-AFO	Regular Cane
C	73	M	1.69	R	5.5	KL-AFO	Fourpost Cane
D	73	M	1.58	R	5	PL-AFO	Regular Cane
E	71	M	1.65	R	4	KL-AFO	Regular Cane
F	51	F	1.60	L	4	PL-AFO	Regular Cane
G	58	M	1.67	R	7	PL-AFO	Regular Cane

Table I.

Temporal Stride Kinematics for the Paretic Limb								
Subject	Orthosis/ No Orthosis	VEL (m/s)	ST (s)	Temporal Phases (% Stride Time)				
				BDS	SS	TDS	TS	SW
A	O	0.60	1.65	10.2	30.2	12.7	53.1	46.9
	NO	0.63	1.63	9.6	30.6	10.0	50.4	49.6
B	O	0.17	2.78	31.2	16.2	27.7	75.1	24.9
	NO	0.15	2.98	31.3	14.4	26.3	72.0	28.0
C	O	0.07	3.67	31.8	10.0	36.0	72.8	22.2
D	O	0.19	2.96	26.4	19.1	22.6	68.1	31.9
	NO	0.22	2.64	25.3	21.2	20.8	67.3	32.7
E	O	0.32	2.15	8.6	20.0	33.8	62.4	37.6
F	O	0.39	1.81	27.9	23.4	17.8	69.1	30.9
	NO	0.37	1.82	20.0	22.8	14.2	57.0	43.0
G	O	0.48	1.51	26.4	23.2	16.5	66.1	33.9
	NO	0.36	1.64	29.2	20.1	18.4	67.7	32.3
*	NO	1.51	1.06	11.0	39.0	11.0	61.0	39.0

*Data for able-bodied males ages 20-65 years of age (Murray, et al., 1966)[19]

Table II.

(the orthosis was a PL-AFO). For instance, if the foot was maintained in a slight plantarflexed position, toe clearance and heel strike may still occur, yet M5 and M1 contact would occur earlier. If the orthosis was rigid as well, the dorsiflexion that normally occurs during midstance, will be resisted and the forward progression of the body would be reduced. The hemiparetic subject may compensate by exerting a greater force at pushoff on the sound side in order to "vault" over the paretic limb. This would result in an early heel-rise, if the plantarflexion orientation was maintained.

Walking speed and single support (SS) time are the principle measures of performance.[2,10,17,20] Single support time has also been used to reflect the subject's abil-

Onset and Duration of Contacts of the Various Parts of the Paretic Foot with the Ground as a Percentage of Stride Time

Subject	Orthosis/ No Orthosis	Support Phase						Swing			
		Heel		M5		M1		Toe		Toe	
		On	Dur	On	Dur	On	Dur	On	Dur	On	Dur
A	O	0	32.4	1.5	45.4	7.4	41.4	46.9	6.2	—	—
	NO	—	0	0	46.5	0.7	40.5	41.6	8.8	—	—
B	O	0	53.8	19.5	36.9	23.7	36.6	38.1	37.0	—	—
	NO	0	52.2	3.0	54.5	26.8	32.6	28.4	43.6	—	—
C	O	0	59.5	9.4	68.8	—	—	—	—	—	—
D	O	0	52.1	8.5	46.3	16.9	41.6	56.3	11.8	—	—
	NO	0	54.2	12.7	44.3	16.7	42.7	58.9	8.4	—	—
E	O	0	18.8	1.3	38.8	1.9	38.3	40.1	22.3	—	—
F	O	0	48.6	14.1	49.2	18.2	46.0	63.3	5.8	—	—
	NO	2.1	36.9	1.6	52.7	5.4	47.8	53.3	3.7	89.1	6.6
G	O	0	57.9	17.3	43.2	24.8	36.3	60.6	5.5	—	—
	NO	0	59.4	9.8	51.3	30.7	31.0	41.4	26.3	—	—
*	NO	0	39.0	9.7	47.7	20.6	35.9	43.3	16.4	—	—

*Data determined from Botranger (1977)[4]

Table III.

ity to load the limb and the symmetry of the gait pattern.[10, 17, 20] In this study, three of five subjects increased the walking speed, albeit marginally in two of the subjects, with a concommitant increase in the SS time. Based on the walking speed and single support time variables, only three subjects improved their gait performance with the orthosis. There was a decrease in four of the five subjects for the SS time. This suggested that the orthoses enabled the subjects to increase the time spent on the paretic leg, and/or decrease the time spent on the sound leg. The longer double support periods (BDS and TDS) reflected the insecurity of the subjects, even with the orthosis.

Two subjects had a decrease in the walking speed and SS time. The decrease suggests a decline in the gait performance, but the stride kinematics do not provide a complete picture of the role the orthoses played. In many pathological conditions, the normal foot/floor sequencing pattern is altered.[17] The altered foot/floor patterns influence the subject's security and safety during ambulation. In two subjects (A and F) the drop-foot pattern was eliminated and a normal sequencing pattern was re-established with the orthosis. Two subjects (C and E) required the orthosis to ambulate, which in itself is indicative of improved performance. In both cases, the orthosis allowed the subject to walk, but there were problems with their gait as reflected in the foot/floor sequencing patterns. In three subjects, although the sequencing was similar, the durations were reduced, approaching normal times. Thus, it appeared that the orthoses improved the foot sequencing patterns and stride kinematics. For some the improvement was minimal, but for others it was quite significant.

There were several limitations to the study:

- the number of subjects and subject trials
- the heterogeneity of the subject group (the subjects were of varying stages of motor recovery and no screening was done)
- the use of only one method of objective gait measurement.

CONCLUSIONS

The AFO is most often prescribed to prevent dropfoot and provide medial/lateral stability to the ankle/foot complex. The orthosis is designed to enable the hemiparetic to walk safely by reducing the risk of stumbling, and efficiently by reducing the need for compensatory movements, such as hip hiking to assist a drop foot in clearing the ground during the swing phase. By controlling the unstable ankle/foot complex and reducing the need for compensatory patterns, walking speed and asymmetry, may be improved. This study found that gait symmetry and walking speed were similar for both conditions in most cases, suggesting that the application of an AFO does not alone lead to improved symmetry and increased walking speed. The role of the AFO was best demonstrated in subjects A and F, who exhibited dropfoot patterns when not using an orthosis. This was eliminated with the application of the AFOs. Three subjects (B, D, G) did not exhibit any major changes in the temporal sequencing patterns or in the measures of gait efficiency. But there are several underlying factors that must be recognized before making any decisions on the function of the orthoses. When the AFO was prescribed, the need for the orthosis may have been greater due to lesser motor recovery level and poorer balance. With improved motor recovery and the constant use of the AFO for several years, the habituated pattern of walking may have been maintained during the short time that the patient was tested without an orthosis. With fatigue and prolonged walking without the orthosis, a footdrop pattern may develop and increase the risk of tripping. All the patients felt insecure without the orthosis, even with the level walking conditions of the laboratory. On uneven terrain, this factor would become far more important. The provision of an AFO does not guarantee improved walking pattern, and in the case of subject C, although the AFO enabled him to walk, the pattern appeared to be unstable due to the contact only on the lateral aspect. There were many possible reasons for this, but optimal anatomical and mechanical joint alignment and periodic checkups, to ensure that footwear and the orthosis are applied and operating properly, will reduce the chance that such a situation will occur.

The footswitches were easy to apply and nonrestrictive. The set up time for the experiment, for each subject required approximately 20 to 30 minutes. The results were not immediately available following data collection in this study, but the system could be automated with on-line data collection and processing performed with a computer. A system which allows this to be done is in fact commercially available through the manufacturers of the telemetry unit. The footswitches do provide useful information which could augment the usually subjective assessment. For example, by quantifying the gait patterns of the hemiparetic patient, unassisted and orthotically-assisted, as has been done in this study, one can demonstrate the effectiveness of the orthosis in attaining a more normal gait pattern. The quantification of the gait pattern may also assist in detecting abnormal gait patterns and may aid in rehabilitation by providing numerical information for future comparison, necessary in monitoring the progress of the patient. However, since the footswitches provide only kinematic data, the underlying reasons for the patterns of foot/floor contact have to be inferred. Supporting analytic methods, such as video, film, or goniometry would provide useful additional information which might, in turn, lead to determining what kinetic measurements should be made to better understand the underlying causes for a given gait deviation. The footswitch system is useful as a

first step in the supply of objective data to augment the observational techniques most commonly used to assess gait in the clinic. Indeed footswitches provide one of the few techniques by which one can determine the sequence in which various parts of the foot make contact with the ground and have proved extremely useful in this study where orthotic devices have been employed to overcome abnormalities in this aspect of the gait cycle.

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Interviewing the Amputee—A Step Toward Rehabilitation

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A wide range of emotional, psychological, and social problems is inherent in the reaction to loss of a limb.[4] Degree of reconciliation to the loss, rapidity of adjustment, and success of rehabilitation vary greatly among individual amputees. Age, emotional nature, level of understanding of the problems faced by amputees, and support received from family or friends are all factors that influence the adjustment process.[3]

A discussion between a health care professional and the amputee, either before or after surgery, can be an important first step in identifying the beliefs and needs of each amputee and can serve as a basis for developing an effective rehabilitation program. Since close to 110,000 lower and upper limb amputations are performed annually in the United States,[2] the need for such individually tailored rehabilitation programs is significant.

A WELL CONDUCTED INTERVIEW

At Harborview Medical Center in Seattle, we have found that a well conducted interview with the amputee can help reduce the information gap that often exists between patient, health practitioners, and support groups. It not only enhances the quality of treatment but also offers the amputee valuable insight and assistance in reestablishing his or her direction in life. The interview focuses on the patient's learning needs regarding amputation; how the patient is adjusting and coping; how well he or she is being supported emotionally, psychologically, and financially by others; and significant problems that may pose roadblocks in the future.

The interview is conducted through the Limb Viability Service, established in 1979 at Harborview because there were no inpatient services in the community specifically oriented to amputees. About 40 amputations are performed each year at Harborview, which is a regional trauma center. Over one-third of these amputations are due to trauma, and the remainder to vascular disease.

A 20 to 30 minute interview before or after surgery follows a variable format that may be adapted to the circumstances of each patient. It is important to keep in mind that this is an initial assessment tool for obtaining specific information. Patient education, extended discussion, and problem solving are not incorporated into this interview but are arranged to take place later. Information obtained in this initial session helps increase decision accuracy throughout treatment and gives members of the team involved in the patient's treatment and rehabilitation an understanding of the patient's needs and goals. The interview also helps health care professionals assess the patient's current level of functioning in reference to available treatment

or rehabilitation options, and it can help them pinpoint particular teaching or training methods that can aid the patient's adjustment to the amputation.

The interview format and questions are revised and adapted for any patient, from the teenager to the elderly. Geriatric patients account for approximately 80% of the amputations performed in the United States each year,[5] and 65% to 75% of the new amputees at Harborview are in this patient population. Unfortunately, this age group may have a relatively narrow band of options available with respect to employment opportunities, income adjustments, and personal goals. But regardless of their limitations, geriatric patients do have goals and aspirations that deserve attention. For younger amputees, the interview process can be vital as they face new choices and decisions in reorienting their lives.

OBTAINING PERMISSION AND DEFINING INTERVIEW LIMITS

Asking permission to conduct the interview is most important because it gives the patient some feeling of control over the process. Most patients welcome a chance to talk, but some do not. The health care professional must be sensitive to the issue of invading the patient's sense of privacy as many of the questions relating to personal matters can appear "nosy." Other family members or friends, however, may not be able to serve the important role of an objective listener, and the amputee needs such a listener during the adjustment to a traumatic experience in life.

Prior to the interview itself, the health practitioner and patient discuss how long the interview will last, how the information will be used, and any concerns about confidentiality of responses. As another means of setting limits, the interviewer clarifies his or her intentions with regard to meeting the patient's needs. The patient is made to understand that these needs will be acknowledged during the interview, but that strategies for dealing with them will be worked out later. For trust to develop between patient and interviewer and for maximum results, the patient must be comfortable with the purpose, use, and mechanics of the interview process.

TIME AND PLACE OF INTERVIEW

The specific time and place of the interview are chosen carefully. The hospital is not an ideal setting in terms of privacy, but every effort is made to ensure the patient's privacy and comfort. Choosing a time when the patient is not overly rushed or anxious shows respect for that individual and enhances the accuracy of his or her answers. In most cases, the interview is conducted after the amputation, when the patient has had time to begin the adjustment process. We have found that many patients are not inclined to talk prior to surgery. The exceptions may be limb salvage patients who may already have tried or considered other treatment options, or patients with vascular disease who have faced the possibility of amputation for some time.

INTERVIEW FORMAT

Questions are of three types: open-ended questions, which give the patient maximum freedom to respond; range-of-response questions, which allow patients the freedom to express both positive and negative aspects of a particular issue; and limited-response questions, which may elicit a simple yes/no answer.

We find it helpful to write down the patient's responses during the interview. These notes are included in the patient's records and may be given to the patient as a reminder of the important issues to be considered in the coming months. Allowing the patient to review his or her responses also ensures that the information recorded is accurate and helps to establish and maintain a high level of trust.

Perhaps the most important aspect of the interview technique is the recognition that there is no one right time or right place during the course of treatment for asking

questions. Each stage of adjustment carries its own specific concerns and anxieties, be it before surgery, after surgery, or during rehabilitation. It may be appropriate to repeat some questions at various times during the treatment process.

CONTENT OF INTERVIEW

Four general categories encompass questions that represent the most common concerns and needs amputees face: learning needs, support systems, coping, and level of function. The following sections include questions that might be asked in assessing the patient's needs in these four areas. A range of patient responses and their probable meanings are also given. Responses listed are actual replies given by various patients interviewed with this format at Harborview Medical Center.

Learning Needs

Most new amputees have very little knowledge about limb surgery and how it will affect their lives. Providing information is a key to minimizing patient anxiety, enlisting cooperation in treatment, and expediting the adjustment process. The interviewer plays an important role in determining the patient's need for information about amputation outcomes and can also alert physicians, nurses, and others on the health care team to the level and extent of this need. Information exchanges come through discussion between the patient and health professionals, through pamphlets or written information, and through the patient's contact with other amputees, arranged by the health team. The patient's responses to the questions regarding learning needs (Table I) also begin to clarify the options available to him or her at the onset of treatment and throughout rehabilitation.

Support Systems

The questions presented in Table II help assess the support systems available to the individual and identify areas of strength and weakness. An experience as intense and as far-reaching as an amputation requires maximum use of support systems, especially if the rehabilitation process will be lengthy. We have found that individuals with close family ties, strong spiritual beliefs, and caring friends seem to handle this loss better than those without such supports. These individuals are able to share the psychological and physiological load with others. Conversely, amputees who are "loners" seem to have a harder time during rehabilitation. Intense emotion, antisocial behavior, and a general inability to "get on with life" seem to plague those who do not seek or cannot accept support from others.

This phase of interviewing focuses on the future and encourages the patient to examine ways of resuming his or her life. Usually, much of the anxiety and worry eases following surgery because the patient has experienced a sense of finality with respect to the treatment decision.[1] It is important for both the health professional and the patient to be aware of the existence and value of support systems. In clarifying questions about existing support and in focusing on additional support possibilities, we find it helpful to give the patient a "laundry list" of options to consider such as spiritual beliefs, meditation, hobbies, or other activities that offer some relief or distraction from concern about the amputation. The health team can then encourage the patient to seek and retain additional support, and the patient can build upon strengths and compensate for weaknesses.

Emotional Reactions/Coping

In reporting their observations on the grief process, several authorities have equated the loss of a limb with the loss of a loved one.[1] Certain universal reactions to amputation can be expected, although individuals vary in how they experience grieving.[6] The six typical stages of the grief process are denial; bargaining; anger; grief, sadness, and depression; adjustment and adaptation; and acceptance.

During the first stage, the new amputee obviously cannot deny the physical loss but may deny that this loss will alter his or her life in any significant way. In the second stage, the patient may bargain with anyone

whom he or she perceives to have some control over his or her physical well-being, e.g., God, the physician, or the health care team. A plea from a young athlete might be: "Call in all the experts and have them fix my leg so that I can run again. Don't worry about money. I'll pay any amount you want."

During the third stage, anger may be directed toward almost anyone or anything, e.g., the individual(s) who caused the accident (in the case of a trauma victim), the patient him- or herself for being physically careless, or the physician who was not able to save the limb. Once the reality of the loss and its implications have been absorbed, depression sets in, and the patient may experience intense emotions, loss of appetite, and sleep disruption. At the end of this stage, the patient also feels anxiety about the short-term and long-term impact of the amputation on daily life. In the fifth stage, the patient begins to adapt to the physical loss and starts to make adjustments in daily activities. Finally, the patient begins to accept the amputation and may no longer perceive it as a tragic occurrence.

In interviewing the patient, it can be difficult to determine what stage of the grief process he or she is experiencing. Some individuals fluctuate. They experience the earlier stages of grieving for a while, start to adjust, and then revert to the earlier stages. Appropriate questioning helps assess the patient's progress in handling the loss.

The first question in Table III is directed at the grief process, and the other questions examine how well the patient is coping with emotional difficulties. We have found that encouraging patients to express their feelings helps them to relieve anxiety and emotion and allows them to see more clearly various approaches to their situation. The health professional can also use this information to direct patients toward the type of support they need.

The final questions in Table III deal with a highly personal area, body image, for example, how amputees visualize themselves and how they believe others see them. Body image involves self-esteem, sexuality, and many fragile emotional concerns.[1] The health professional may feel reluctant to ask these questions for fear of invading the individual's privacy. However, body image, and especially sexuality, are such important topics that they ought to be approached.[1] We introduce these topics and then let the patient decide whether to continue discussing.

During this phase of the interview, it is not unusual for a patient to express a range of emotions from weeping to withdrawal. Even though some of the major treatment decisions have been made, many smaller but emotionally charged decisions remain, and the patient may need permission to cry out for help. Here, the interviewer assists the patient in discovering what resources may be available for finding answers to his or her questions. Since interviewing often triggers information seeking, the interviewer does everything possible to make sure patients have immediate access to resources, especially those who are immobilized or isolated. A telephone, for example, can be a valuable information seeking tool.

Level of Function

The questions in Table IV are directed at vocational and recreational activities. Here, the interviewer helps the patient focus on areas of life over which he or she may or may not have control, and helps to identify areas in which the patient is experiencing excess demand. If, for example, a patient is overly burdened about the cost of not working for a time, or about the psychological adjustment to a loss of "sex appeal," the interviewer helps him or her focus on understanding how these concerns are posing undue demands. The interviewer's role is that of a supportive coach, letting the patient express concerns but asking questions in such a way that the amputee can consider a range of options. Range-of-response questions are extremely useful here because they encourage the patients to explore a variety of ideas and consider different courses.

The rehabilitation phase can be both exciting and frustrating. Excitement occurs when the amputee realizes that the so-called handicap or disability may not be

nearly as restrictive or significant as originally thought. Frustration can occur through the loss that accompanies amputation, and also because range of activity or endurance does change, even if in minor ways. An exchange of questions and answers on level of function helps to build a sense of realism about the best options for the future.

During the interview, the patient may ask the health practitioner: "What do you think I should do?" Patients often seek answers for their personal concerns from health professionals. While it is tempting to engage in problem solving with the patient, it may be more helpful for the patient simply to record information rather than to exchange it. Problem solving during this initial interview is undesirable because it tends to foster dependency rather than support, and it can be very time consuming. It also causes the interview to be focused on one aspect of treatment rather than on a broader range of concerns. At Harborview, the interviewer makes plans with the patient to return for another discussion or has the appropriate health care worker contact him or her regarding the expressed problems and concerns.

The interviewer needs to resist the temptation to be highly positive or optimistic without also acknowledging the patient's realistic anxiety. A "low-key" approach reassures the patient that the interviewer is merely obtaining information and is not trying to alter the patient's feelings.

We have found that the interview questions elicit widely varied responses according to the unique situation of each individual. For example, older people often convey a concern for independent function and self-care, while the young athlete is typically concerned with returning to sports and recreation. The tough, ultra-masculine man may be unwilling or unable to share any strong emotion other than anger, while someone experiencing the full impact of his or her loss may be unable to answer questions because of intense emotions. Occasionally, an individual has a full understanding of what lies ahead because of a close association with an amputee in the past. More commonly, however, the patient is ignorant about amputation and how an altered body will affect his or her future.

THREE EXAMPLES

Three examples follow that illustrate how the interview format has been used during the past three years at Harborview to generate information to meet patient needs.

Example 1

One middle-aged man indicated uncertainty about his insurance coverage for a prosthesis. Investigation by the Limb Viability Services Coordinator revealed that even though he had been forced to retire early because of his condition, the policy still covered his medical expenses fully, including the cost of the artificial limb.

Example 2

An elderly lady expressed dramatic relief during the interview when she learned that the phantom limb sensation was normal. She was afraid to share the experience until she was told how common it was. "I knew I had lost my leg, but I was afraid I was beginning to lose my mind," she said.

Example 3

In commenting on the value of the Limb Viability Service, one patient observed: "I never realized how lucky I was to have been treated here until I talked with other amputees who had no specific support at other hospitals. They have very little idea of what's happening or what's coming. Things went so much more smoothly for me."

CONCLUSION

We have found the interview technique outlined in this paper to be extremely useful in enhancing the care and rehabilitation of our amputee patients, and we recommend its use in all centers handling this patient population. This interview technique need not be confined to major trauma centers with specific amputee rehabilitation

LEARNING NEEDS

Questions	Possible Responses	Probable Meaning
1. Tell me in general what you know about amputations.	"My uncle Fred had a wooden leg and he did fine with it."	Probably has a better background than most about the reality of amputation. Understanding may depend on how close he and Fred were—if they did things together and talked about Fred's amputation, and if the patient had a similar type of surgery.
	"Nothing really. There's a guy with a missing arm who comes into the bar I go to."	Typical response. Most people have very minimal knowledge of amputations and their implications for daily living.
2. Tell me what you understand about what will happen during your hospital stay.	"They're going to take my leg off but I don't know what happens after that."	Obviously does not know what is ahead. May have been told and not comprehended, or may not be an information seeker.
	"I hope to get a cast on after surgery and be up walking with it before too long."	Probably has some understanding of immediate cast fitting.
3. Many amputees have indicated that they can still feel all or part of their missing limb. Do you have any of these sensations?	"Yes, I feel like my foot is still there but I can see it isn't."	Relaying accurate information and perhaps seeking approval for having the sensation.
	(Hesitates) ". . . no, of course not."	May actually feel sensations in the missing limb but may not want to admit this.
4. How long do you expect it will take for your leg (arm) to heal?	"I guess I really don't know."	Direct admission of lack of information.
	"The doctor said I could probably go home late next week."	Probably assumes that he will be well along in the healing process by then. May be unsure of duration of healing period and when prosthesis will be fitted.
5. How much do you know about special community services available to amputees?	"I already have a special bus pass for the disabled."	Has some awareness of unique benefits for disabled. May desire more information on other specific benefits.
	"Nothing really."	May not want to identify with disabled population by accepting such services. Presently may not be aware of any need for them.

Table I.

SUPPORT SYSTEMS

Questions	Possible Responses	Probable Meaning
1. Whom do you feel you could call on for assistance among your close family and/or friends?	"My wife (husband) will take care of whatever needs to be done."	Feels that home situation is adequate and supportive.
	"My biker (motorcycle) friends will be around."	May not be a realistic support. Frequency of contact with these friends while the patient is hospitalized may indicate how available/reliable they may actually be.
2. Where do you plan to go when you leave the hospital? What kind of help will be available there?	"I think I'll have to go to a nursing home for a while before I go to my apartment."	Has considered short-term goals and circumstances.
	"I haven't really thought about it."	Probably still feeling impact and intensity of present crisis and has not looked beyond it.
3. How do you think your family and friends are accepting the experience that you are going through?	"Real well, I think. They told me they were glad I was still alive and that losing my leg was not important in comparison."	Patient is benefiting from a supportive, healthy attitude of close family,
	"Not too good. My mother keeps crying a lot about me being crippled now."	Patient is required to give support instead of receiving it from his mother. This situation may inhibit his or her ability to express grief or true feelings.
4. Other than your family and friends, what things may be supportive to you at this time?	"I feel that God has really helped me get through this."	Receives healthy support from spiritual beliefs, whatever they may be.
	"I do a lot of reading and that helps me keep my mind off all this."	His or her pastime may be a means of avoiding facing present circumstances or may be merely a healthy delay to permit normal adjustment.

Table II.

programs; it can easily be adopted by smaller hospitals as well. In this case the interview could be conducted by a physician, nurse, social worker, physical therapist, or other health care professional. All that is required is sensitivity to patient needs and the willingness to invest some time in providing information and support to the new amputee.

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EMOTIONAL REACTIONS/COPING

Questions	Possible Responses	Probable Meaning
1. Losing a part of one's body is similar to losing a member of one's family. Describe any strong feelings that you have, or have had, about this loss.	"Two nights ago I broke down and cried about it."	Evidence of normal grief reaction.
	"I'm not mad or anything. But if the courts don't take care of the drunk lady who hit me, I'm going to kill her."	Unsuccessfully trying to repress some intense anger about his injury and loss.
2. When you have been in difficult sitations in the past, how have you handled them?	"I was overwhelmed for a while, but time and determination on my part seemed to work things out."	Probably experiences grief reaction and progresses on to normal acceptance.
	"I usually go down to the bar and knock a few heads around. Then I feel better."	May feel that antisocial behavior is appropriate when facing stressful circumstances.
3. People have a picture or idea in their minds of how they look to others. How do you see yourself now?	"I'm not sure. I guess I don't have a really clear picture of myself right now."	It takes time for the mind to absorb the impact of a significant change in the body.
	"I'm still me. The same person I've always been."	May have a healthy concept since does not view himself or herself as deficient because of a change in physical appearance. Alternatively, may not want to consider the fact that he/she looks different now.
4. Are you more aware of one part of your body?	"I guess I think about my legs more. I haven't made myself look at it (the stump) yet."	Normal anxiety about a change in body image. Probably expecting the limb to look different and maybe ugly.
	"No, not really."	May be at point of denying loss or merely unwilling to discuss it.
5. Do you have any concerns about being sexually appealing?	"Yes. I can't imagine a man (woman) really wanting to be intimate with me the way I am now."	Body image has been altered and self-esteem threatened. Apparently does not now feel sexually appealing.
	"I don't think so. My wife (husband) and I have talked about this and she (he) says it doesn't matter."	Has given the issue some consideration and has discussed it with the appropriate party.
6. Do you anticipate any problems with regard to sexual performance that amputation may create?	"I don't know. Will it really be a problem?"	Honestly concerned about topic. Probably has been unsure whom to ask about it. Would like information/discussion on the issue.
	"No."	Either does not anticipate problems or does not want to discuss the topic further.

Table III.

LEVEL OF FUNCTION—VOCATIONAL AND RECREATIONAL

Questions	Possible Responses	Probable Meaning
1. Describe the kind of employment you were involved in before your amputation.	"I've been retired for five years."	Does not see employment as a concern.
What are your job plans for the future?	"I'm a heavy equipment operator and I plan to go back to that."	Concerned about employment. May be unwilling to explore the appropriateness of this vocation in relation to the amputation or may be looking for the opportunity to discuss whether his or her goal is realistic.
2. If you anticipate a change, what kind will it be?	"I don't know if I'll be able to handle the heavy warehouse work. Maybe now would be a good time to go back and finish school."	Has given realistic consideration to his or her job future. May want to discuss options.
	"No changes. I'm a 'bouncer' and plan to go back to that"	Not inclined to discuss job changes at this time, but may need to deal with more immediate problems first.
3. What would be the best and worse things that might happen to you at work in the next few years?	"I hadn't really thought about it. There's so much happening to me now."	Presently overwhelmed with crises of moment. Needs more time to accept facts of loss and then begin to set goals.
	"People might think I'm not capable of doing my job anymore."	Is concerned about demands of the job and responses of others. Will need additional support and information.
	"My boss came in and told me that my job is secure and that they will find me another position if I can't go back to my old one."	Is receiving positive support and is willing to consider various job adjustments.
4. Describe the kinds of activities you were able to do before surgery.	"I live alone in my own apartment. Occasionally, I go shopping or take a bus ride."	Has independent lifestyle with only moderate physical demands. Therapy can be directed toward allowing him or her to meet these needs.
	"Very athletic. I play basketball and tennis, and I backpack and water ski."	Vigorous lifestyle with much physical activity. Might need information on adaptive sports equipment.
Which of these activities do you expect to resume?	"I just want to go back to my own place and not go to a nursing home."	Goal is to maintain sense of control over lifestyle by continuing to live independently.
	"I'd sure hate to give up my sports, especially tennis. Do you think I'll still be able to play?"	Concerned about threatened change in activity level. Seeking information about this concern.
5. Do you anticipate that the expense of an artificial limb will be a problem?	"I hadn't really thought about it. Do they cost very much?"	No concept of prosthetic costs.
	"I expect my insurance will pay for it."	Typical assumption. Not always accurate. Needs to have it investigated.

Table IV.

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Complications in the Use of the Halo Fixation Device†

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Since its introduction in 1959 by Perry and Nickel,[15] the halo fixation device has become the most common means used to immobilize the unstable cervical spine. Although it was initially designed to be used after surgery on patients paralyzed by poliomyelitis, its current use is primarily related to spinal trauma or reconstructive procedures on the cervical spine. The advantages include early mobilization of the patient and avoidance of the complications associated with prolonged bed rest, psychological benefits to the patient in terms of being able to walk or more fully participate in the rehabilitation program, and a shorter hospital stay. Compared with conventional orthoses, the halo vest or halo body jacket offers more rigid immobilization of the cervical spine, the ability to more precisely position the neck to obtain or maintain cervical alignment, and less interference with mandibular motion and eating.[1, 7-12, 14-17] However, the majority of the reviews in the literature concerning the halo have concentrated on its ease of application, the tolerance of the device by the patient, the degree of immobilization obtained, and its success in maintaining reduction and achieving healing after a fracture or arthrodesis.[3, 6-10, 12-14, 16-20]

Although other authors have reported complications in their patients, no prior report has concentrated specifically on the complications that may be associated with use of the halo fixation device. The purpose of this study is to evaluate the problems that we have observed.

MATERIALS AND METHODS

The medical records from the University of California at San Diego and affiliated hospitals and the Rancho Los Amigos Medical Center, Downey, California, of all patients with a diagnosis of fracture, dislocation, or instability of the cervical spine that occurred during the period from 1973 to 1983 were reviewed. Requirements for inclusion in the study included: (1) a history of continuous treatment with a halo device for a minimum of two weeks, (2) availability of the hospital chart and radiographs, and (3) a minimum follow-up of three months after the halo was removed. Emphasis was placed on identifying specific complications that resulted from the placement and use of the halo device. These included infection at pin sites,

loosening of pins, radiating pain or numbness around pins, pain with mastication, localized discomfort about a pin, residual scars left by pins, and pressure sores beneath the vest or cast.

The charts of 512 patients were reviewed. Due to lost charts or radiographs, incomplete records, or patients moving or being transferred to other facilities, only 179 charts were considered to have adequate documentation to be included in the study. Eighty-seven of these patients were from the Rancho Los Amigos Medical Center and 92 were from the University of California at San Diego Medical Center and affiliated hospitals. Fifty-nine of the 179 patients were contacted by telephone and asked to subjectively evaluate their pin-site scars and to classify them as either minimum, moderate, or severe. A minimum scar was defined to the patient as being unnoticeable or barely perceptible by close examination. A moderate scar was defined as noticeable, but shallow and not disfiguring. A severe scar was considered as disfiguring, deep, and associated with patient dissatisfaction.

These 59 patients were also questioned as to whether they had had pain at the pin sites while the halo was in place. Their replies were placed in four categories: no discomfort; minimum discomfort, which was tolerable; moderate discomfort, painful at times; and severe, prolonged discomfort.

One hundred and forty-three patients were male and 36 were female. The patients' ages ranged from 2 to 90 years, with a mean of 28.3 years. The length of follow-up ranged from three months to ten years after removal of the halo. The most common cause of cervical spine injury was a motor-vehicle accident (47%), followed in frequency by a diving injury, fall, motorcycle accident, or other trauma. Twelve patients had a congenital defect of the cervical spine.

Fifty-four patients (30%) had no neurological impairment, 53 (30%) had quadriparesis, and 61 (34%) were quadriplegic. Eleven patients (6%) had an isolated nerve-root injury.

Complications Associated with the Halo Immobilization Device in One-Hundred and Seventy-Nine Patients

Complication	No. of Patients	Percent of Patients
Pin-loosening	64	36
Pin infection	35	20
Pressure sores	20	11
Bleeding at pin sites	2	1
Nerve injury	3	2
Dural puncture	1	1
Dysphagia	3	2
Severe scars*	5	9
Severe pin discomfort**	18	18

Table I.
*Fifty-nine patients evaluated.
**One hundred and one patients evaluated.

RESULTS
(Table I)

Pin-Loosening

Loosening was considered to be present when a pin could be freely twisted by the examiner without resistance, or the tip of the pin was visible at the edge of the skin, rather than being secured against the skull. Loosening of one or more pins occurred in 64 patients (36%). A total of 716 pins (four per patient) had been used, of which 180 (25%) became loose. A loose pin was treated by either removing the pin and placing a new pin into a new site (75 pins) or tightening the existing loose pin *in situ* (105 pins). Of the 75 pins for which the site was changed, 55 remained tight, 13 loosened again, and seven became associated with infection. Of the 105 pins that were tightened *in situ*, 88 remained tight, ten reloosened, and seven became associated with infection.

Forth-three percent of the loose pins were diagnosed during the first month after application and 42%, during the second. Fifty-three percent of the pins that

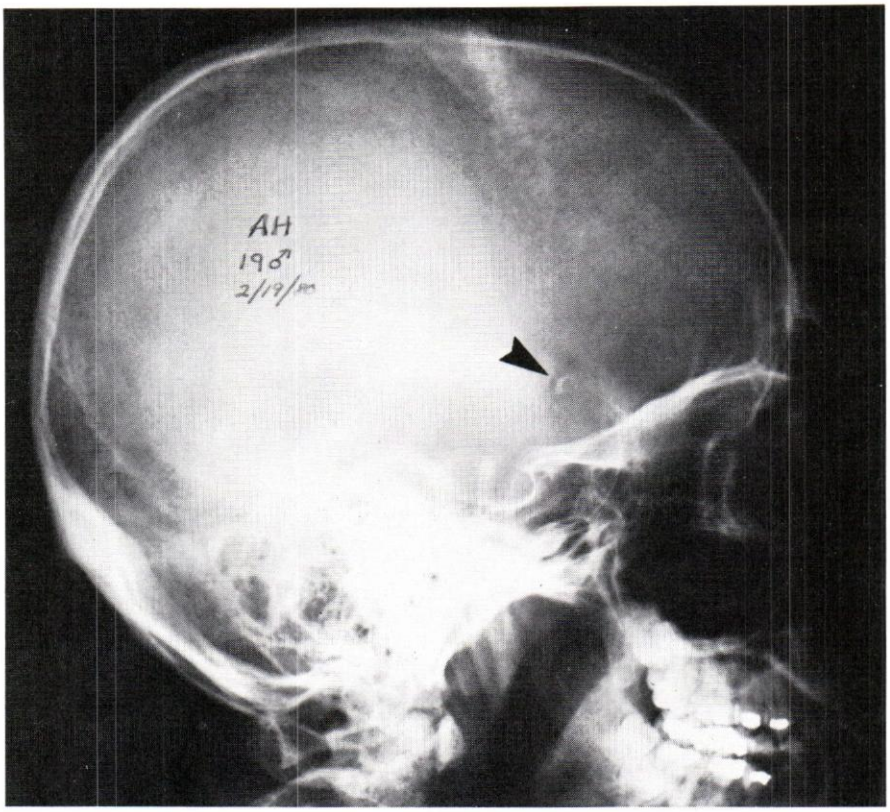

Figure 1. Lateral radiograph of the skull of a nineteen year old man in whom osteomyelitis developed (arrow) from a halo pin-site infection. A craniotomy was required to drain the resulting subdural abscess.

became loose were located anteriorly. Four of the six patients in whom the halo became completely dislodged gave a history of falling or sustaining a direct blow to the halo. In the other two, the dislodgement was noted when the patient arose in the morning.

Pin-Site Infection

Thirty-five patients (20%) had an infection at one or more pin sites. Sixty-seven pins (9%) were involved. Pin-site infection was diagnosed by either a positive culture or surrounding cellulitis. There were 26 superficial infections and ten deep infections. The deep infections included three cases of osteomyelitis (one resulting in a subdural abscess) (Figure 1) and two cases of septicemia.

The treatment of the infected pin sites varied. Thirty-three pins were changed and a new pin was placed at a different location. Thirty-one of these pin sites showed no further evidence of infection after the change, but two became infected a second time. Nine of the ten pin-site infections that were treated with systemic antibiotics, without changing the pin, healed. Eleven patients required removal of the halo device because of multiple pin-site infections. Seven of these infections healed, but four had persistent, chronic drainage from the pin sites. Nineteen percent of the infected pin sites were detected during the first month; 44%, during the second month; and 19%, during the third month. Sixty percent of the infections were observed around the anterior pins. Three of the 35 patients in whom a pin-site infection developed were treated with intravenous antibiotics, and eleven were given oral antibiotics. Surgical débridement was required in three patients with a pin-tract infection, including one craniotomy for drainage of a subdural abscess.

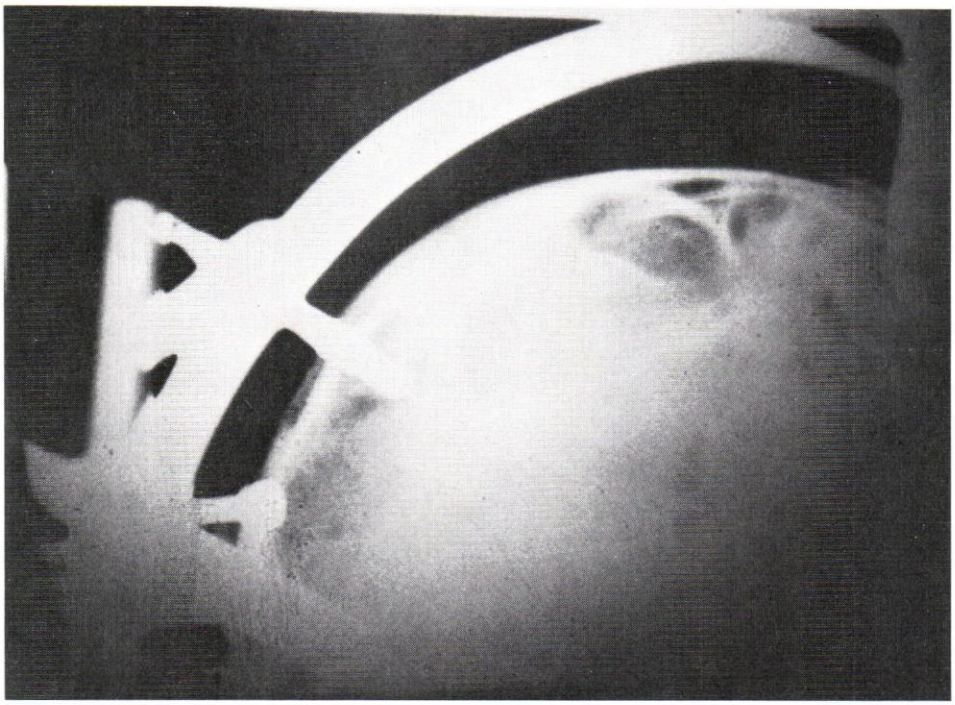

Figure 2. Lateral radiograph of the skull of a seventy year old man, showing penetration of a halo pin through the inner table of the skull.

Pin Penetration

A halo pin penetrated through the inner table of the skull in a 72-year-old man with a type-II fracture of the odontoid process (Figure 2). Nine weeks after application of the halo, the patient fell onto the left side. He felt minor pain around the anterior left pin, and a radiograph showed that the pin had penetrated through the inner table of the skull. When the pin was removed, a small amount of cerebrospinal fluid was noted. The patient was hospitalized and treated with antibiotics and elevation of the head, and a new pin was placed in a different site. The original pin site healed uneventfully, and no detectable neurological sequelae from the pin penetration were noted. No other patient had penetration of the pin through the inner table.

Pressure Sores

Twenty patients (11%) had the development of pressure sores under a halo plaster cast or a prefabricated vest. Fifteen sores developed under 83 casts and five, under 96 prefabricated vests. The sores were located on the trunk, usually in the region of the scapula or sternum. Of the 20 patients, 11 were completely quadriplegic, six were incommpletely quadriplegic, two were neurologically intact, and one patient had a head injury with impaired mental status. Four patients had the halo removed to aid in the treatment of the pressure sore. One patient required débridement only, one had a split-thickness skin graft, and one had a transfer of a local skin flap. All subsequently healed.

Nerve Injury

Injury to the supraorbital or supratrochlear nerve occurred in three patients. These patients all had the anterior pin placed above the medial one-third of the eyebrow. The complication was manifested by severe pain and paresthesias in

the region of the forehead and scalp above the anterior halo pin. All of these patients obtained relief after the pin was removed and the application site was changed to a slightly more lateral position. One patient had persistent paresthesias for six weeks, which then gradually resolved.

Pin-Site Bleeding

Two patients had sustained bleeding at all four of the pin sites while receiving heparin for the treatment of thrombophlebitis. In both patients, the bleeding subsided after the heparin dosage was decreased. None of these pin sites became infected.

Dysphagia

Three patients required readjustment of the position of the head in the halo because of dysphagia. In all three, the cervical spine initially was immobilized in hyperextension. Repositioning of the neck to less extension was performed without loss of reduction of the cervical spine fracture-dislocation for which the halo had been applied and resulted in immediate improvement in the ability to eat and swallow.

Pin Scars

Fifty-nine patients were contacted by telephone and asked to comment on the appearance of the pin scars. Five patients stated that they had obtrusive, severe scars and were dissatisfied with the appearance. Seventeen patients felt that they had moderate, noticeable scars, but that they could tolerate them. Thirty-seven patients reported minimum or no scars and had no complaints. One patient, a 21 year old black woman, had the development of keloids at both anterior pin sites; the keloids were treated successfully by surgical revision.

Pin Discomfort

Evaluation of pin discomfort while in the halo was made either by telephone contact (59 patients) or from statements included in the medical records (42 patients). Seventeen (17%) of the patients stated that the pain had caused severe discomfort. Twenty-two patients (22%) reported moderate discomfort; 23 (23%), slight discomfort; and 38 (38%) reported no pin discomfort.

Two patients complained of pain at the anterior pin sites while eating or laughing. In both of these patients the anterior pins were located in the temporal fossa, behind the temporal hairline. Placing new pins more anteriorly, over the eyebrows, and removing the existing pins led to immediate relief of the symptoms.

DISCUSSION

We have identified some of the major problem areas that are directly related to the halo immobilization device used for stabilization of the cervical spine. The largest percentage of complications were related to loosening and infection. At Rancho Los Amigos Hospital, loose pins have routinely been tightened rather than changed. No obvious negative consequences have been observed from this practice. We have noted, in the laboratory, that in cadaver skulls that have had halo pins applied experimentally at the recommended six-inch-pound (0.69-newton-meter) application torque the outer cortex of the skull is only partially penetrated by the halo pins. There is a solid margin of cortical bone to allow safe retightening. We have concluded, therefore, that it is safe to tighten loosened pins, assuming that some resistance is met during that procedure. Since loosening is often a forerunner of infection, its elimination or early correction is beneficial in the prevention of pin-tract infections and their sequelae. If no resistance is noted after a few turns of the pin, the pin should be removed, and a new one should be placed in a different site.

If infection at a pin site does develop, it seems prudent to administer systemic antibiotics and initiate early local wound care. If drainage, cellulitis, or other signs of infection do not improve, the site of the pin should be changed and more aggressive local, and perhaps parenteral, anti-biotic treatment should be instituted. Certainly, the prevention of infection would be preferable, and pin-site-care techniques, in-

cluding cleaning the pin sites with Betadine (providone-iodine) or hydrogen peroxide every other day, should be performed in the hospital and taught to the patient before discharge from the hospital. More frequent cleansing is not desirable and may lead to a low-grade infection caused by constant manipulation of the wound site. We do not know why the anterior pins are more apt to become infected.

The literature on the use of the halo device has paid little attention to the problems of loosening or infection of the halo pins, although these complications have been described.[3, 8, 9, 14] Four of the eleven patients with an injury of the cervical spine whose cases were reported by Thompson had loosening of the pins, and one had an infection. Nickel, et al. reported on 204 patients who had been treated with the halo device.[12] All of the patients who had been in a halo for more than two months had loosening of some of the pins. Most patients required at least one change in pin site. Many patients also had inflammation or infection in at least one pin site that required a change in the site. In two patients the halo dislodged, and three patients had osteomyelitis of the skull. Other authors have listed the same complications.[1, 3, 5, 8, 9, 12, 16, 17, 21] These findings, although incidental to the major emphasis of these other reports, are consistent with ours.

Pressure sores under the halo cast or vest have also been reported previously.[1, 9, 17, 21] In our series, 11% of the patients had pressure sores. The majority of patients with this problem were quadriplegics who lacked sensation in the area of the skin breakdown. This problem decreased markedly in our patients as awareness of this complication heightened, and early prophylactic medical and nursing care was initiated. Only five patients had pressure sores in the last four years of this review. A halo cast is now used less frequently, a prefabricated or molded vest being preferred. These allow easier inspection of the skin, perhaps more uniform pressure distribution, and better padding. Because of the problem of pressure sores and their effect on rehabilitation and health, early surgical stabilization of patients with a spinal cord injury should be considered when possible. Although this may lead to an entirely different set of complications, pressure sores in patients with a spinal cord injury can be devastating. Therefore, if possible, we now recommend early internal fixation and fusion of the cervical spine, particularly in elderly patients, quadriplegics, and quadriparetics, to eliminate the need for the halo and replace it with a more limited immobilization device which hopefully can be confined to pressure-sensitive areas.

Prolonged bleeding at pin sites occurred in two patients who had been receiving heparin for thrombophlebitis. Neither of these patients responded to packing or dressing of the pin sites, but the bleeding ceased after a decrease in the dosage of heparin. This possibility must be considered in those patients who require anticoagulative treatment while in a halo device.

Three patients in this series sustained an apparent compression of the supraorbital or supratrochlear nerve.[9] These nerves exit over the medial one-third of the orbit, and involvement occurs because of too medial a placement of the anterior pins. If the anterior pins are placed over the middle portion of the orbit, or slightly lateral, this complication should not occur.

Nine percent of the patients in this series were markedly dissatisfied with the scars. In general, most of the patients felt that the scars were acceptable or were a necessary outcome of the treatment of the spine injury. The older patients and the more severely injured patients were less likely to express concern about the presence of residual halo-pin scars. In the majority of patients there was only a small residual dimple.

Some authors have reported no complications with the use of the halo device.[4] However, we have found the overall complication rate to be relatively high. Loosening and infection are particularly common and imply that further basic research in halo-pin design and application is needed. To date, only changes in the suprastructure of the halo have been made since its first description by Perry and

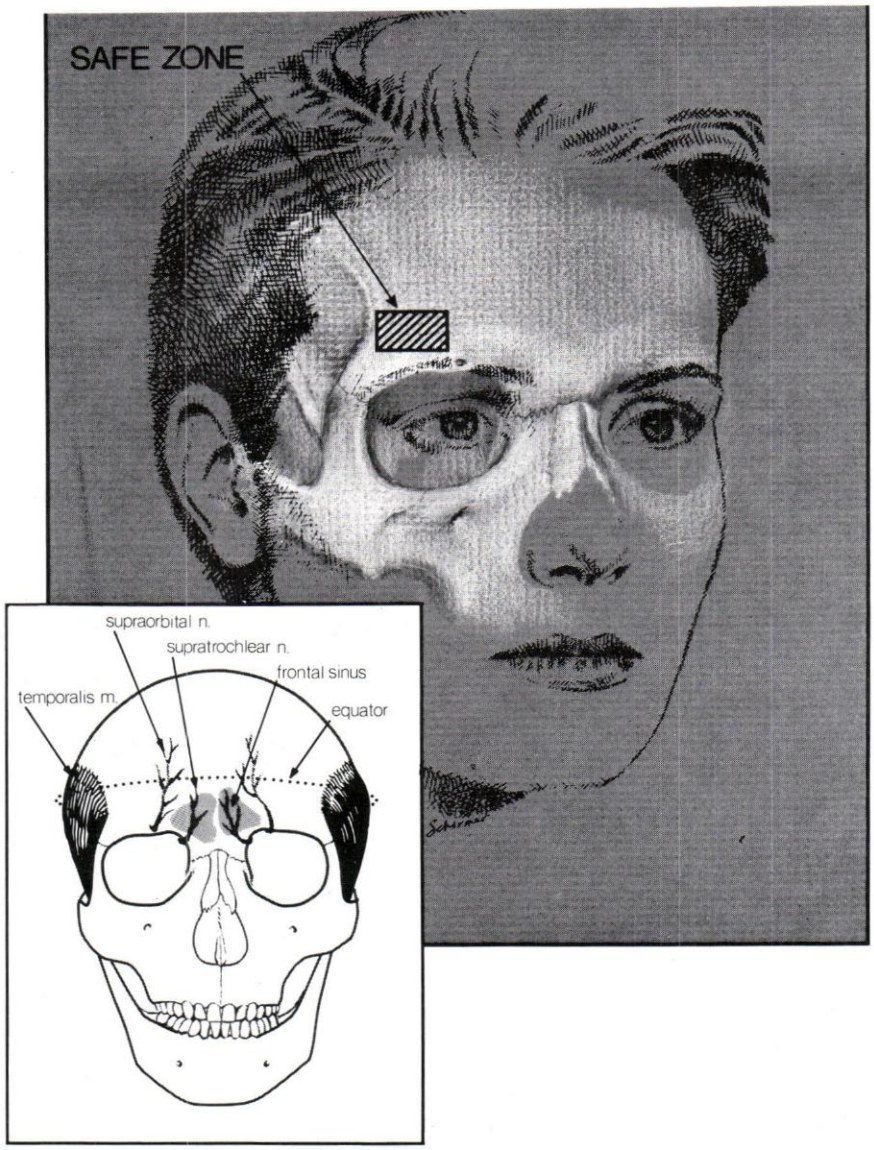

Figure 3. Drawing depicting the safe zone for anterior halo-pin placement. Laterally, the pin should be placed anterior to the temporalis muscle and fossa, to avoid possible painful mastication or penetration through thin cranial bone. Medially, the pin should be kept lateral to the middle portion of the superior orbital rim, to avoid the supraorbital and supratrochlear nerves or the frontal sinus. Superiorly, the pin should be kept below the level of the greatest skull circumference (skull equator), to avoid cephalad migration of the pin. Inferiorly, the pin should be kept above the supraorbital ridge to prevent displacement or penetration into the orbit.

Nickel[15] in 1959. The high-profile design has been modified to lower the uprights, in some cases four uprights or an interdigitating ratchet system have replaced the two high-fixation parts, and materials have been altered. However, the basic ring-and-pin design, as well as the recommendations for application, have not been altered. These concepts, also, have never been rigorously scientifically tested or challenged.[11] Our review is the initial step in an evaluation of the halo, and it does delineate areas in need of further investigation. We would like to emphasize, however, that no permanent serious sequelae from these complications occurred despite the documentation of problem areas.

Based on our experience, we recommend that the following strict guidelines be followed when applying and treating adult patients in a halo orthosis. The initial application torque in placing the pins in adults should be at least six to eight inch-pounds (0.69 to 1.12 newton-meters). We routinely tighten the pins 24 to 48 hours after the halo is first applied. Local pin care should be standardized, but not overly aggressive or disruptive to the pin site. If a pin is noted to be loose, an attempt at retightening to the original application torque should be performed, assuming that resistance is met during this procedure. The pin site should be changed and a new pin should be used if osseous engagement does not occur after a few complete turns. If infection or drainage is seen, cultures should be grown and the antibiotic sensitivity of the organism should be determined. If the patient's response to the antibiotics is not rapid, a change in the pin site should be considered. Anterior pins should be placed superior to the middle or lateral one-third of the orbit, below the greatest circumference of the cranium, to minimize the risk of loosening, dislodgment, and nerve damage. Also, the pin should not be placed over the temporal fossa or in the temporalis muscle. The cranial cortex is thin in that area, and pentration of the temporalis muscle may cause pain during mastication[2] (Figure 3).

Care and awareness should be exercised in applying a halo jacket or cast in the quadriplegic patient to avoid pressure sores. Although the halo is a very useful immobilizing device to apply initially to the patient with a spinal cord injury, consideration should be given to early surgical stabilization with internal fixation, thus avoiding the risk of pressure sores under the vest or cast.

By following these recommendations, we think that the risks of employing the halo cervical immobilizer may be minimized, although not completely eliminated.

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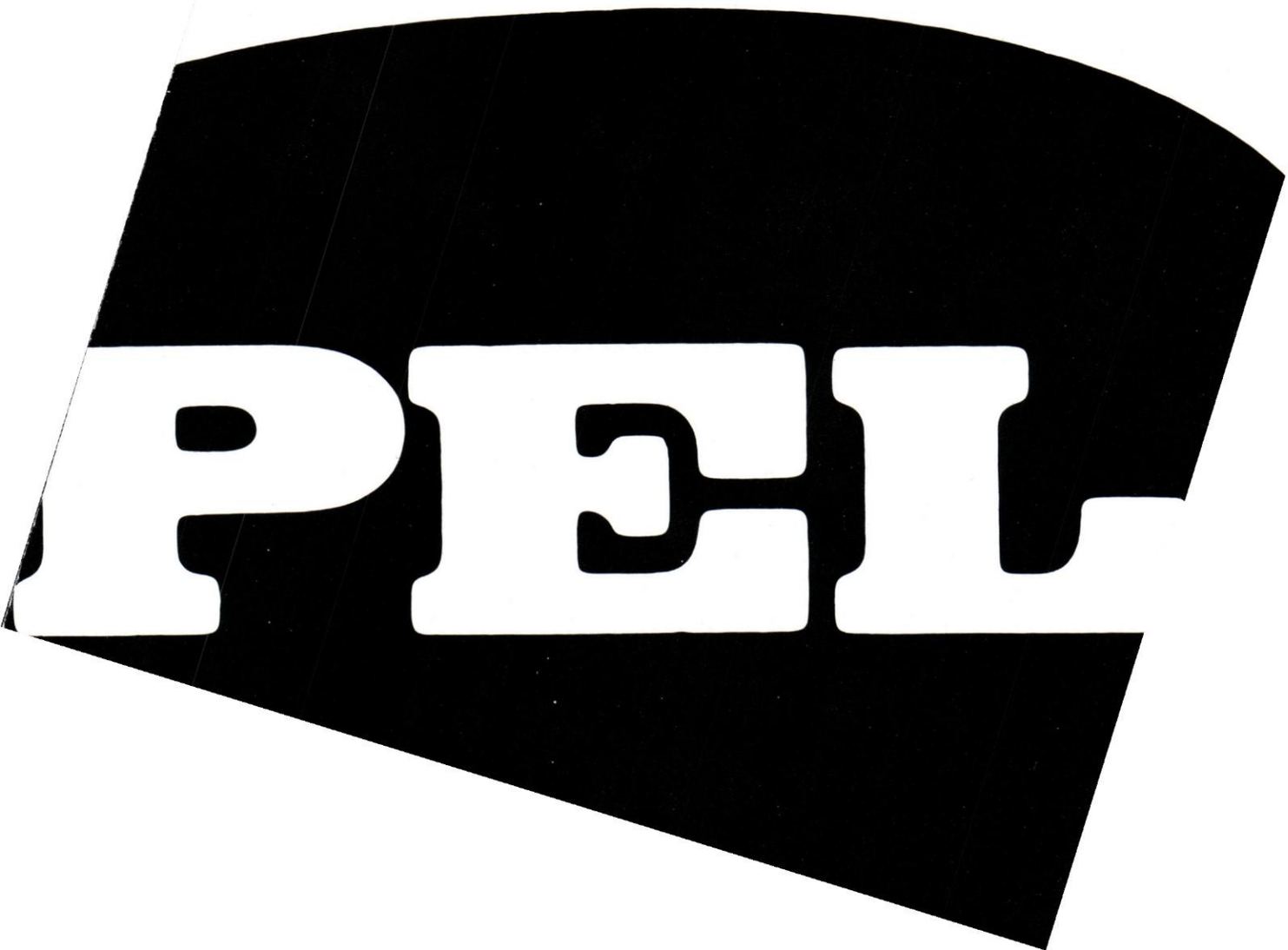

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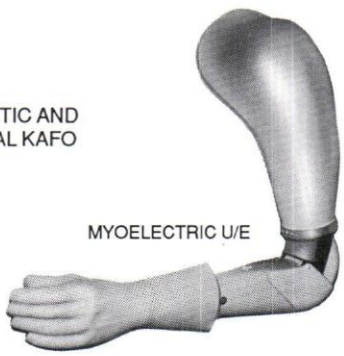

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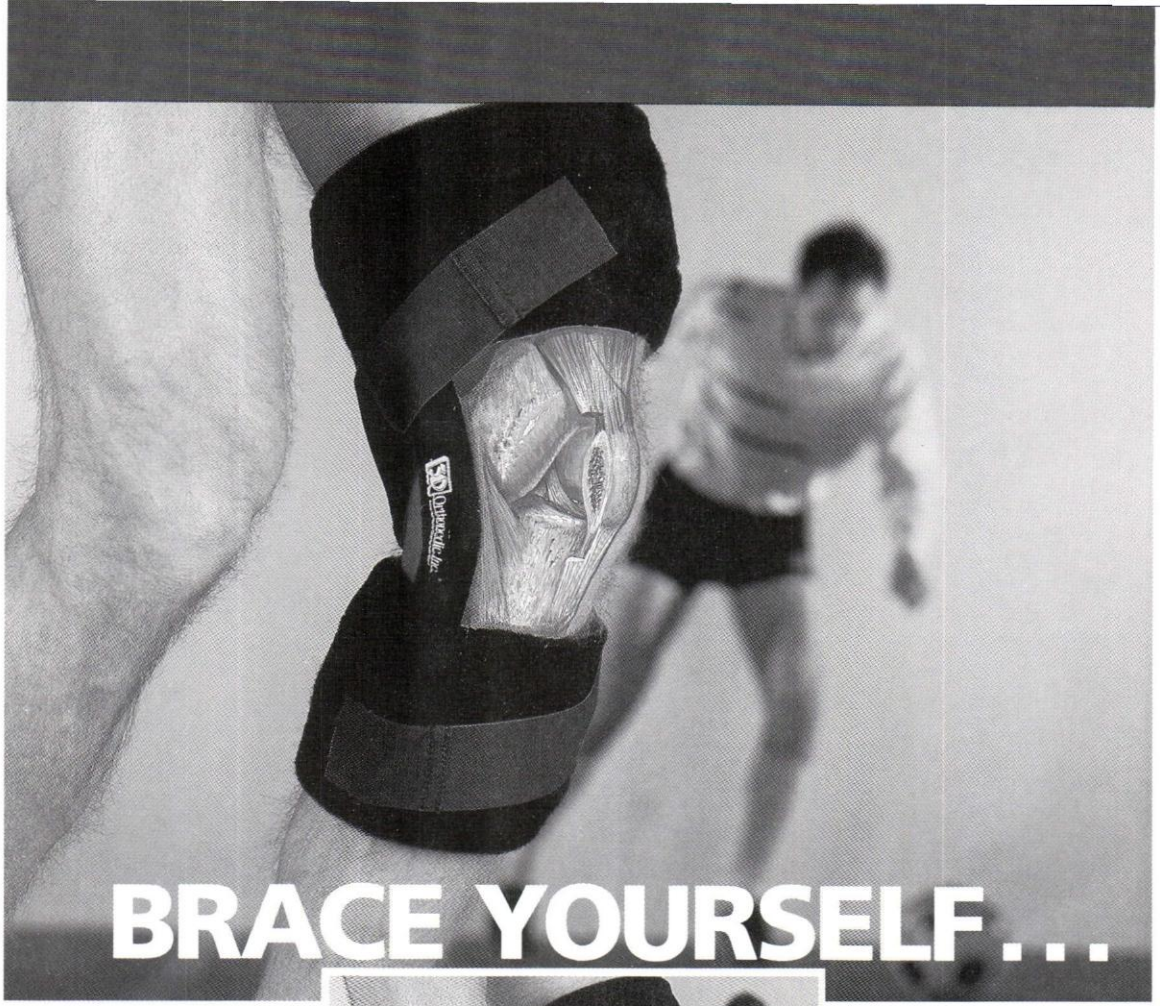

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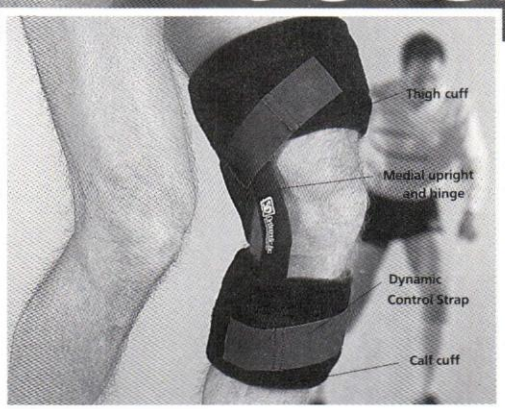

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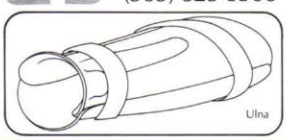

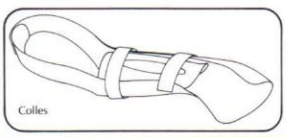

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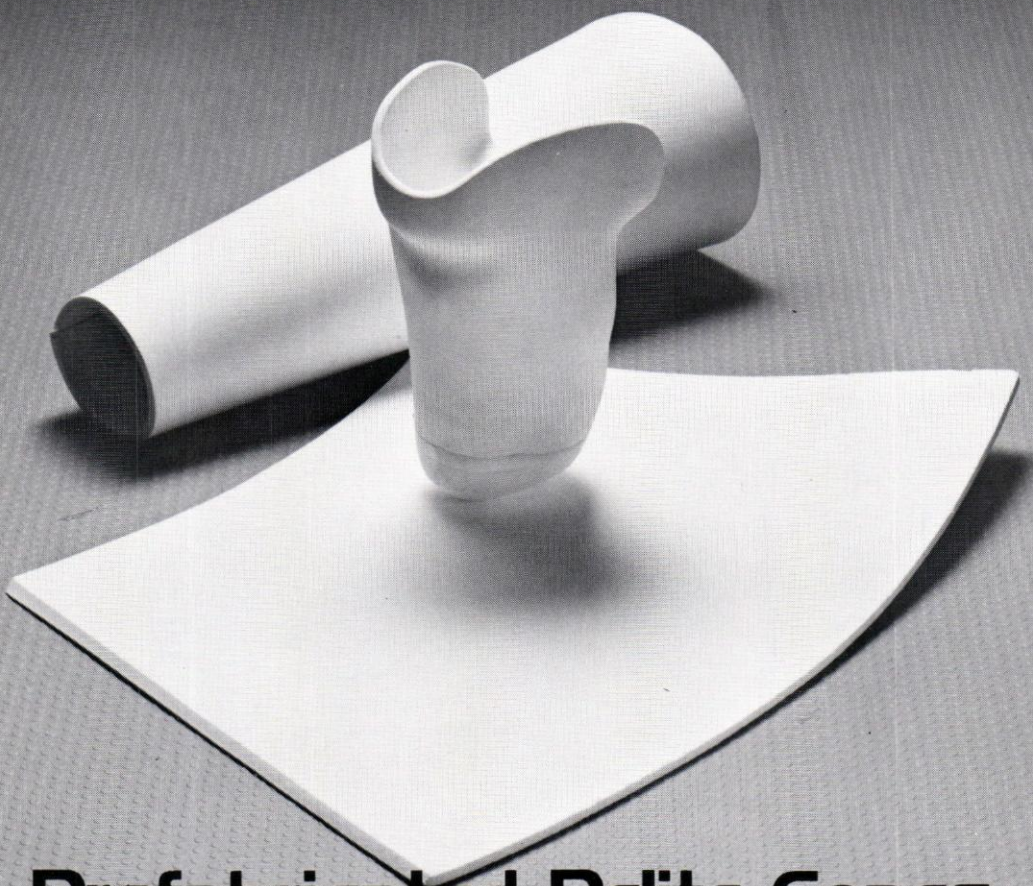

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Book Reviews

Prosthetic and Orthotic Educational Aids, Compiled

Joan E. Edelstein, M.A., P.T., American Academy of Orthopedic Surgeons, 222 S. Prospect Avenue, Park Ridge, Illinois 60608. 52 pages, 1987.

Increasingly, prosthetist/orthotists find themselves involved in a great variety of educational efforts. These activities occur not only in professional circles but among lay audiences as well. One of the most effective tools that can be used in such circumstances is an audio-visual presentation.

This book is an up-to-date catalog of such materials. It lists movies, video cassettes, and slide programs. Each entry is annotated briefly and includes instructions for obtaining the presentation. The book should be very useful to those who find themselves called upon to participate in the education of others about prosthetics and orthotics.

Lower Limb Amputations: A Guide to Rehabilitation

Gloria T. Sanders. F.A. Davis Co., 1915 Arch Street, Philadelphia, Pennsylvania 19103. 607 pages, Index, 1986. $45.00.

This book reveals the results of much effort and research. Its profusely illustrated and extensive bibliographies accompany each chapter. A good deal of space is devoted to extensive descriptions of surgical procedures, prosthetic fabrication techniques, and analysis of the static and dynamic alignment of prostheses. Relatively less material is devoted to therapy.

However, the book for all of its excellent qualities is uneven and even disturbing. The amount of attention devoted to a particular topic seemingly has less to do with the significance of the topic and more to do with the availability of written material devoted to the matter. It would seem that the reader is expected to be equipped to perform a variety of amputations and build a PTB prosthesis after reading the book. Less attention is paid to prostheses for other levels and to other topics. A number of devices of an experimental basis which are produced locally on a limited on-off basis are presented as though they were commercially available. Yet, transparent thermoplastic check sockets, which are perhaps the single most important factor to influence prosthetic practice in the last 15 years, are given scant attention and described as primarily research tools. The advantages and disadvantages of below-knee prostheses with open end sockets, joints, and corsets receive equal attention as PTB style prostheses, as though the author would seriously suggest that the two receive equal attention in a prescriber's consideration for a new amputee.

The reviewer is left with the feeling that the book is illuminated less by practical experience than by exhaustive research and that not enough attention was given at the outset as to what the purpose of the book is and who the audience is.

The advanced student of the topic capable of forming independent judgements will find the book useful, nonetheless, for its excellent bibliographies and broad scope.

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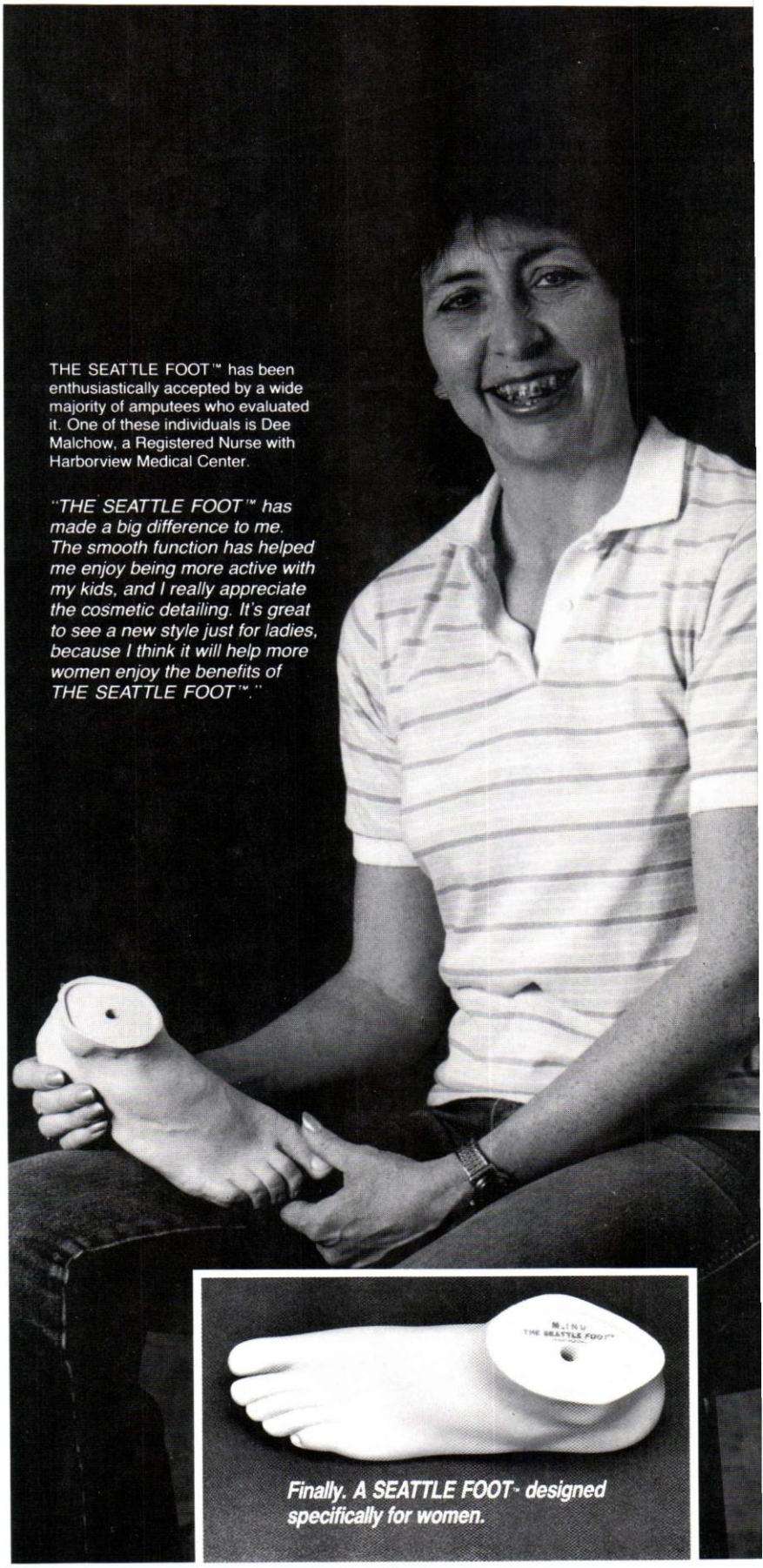

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Prehension Assessment Prosthetic Therapy for the Upper-Limb Child Amputee

Ed. David E. Krebs. Slack, Inc., 6900 Grove Road, Thorofare, New Jersey 08086. 898 pages, 3 appendices, bibliography.

This book reports the efforts of a number of clinically experienced therapists who were drawn together in a brief symposium. Their goal was to develop a test instrument to be used in evaluating the prehension capabilities of unilateral below elbow preschool children. It is envisaged that such a test would be used to assess not only the capabilities of an individual patient but also terminal devices and therapy techniques.

It contains a number of papers of a conceptual nature, the proposed test and instructions for the use of the test. It must be borne in mind that the efforts and the technique are tentative. This book should primarily be of interest to those who are deeply involved in the subject.

Charles H. Pritham, C.P.O.

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