
December 1981
Volume 35
Number 4

# Orthotics and Prosthetics

Journal of the American Orthotic and Prosthetic Association

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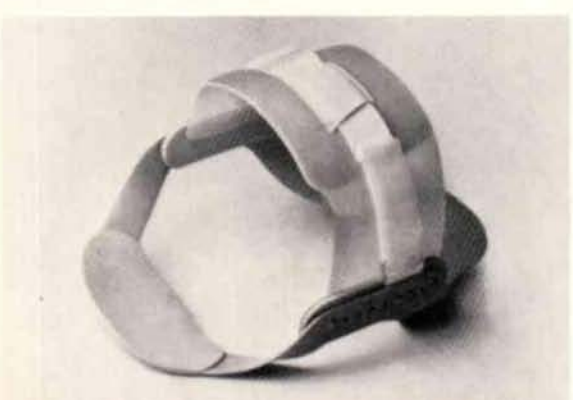

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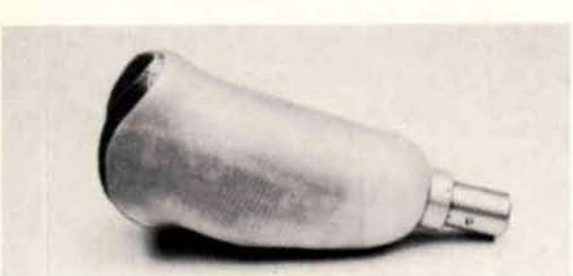

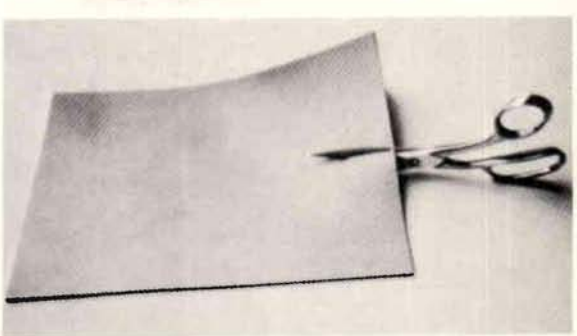

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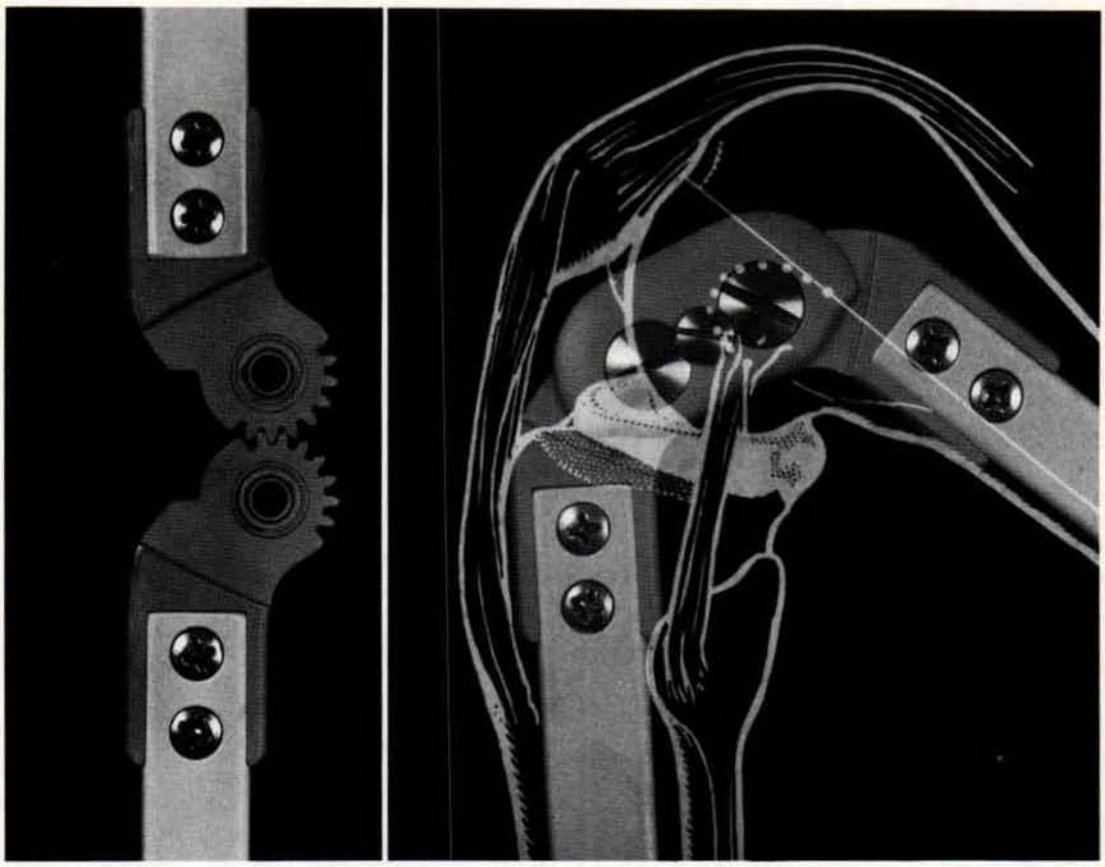

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# Orthotics and Prosthetics

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**December 1981 Journal** **Volume 35, No. 4**

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# Meetings and Events

**Please notify the National office immediately concerning additional meeting dates. It is important to get meeting notices in as early as possible. In the case of Regional Meetings, check with the National Office prior to confirming date to avoid conflicts in scheduling.**

**1982, February 4-6,** AAOP Annual Round-up Seminar, Fairmont Hotel, New Orleans, Louisiana.

**1982, March 2-6,** Boston Scoliosis Brace Course, sponsored by the Children's Hospital Medical Center of Boston. Course location: Cincinnati, Ohio.

**1982, April 16-17,** AOPA Region I Meeting, Marriott Hotel, Worcester, Massachusetts.

**1982, April 29-May 1,** AOPA Regions VII, VIII, X, XI Combined Meeting, Alameda Plaza, Kansas City, Missouri.

**1982, May 6-9,** AOPA Region IV Meeting, Radisson Plaza Hotel, Nashville, Tenneessee.

**1982, May 10-13,** Advanced Course on Below-Knee and Through-Knee Amputations and Prosthetics, ISPO, Copenhagen, Denmark.

**1982, May 27-29,** AOPA Region V Meeting, Charleston House, Charleston, W. Virginia.

**1982, June 1-3,** Canadian Association of Prosthetists and Orthotists, National Convention, Skyline Hotel, Ottawa, Ontario, Canada.

**1982, June 4-6,** AOPA Region IX, COPA, and the California Chapters of the AAOP Combined Annual Meeting, Harrah's, South Lake Tahoe, Nevada.

**1982, June 10-13,** AOPA Regions II and III Combined Meeting, Claridge Hotel, Atlantic City, New Jersey.

**1982, June 17-20,** AOPA Region VI and AAOP Midwest Chapter Combined Meeting, Indian Lakes Resort, Bloomingdale, Illinois.

**1982, September 8-10,** Second Annual Advanced Course of Lower Extremity Prosthetics, Nassau County Medical Center, East Meadow, New York.

**1982, October 17-24,** AOPA National Assembly, Shamrock Hilton, Houston, Texas.

**1983, May 12-14,** AOPA Regions II and III Combined Meeting, Colonial Williamsburg, Williamsburg, Virginia.

**1983, June 3-5,** AOPA Region IX, COPA and the California Chapters of AAOP Combined Annual Meeting, Harrah's, South Lake Tahoe, Nevada.

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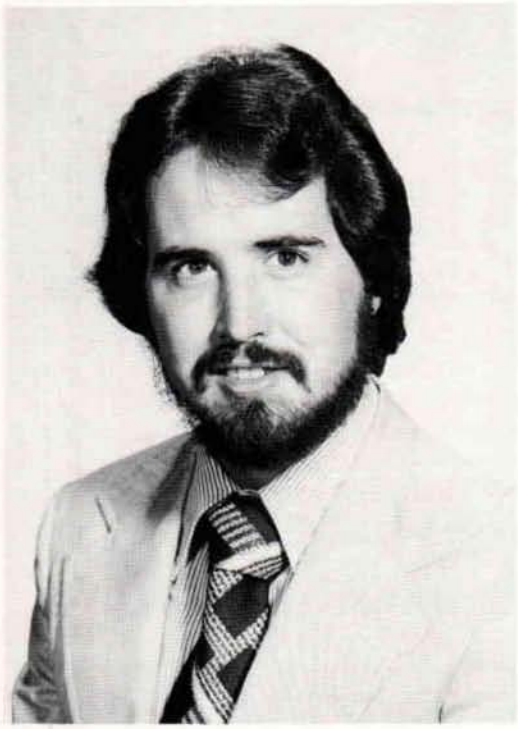

Mike Quigley, CPO, editor of the *Orthotics & Prosthetics Journal*, and the National Office staff have initiated an "Author Assistance Program" to assist new authors in the preparation of *Journal* articles. The purpose of the program is to generate new articles for the publication.

If a practitioner has an idea for an article, he would contact Mike or the National Office. Mike or the National Office staff would assist the practitioner in developing an outline and abstract to be reviewed by the Editorial Board. Upon approval of the abstract, the practitioner would receive assistance in the preparation of the article. This assistance would include tips on taking photos or providing other illustrations, general organization of the article, grammar and style. Upon completion of an article, the Editorial Board would conduct a final review before approving it for publication.

This program will provide many practitioners who have developed procedures; developed or adapted prosthetic/orthotic device(s) and/or their components, but are unsure of writing, with a means to contribute to the *Journal* and to share their valuable knowledge and experience. With the abstracts reviewed by the Editorial Board, a practitioner who is uncertain of his idea would have an answer before spending the time and effort writing an article. The result is more articles published in the *Journal*, thereby increasing the technical information pool from which all practitioners may have access and learn, and increasing the professionalism and prestige of the publication.

If you would like to take advantage of the program, please contact Mike Quigley, CPO, Oakbrook Prosthetics & Orthotic Services, Medical Arts Center, 1634 S. Ardmore St., Oakbrook Terrace, Illinois, 312-620-5333 or the National Office.

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# Prosthetic Management of Adult Hemicorporectomy and Bilateral Hip Disarticulation Amputees

**Charles H. Dankmeyer, Jr. C.P.O.**
**R. Doshi, C.P.O.**

## INTRODUCTION

Since the origin of prosthetics, cases of significant challenge or those which are by nature very rare have spurred considerable interest. Cases which were at one time extraordinarily difficult to provide an acceptable prosthetic restoration have now become very manageable. Concurrently, medical technology has provided life saving techniques which have produced classifications and levels of amputations unknown to us only a few years ago. As the surgical techniques which were used to create the following cases become more common, all of us will have to address the best approach to provide prosthetic care for these individuals. The case histories which follow demonstrate the development of our current management system for hemicorporectomy patients.

## CASE ONE: HEMICORPORECTOMY PATIENT

The first case is a level L•4 hemicorporectomy due to a traumatic injury. This patient had not been able to be upright since his injury. The distal spine was sharp and extremely sensitive. He was unable to lie on his side because he had no means to maintain himself in that position. He alternated between being prone and supine, neither of which were acceptable for a lifetime. The initial effort in this case was to get the patient erect at a normal sitting height and prevent excessive inferior aspect pressure. The problems were how to suspend him comfortably without any pressure on his distal spine and provide him with balance so that he could lean from side to side as well as fore and aft without tipping over.

On clinical examination this patient could be supported under his ribs with our hands while another prosthetist balanced his upper trunk; rib suspension, not unlike but different from the concept of suspension seating used in orthotics, could therefore be used. However, no distal weight bearing could be tolerated and trunk balance would also need to be provided. Confining the use of this device by mounting it to a wheelchair was restrictive and therefore undesirable.

## *Negative Mold*

A negative mold of the patient was taken by suspending him under his axillae inside a Hoyer lift. This technique was felt to allow for a more natural extension of his lower body and provide an accurate means of determining the proximal sizing of the trunk support. This technique has since been abandoned as this information is not necessary in the negative mold and the casting system is uncomfortable to both patient and prosthetist.

## *Mold Modifications*

Modifying this mold so that the underside of the rib cage is fully supported requires deep undercuts the thickness of the ribs themselves plus approximately one inch. The undercut followed the natural contour of the ribs and had a generous radius of 1½" as the mold began to extend distally. The proximal radius, which encases the outer border of the lower ribs where the mold extends proximally was allowed to follow the natural shape of the patient. A small amount of relief was made for the spinous processes. Modifications to this point provide a good weight bearing surface, and an accurate trunk mold.

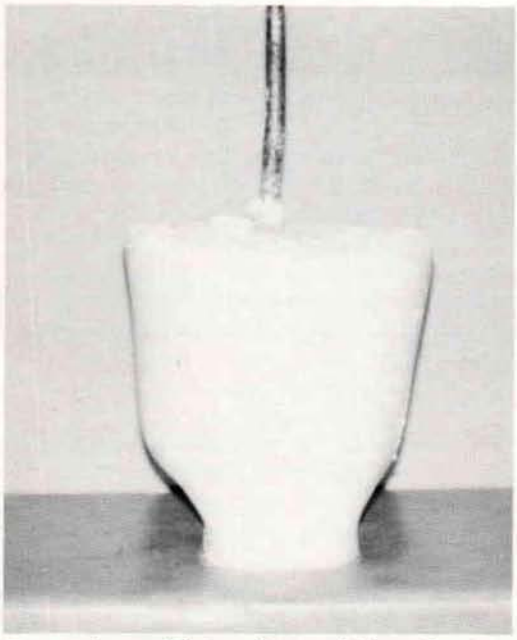

**Fig. 1 – The modified positive mold for a hemicorporectomy patient. A base extension was added to provide a base of support and was originally intended to house the iliostomy and colostomy containers.**

The next step in modifying the mold was to provide a surface which would allow the patient to sit erect without external support and not be so bulky as to inhibit transfer activities. A base equal to the size of his rib cage in the transverse plane would cause a great deal more effort to be expended in transferring from floor to an armchair, wheelchair to auto, etc., since the additional hollow bulk would cause him to reach farther and lean at a greater angle in order to complete these manuevers. The distal extension was also intended to make his sitting height more normal to make up the trunk length lost. Initially, this extension was designed to house the iliostomy and colostomy containers. We made our extension so that it was 6" long and from a frontal plane center line extended 30% of the width of the rib cage on each side of center. In the sagittal plane, the extension was made 40% the width of the rib cage to each side of the center. The resultant form was quadrilateral and almost square (Fig. 1). The mold was left high under the arms, over the scapulae, and over the sternum anticipating that the final trim lines would be determined at the fitting.

## *Fabrication*

The socket was laminated with polyester resin at 90% rigid, 10% flexible and eight layers of nylon stockinette using fifteen inches of mercury vacuum. After the socket was removed from the mold, it was found that the length of the extension would not be adequate to provide proper sitting height. To correct this, the socket was fitted into a wood block left very long to be adjusted at the fitting (Fig. 2).

## *Fitting*

At the fitting, the proximal trim was cut one inch below the inferior angle of the scapulae. This line was carried under the arms and across the anterior portion just below the nipple line and covering part of the sternum.

**Fig. 2—In the original design, a wood block was added to the socket extension and left long. This would be adjusted at the fitting for proper sitting height. In later designs, it was found that a measurement could provide the correct height so the wood block was eliminated.**

In order to don the prosthesis, the patient had to lay supine, raise his lower trunk by pushing downward with his arms, simultaneously inching himself into the socket. This was a slow and tedious process and also caused the iliostomy and colostomy containers to be forced upward and eventually upside down. An anterior panel was cut out of the socket which allowed the patient to raise his trunk and place it in position inside the socket in one swift motion. The inferior edge of the panel was cut to allow two inches between it and the remainder of the socket. This created a small "window" which allowed easy access to the iliostomy and colostomy bags. The panel is held in place with four 1½" velcro straps and metal loops. The anterior panel also allowed some position adjustment for tightness.

With the patient upright in the socket, the height of the extension was modified to allow his palms to touch the table while the elbows were just slightly flexed. This was just enough to allow him to lift the socket up for transfer and also provided a very natural trunk height allowing his arms to fall in good position on chair armrests. Shoulder straps were attached to suspend the socket.The wood block had been almost completely removed which confirmed the original amount we had extended the mold as correct. The patient was able to balance easily on the smallish appearing base and could reach objects in all directions without fear of tipping over (Fig. 3).

The prosthesis was given a finish of two nylon stockinettes impregnated with 90% rigid, 10% flexible polyester resin. The base was covered with a ¼" thick piece of neoprene crepe. Medium density ⅛" thick plastazote was applied over the rib support area to provide some cushioning, but more to increase the friction and prevent slipping in the smooth socket. The sitting prosthesis was then considered complete (Fig. 4). A pair of hand held blocks were made so the patient could clear the floor and move about his house without being in a wheelchair.

## *Addition of Limbs*

After using this device for approximately six months, the patient returned to report that he was able to transfer, move about his house, and drive a car with hand controls. The quality of his life had definitely been improved and he was satisfied with his functional level. He requested that limbs be attached to the prosthesis for cosmetic purposes. A ¼" thick steel plate was fastened to the socket base extending laterally to each side to allow attachment of Otto Bock free motion modular hip joints in a normal position (fig 5). The balance of the limbs consisted of Otto Bock modular safety knees, rotation units, and SACH feet.

The patient was able to ambulate in the parallel bars with a swing through gait as well as twisting gait due to the rotation units (fig 6). This system satisfied the patient's desire to "walk" in parallel bars and his need for cosmesis, but the addition of limbs made the entire system less functional for transfer and mobility at home. The patient gained a significant amount of weight after this modification and returned for a new prosthesis.

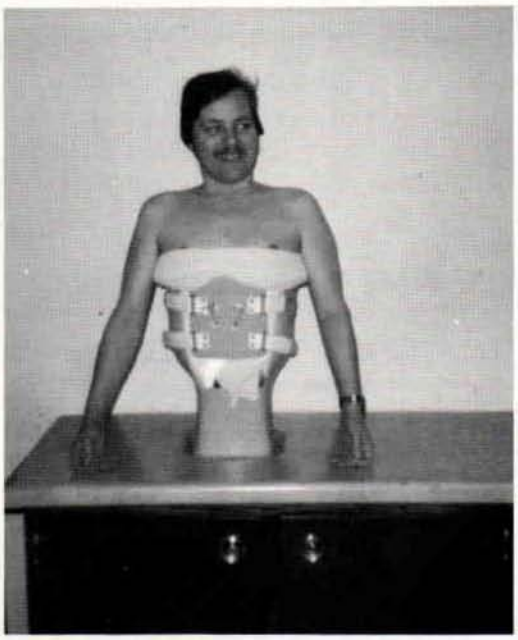

Fig. 3 – The patient was able to balance easily on the smallish appearing base and could reach objects in all directions without fear of tipping over.

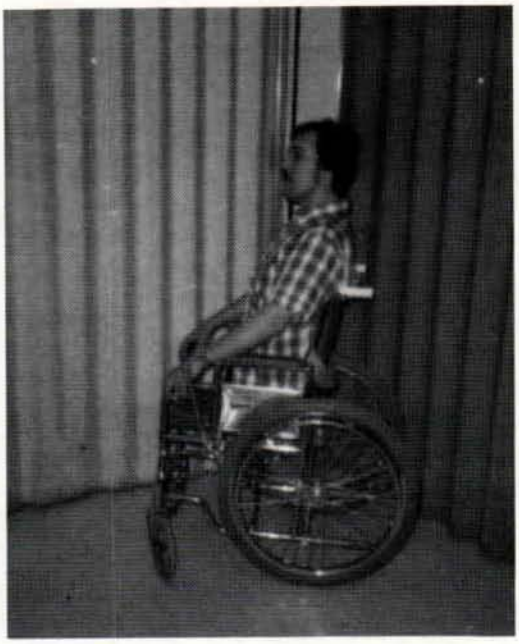

Fig. 4A – Wheelchair sitting. The patient could lean back comfortably in the wheelchair.

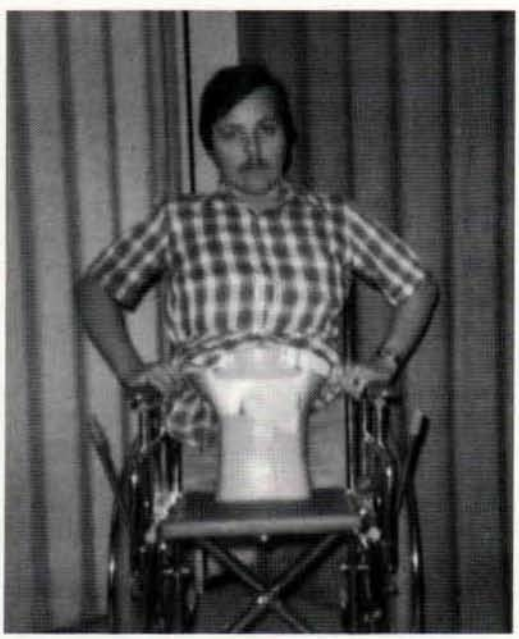

Fig. 4B – Elbow clearance is not a problem and the patients sitting height appears normal.

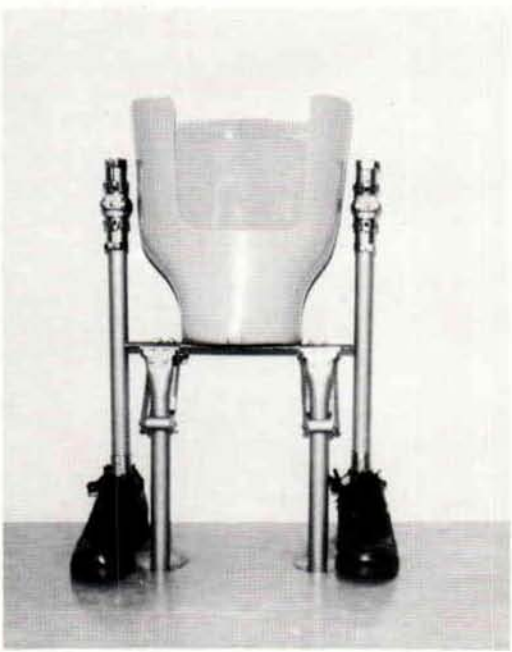

Fig. 5 – After the sitting prosthesis was in use for six months, the patient requested that the limbs be attached. A ¼" steel plate was bolted to the base and the modular system was attached.

## *Removable Socket System*

Having learned that the socket alone was more functional, but that cosmesis was also very important, the second prosthesis was made in two segments. The new negative was made by a split cast technique. With the patient prone the posterior half was made. This was used for the patient to rest in when turned to supine position. The anterior mold was then made. The casting was easier for both patient and prosthetist. Identification of the lower margin of the ribs was easily formed as the plaster bandage set. This technique was more accurate than the first because the trunk was not suspended freely allowing it to both extend and narrow down.

The modifications were done the same as previously described. No wood block was attached as the proper amount of extension was predetermined. Socket fitting and trim were also done in the same manner. The difference was in providing a system which would permit the patient to use the socket alone or attach it to the modular lower limbs at his discretion.

The socket was placed on the mold and a PVA sleeve pulled over it as a parting agent. A lay up of four layers of nylon stockinette was made over the socket and again laminated with polyester resin. Wood blocks were glued to the thin shell to allow attachment of the Otto Bock modular hip joints in a standard position. The hip attachment plates were attached to the wood and the entire assembly smoothed and given a finished coat of two layers of nylon stockinette. The balance of the modular units were attached and finished to this lower segment. The socket was then able to be easily removed from the cosmetic lower limbs. The square shape of the extension of the socket allows it to key into the prosthesis allowing no relative motion between the segments. This system proved very satisfactory and answered the prosthetic needs the patient required (Fig. 7-11).

**Fig. 6—The patient could ambulate in the parallel bars with a swing through gait. The rotator units in the limbs also allowed a twisting gait. The prosthesis was more cosmetic, but less functional with the limbs attached because they could not be removed easily from the socket.**

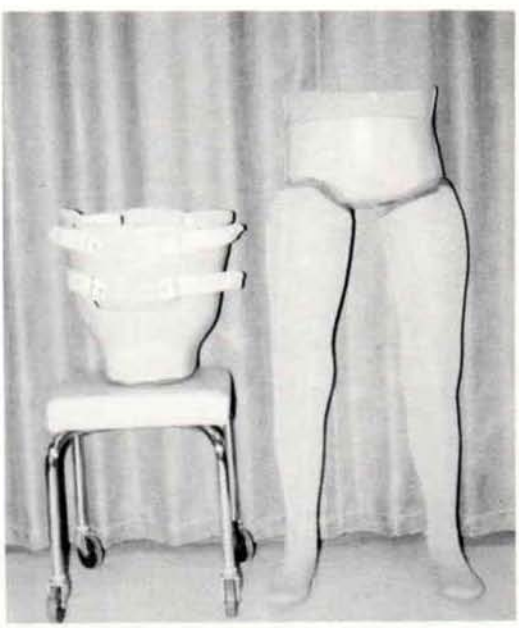

**Fig. 7—The patient's second prosthesis had a removable socket which enabled him to use the sitting prosthesis (socket and extension) for maximum function, or to key the socket into the prosthesis for cosmesis. The square shape allowed no relative motion between the segments.**

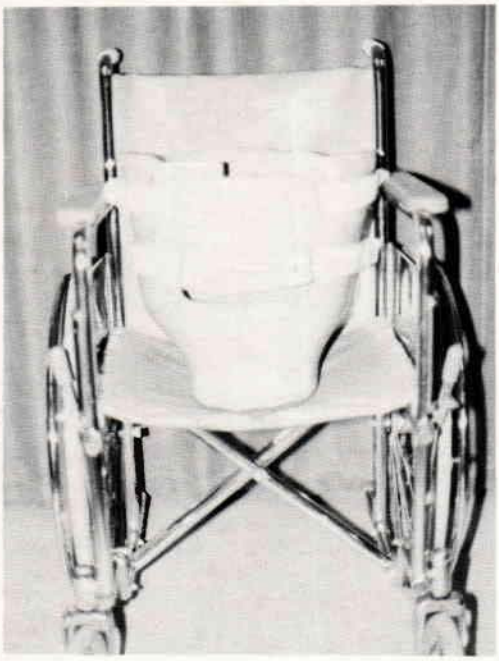

Fig. 8 – The socket in place in a wheelchair. The removable anterior panel allowed ease of donning and adjustability of fit.

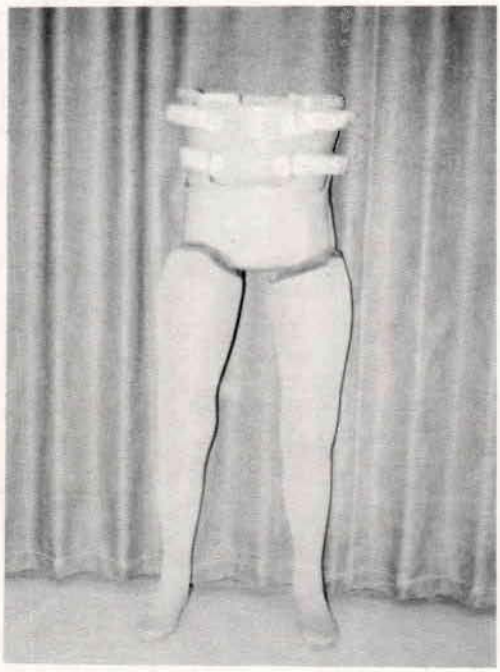

Fig. 10 – The socket keyed into the prosthesis in a standing position.

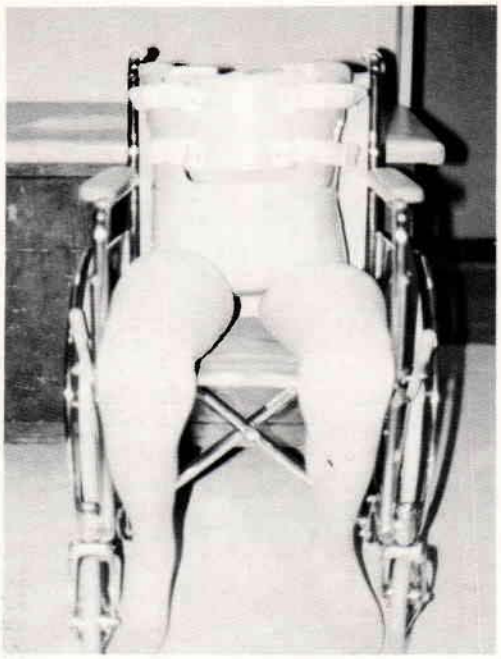

Fig. 9 – The socket keyed into the prosthesis in a sitting position.

## CASE 2: BILATERAL HIP DISARTICULATION

One bilateral hip disarticulation patient was fitted with this same technique. This patient could not tolerate any distal pressure due to a large ulcer over the sacrum. His amputations were secondary to circulatory problems and diabetes. A minimal amount of extension of the socket was needed as his pelvis was intact and only needed suspension to protect the unhealed area (Fig. 12). This patient did not desire lower limbs. The socket only provided him with protection for his wounds, sitting balance, and ease in transfer. Since there was no trunk length loss, the base of this prosthesis is the full size of the socket.

## CASE 3: HEMICORPORECTOMY PATIENT

A second hemicorporectomy was fitted with the complete socket and removable cos-

metic limbs. This patient was a high level paraplegic and also diabetic. His amputations were the result of repeated pressure sores from sitting. He had little trunk balance but the high trim lines of his socket provided support. The trim lines were made much higher in this case to provide more trunk support because of the high level paraplegia (Fig. 13). A special "seat base" was also needed to make this patient feel secure from tipping over, again due to the paraplegia. This base was used primarily in the wheelchair and was a female key to the distal square shape of the socket. This keying provided security between the socket and base. After a few months use, this patient returned to us at which time the trim lines were lowered as he now demonstrated improved trunk balance. The posterior trim was brought down to one inch below the inferior angle of the scapulae; The same anterior trim line just below the nipple line has been satisfactory on all cases.

**Fig. 11 – Prosthesis as it would appear in normal use.**

**Fig. 12 – Bilateral hip disarticulation patient. The entire width of the socket was used as the base since there was no trunk length loss.**

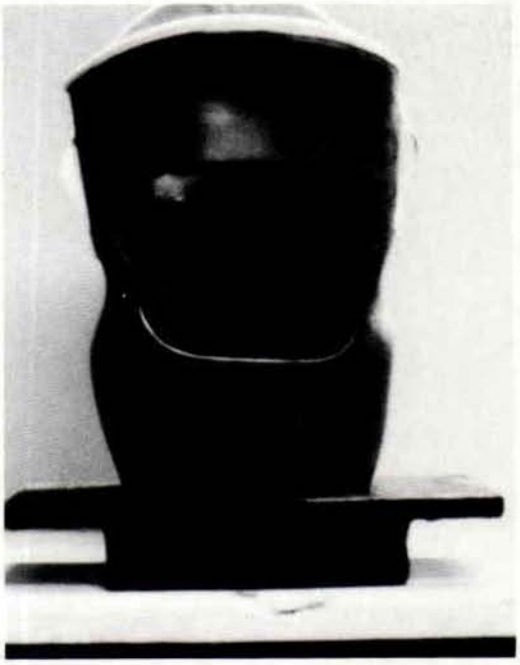

**Fig. 13 – Socket for hemicorporectomy patient with paraplegia and diabetes. A higher term line was required for trunk support. A wider base was also needed for more support.**

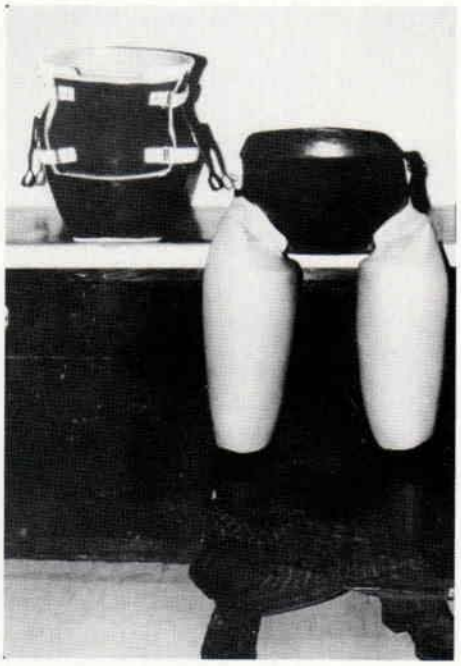

**Fig. 14—Removable socket system used on hemicorporectomy patient with paraplegia.**

A third hemicorporectomy secondary to parplegia and pressure sores with an unhealed grafted area over the distal spine was also fitted with the socket only to provide him with an upright position, protect the skin graft, and provide mobility. This patient is currently a college student.

A few additional measurements will greatly ease the fabrication of these devices. The length of the extension can be determined by measuring the amount of space from the end of the trunk to the table top while the patient is supported on the palms of his hands with elbows slightly flexed. This length is the amount of extension needed. The diameters of the rib cage, both lateral and anterior posterior will provide a more accurate positive mold modification.

# A Method For Custom Seating of the Severely Disabled

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**Carol I. Leiper, M. Ed., L.P.T.**[2]

## INTRODUCTION

The need for specialized seating systems for the severely involved individual has been apparent for many years. Such individuals can be described as being dependent in transfers, severely contracted in many joints, with significant fixed spinal deformity involving severe rotation as well as lateral deviation. Generally, one hip is dislocated and there is concomitant thigh length inequality. Frequently there is a problem with control of the neck and head. These individuals are often stunted in growth, and have sparse soft tissue. Techniques to provide seating systems for such persons have been extremely limited and consist mainly of carving pieces of open cell foam to fit around body prominences. The execution of this method has frequently been the responsibility of the occupational or physical therapist, requiring large amounts of the therapist's time and still resulting in an unsatisfactory product. With the introduction of modern plastic technology into the field of rehabilitation the means of providing improved postural support systems has become more readily available.

One approach has been the development of a modular seating system, the Molded Plastic Insert (M.P.I.), to meet the needs of the moderately involved child with cerebral palsy (1,2,3). Recently the M.P.I. system has become commercially available.[3] Another approach, Foam-In-Place, results in a flexible foam cushion contoured to the body surface and derived from using the body directly as the mold (4,5). Other techniques that use the body as the mold for an impression that leads to a custom made total contact shell have been described. (6,7,8,9).

In general, two methods of obtaining the impression have been documented; i.e. prone or supine positioning of the client. In prone positioning (6), the individual is positioned face down with hips flexed over the edge of an examining couch or an "A" frame. While the client is held in the proper position by assistants an impression is taken using either plaster-of-Paris splints (protecting the clothes with drapes) or with a vacuum dilatency bag. This method of acquiring an impression has the advantage of being simply and inexpensively achieved. Doubts persist, however, about its efficacy as the individual is being cast in an unnatural position where none of the gravitation or postural reactions are active.

For the supine positioning method, the subject is held in the actual desired seated position, and the impression is taken using vacuum dilatency bags. Vacuum dilatency bags consist of airtight bags filled with some small grained medium (polystyrene beads, crushed walnut shells, sand, etc.) attached to a vacuum pump. At normal atmospheric pressure, the contents of the bag will slide past each other and thus are moldable. When a vacuum is applied the bag is sucked in on itself, the contents are compressed, the surfaces interlock preventing slippage, and the bag becomes rigid. The great virtue of this technique is that the fit of the impression can be evaluated while vacuum is maintained and if judged unsatisfactory the vacuum can be released and the bag remolded. In effect, the vacuum dilatency bag can be used much the same as a test or check socket is used in prosthetics.

After observing and attempting several of the previously described methods, it was decided to combine the more desirable features and materials of each in order to construct a custom, padded, covered seat easily interfaced with a variety of wheeled bases.

## EQUIPMENT

An adjustable fitting chair was used with vacuum dilatency bags. The base of the chair was the same as that used in the Foam-in-Place process (4). The chair was modified for the vacuum dilatency bags by the addition of plywood surfaces. The horizontal seat panel slid back and forth to allow for adjusting to proper seat depth and was further adjustable by means of two "trays" to accommodate for thigh length inequality. The vertical back panel is non-adjustable but removable (Fig. 1). The chair itself, by virtue of the original design, allows for the patient to be reclined to various angles and for the angle of the seat relative to the back to be changed.

Instead of one large vacuum dilatency bag, as is commonly used, it was decided to use one bag for the pelvis and thighs, and a second bag for the trunk. This meant that full attention could be devoted to positioning the lower supporting segments of the body prior to any attempt being made to position the trunk. Polystyrene beads, by virtue of their

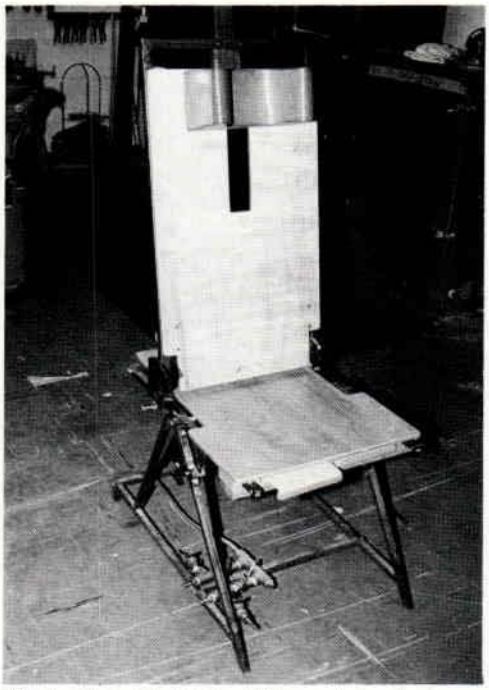

**Fig. 1—The adjustable fitting chair. Seat reclining, fitting and depth may be adjusted.**

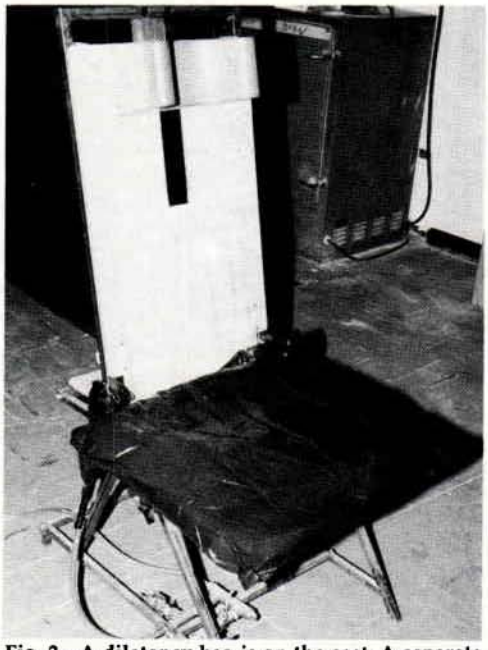

**Fig. 2—A dilatency bag is on the seat. A separate bag is used for the back. A double knit pillow seat is filled ⅓ to ½ full with polystyrene beads. A vacuum hose inserted in the bag will evacuate the air and provide a firm mold.**

static charge, cling to everything and are messy to work with. To obviate the need to handle them directly, two sacks of thin double-knit material were constructed, each about 24" × 24" and filled about 1/3 to 1/2 full with the beads. The top and bottom surfaces of the sack were loosely sewn together with a mattress stitch about every 4" in a grid pattern to keep the beads more evenly distributed. One end of a plastic tube was masked with a layer of cloth and secured to an edge of the cloth sack. To prepare the sacks for use each was positioned flat inside a 2 or 3 ply plastic trash bag and the opening sealed shut using double faced adhesive carpet tape and electrician's tape. The bags were smoothed flat and held in place on the chair using the same double faced adhesive carpet tape. The plastic tubes were secured to the valve arrangement that permits one or both bags to be depressurized, and full or partial vacuum to be applied (Fig. 2).

## NEGATIVE IMPRESSION PROCEDURE

The client should be accompanied by the mother, physical therapist, or other adult familiar with the client's daily activities and postural pattern. The goals to be achieved with the seat should be carefully defined and a physical assessment completed to determine ranges of motion, body prominences, and other relevant factors. The fitting chair, minus the bags, should be set to roughly the proper dimensions and attitude. If desired, the client can be briefly positioned on the chair to refine the desired position. The vacuum dilatency bags, connected to the vacuum source, are laid flat on the floor, and smoothed to a uniform thickness. As an aid in this step it may be desirable to apply a partial vacuum. The bags are then secured in place on the chair, while the partial vacuum is retained, and the client positioned on them. The partial vacuum makes the bags malleable and of a consistency like modelling clay or lead. The seat portion should be molded first before doing the back. Care should be taken to insure that the anterior edge extends fully in the popliteal space of both legs and that an adequate pommel, if desired, is present (Fig. 3). It should be borne in mind that the bag will shrink as full vacuum is applied.

Once a satisfactory fit has been achieved and full vacuum applied to the seat, the trunk section is done in a similar fashion. Make sure that adequate support is provided in the lumbar region and from any lateral extensions, although if the bag extends anteriorly much past the mid-line on both sides of the trunk difficulty may be encountered in extricating the individual. The mold can extend up to include the head if required. If the mold is judged unsatisfactory the vacuum can be released and the process started over. To facilitate this, the bag or bags can be reinflated by briefly using an air hose. Once a satisfactory impression has been achieved the subject should remain in it for 15–30 minutes and observed for his reactions. During this time, the angle of inclination can be varied and its effect on the individual observed. Trimlines should be marked on the trash bags using a broad tip felt pen. The individual should be removed with care so as not to disturb the position of the bags and the

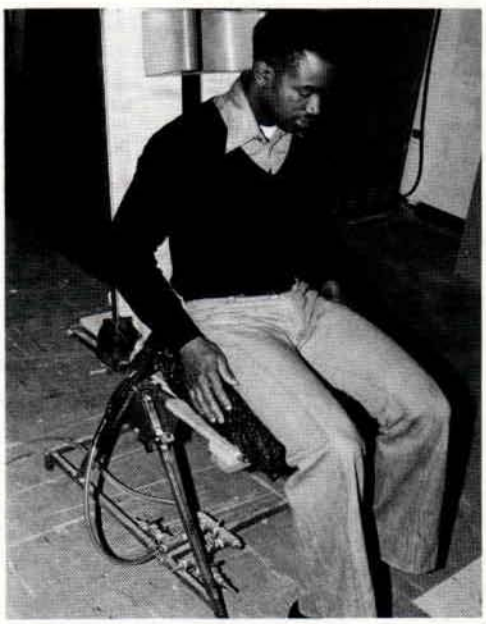

**Fig. 3 – The dilatency bag is smoothen and placed on the seat. After the seat depth and angle has been set, the patient sits on the bag and is comfortably positioned. Vacuum is applied and the cushion becomes firm, leaving a negative impression. Partial vacuum may be used to modify the impression.**

skin inspected for pressure areas. Measurements denoting the desired inclination should be taken from the chair and vertical reference lines marked. At no time can the vacuum be released without losing the impression (Fig. 4). If the patient has a wheelchair or other wheeled base that is to be used with the finished seat, it should be measured. This concludes the evaluation and casting session, and the client can return home.

An impression is now taken of the vacuum dilatency bags using plaster-of-Paris splints. The transition zone between the two bags can be bridged with broad masking tape to provide continuity of surface and trimlines. While it adds considerably to the time spent on the casting process covering the entire involved surface of the two bags with masking tape creates a smoother cast. Indelible pencil should be used to make sure that all previously marked lines transfer to the splints. Once the plaster has set, the vacuum can be released and the two bags separated from the plaster-of-Paris model. The trash bags can be removed from about the cloth sacks and discarded.

**Fig. 4—Completed seat impression. The patient remains in the seat for 15-30 minutes to test the fit. The patient's skin is checked for pressure areas. Plaster splints are used to make a permanent impression. When a back mold is also required, masking tape may be used to bridge the gap between the seat and the back.**

# FABRICATION

The plaster model should be positioned upside down on a table and the edges extended down to the table top with more splints. The interior of the model should be reinforced with a thick coating of plaster-of-Paris with rigid urethane foam (8). The plaster-of-Paris splints are left in place and not stripped off. The top surface is scraped some to smooth it, but the vast majority of the smoothing is done by adding plaster. Undesirable undercuts or protruding areas are filled. Two or three coats, smoothing with rasps and sand cloth after each, may be necessary to attain the desired results (Fig. 5). The model is prepared for vacuum-forming by drilling holes in the low areas, positioning it on the platen, and covering it with orlon-spandex bathing suit (or leotard) material.

The seat is fabricated of three separate layers. The first or innermost layer is of Naugaform®[4], a vacuum-formable version of Naugahyde®. Naugaform® comes in two ver-

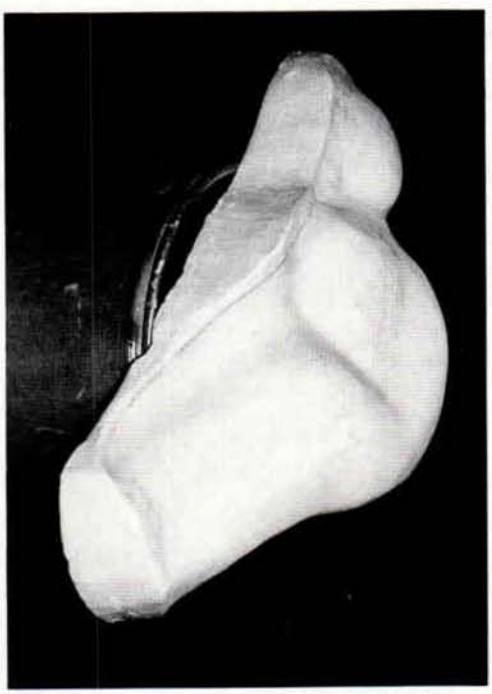

**Fig. 5—Positive mold ready for vacuum forming.**

sions, one cloth backed and the other foam backed (no cloth reinforcement). The foam backed version is the one of choice as the absence of reinforcement means it can be formed over objects of greater surface complexity and of greater height. Foam back Naugaform® is available in limited quantities by inquiry directly to Uniroyal. It is a polymer of PVC and therefore moldable in a temperature of 350°F to 400°F. Once vacuum formed, the Naugaform® is left on the model and secured in place with staples about the periphery.

The second layer is of one inch closed-cell foam padding vacuum formed over the Naugaform®. The padding used was Enso-Foam®[5], a closed-cell Polyolefin foam manufactured by Uniroyal. Enso-Foam® behaves like the various closed-cell polyethylene foams long familiar to the field of prosthetics and orthotics and is available in two densities and a range of thicknesses. The most reasonable way to fasten the two layers together is to actually do it during the process of vacuum forming the Enso-Foam®. Royal® M6321-Contact Bond Adhesive[6], another product of Uniroyal, is recommended for this application. The adhesive is applied to the two surfaces, the Enso-Foam® is heated, and vacuum formed over the Naugaform® and model. It may prove necessary to puncture small holes in the Naugaform® with a hypodermic needle in the various low lying areas of the model. Once the Enso-Foam® is vacuum formed it is left in place, untrimmed, and the third layer is molded over it. This is of 3/16″ or 1/4″ Kydex, a copolymer of acrylic and PVC. To facilitate vacuum forming the Enso-Foam should be covered with a layer of bathing suit material. Once the Kydex has cooled the seat is trimmed to approximate trimlines and is ready for temporary mounting on an interface. To finish the edges of the two interior materials, either trim the edges even and then dye the exposed Enso-Foam® surface, or leave the Naugaform® longer and roll it over the Enso-Foam. Both methods avoid permanent attachment to the third layer of Kydex. The eventual need to dismantle the seat either in part or in total should be

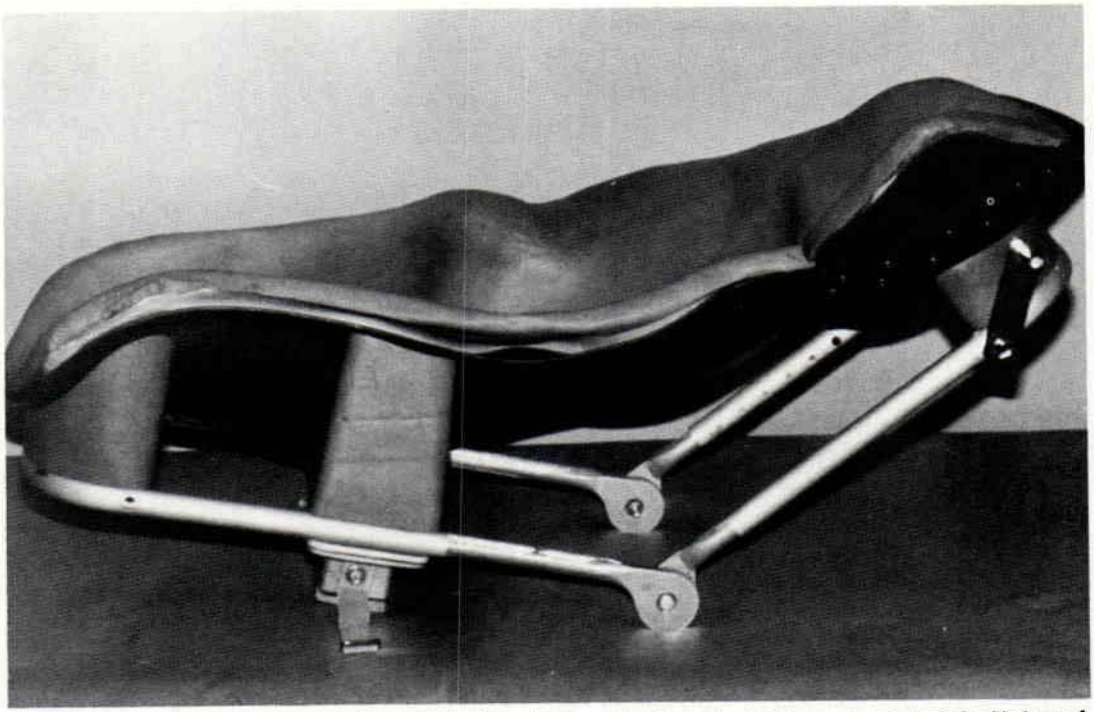

**Fig. 6—Finished seat mounted on plywood platform to frame for the wheeled base, also called the Universal Telescoping Interface.**

kept in mind. Fastening the Enso-Foam® to the Kydex with Velcro patches allows for this.

Devising and fabricating a suitable interface to mount the seat on a wheeled base can involve considerably more time and effort than the rest of the seat put together. One method involves the use of plywood and urethane foam. Another uses metal fixtures that are attached to the seat and hook in brackets mounted on the frame of the wheeled base. A third technique employs an outer plastic shell in which the seat is placed and the void between the shell and seat filled with foam (8). A newer technique which offers particular promise involves the Universal Telescoping Interface (UTI). The UTI is an integral part of the previously described MPI system and is used to hold the seat and back portions in proper position and to mount them in a wide variety of wheeled bases. The seat and back portions of the UTI can be elongated or shortened and the angular relationship between them changed. Four metal outriggers are mounted on the frame and can be adjusted for width. The outriggers

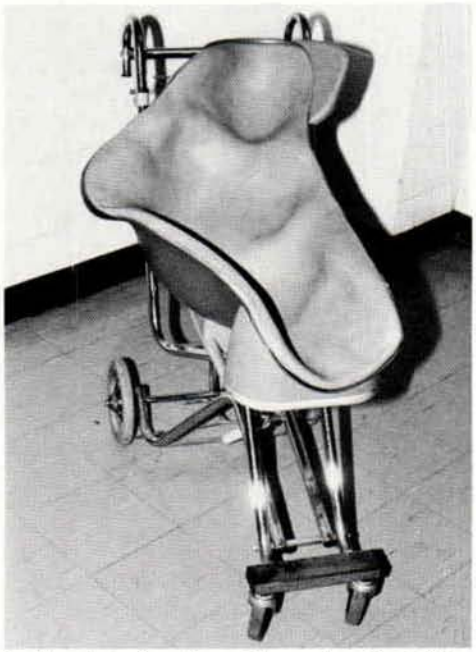

**Fig. 7A – Anterior view of the seat on the orthokinetic travel base. Small, lightweight and inexpensive wheeled bases, such as strollers or the Pogon (McClaren) buggy are satisfactory.**

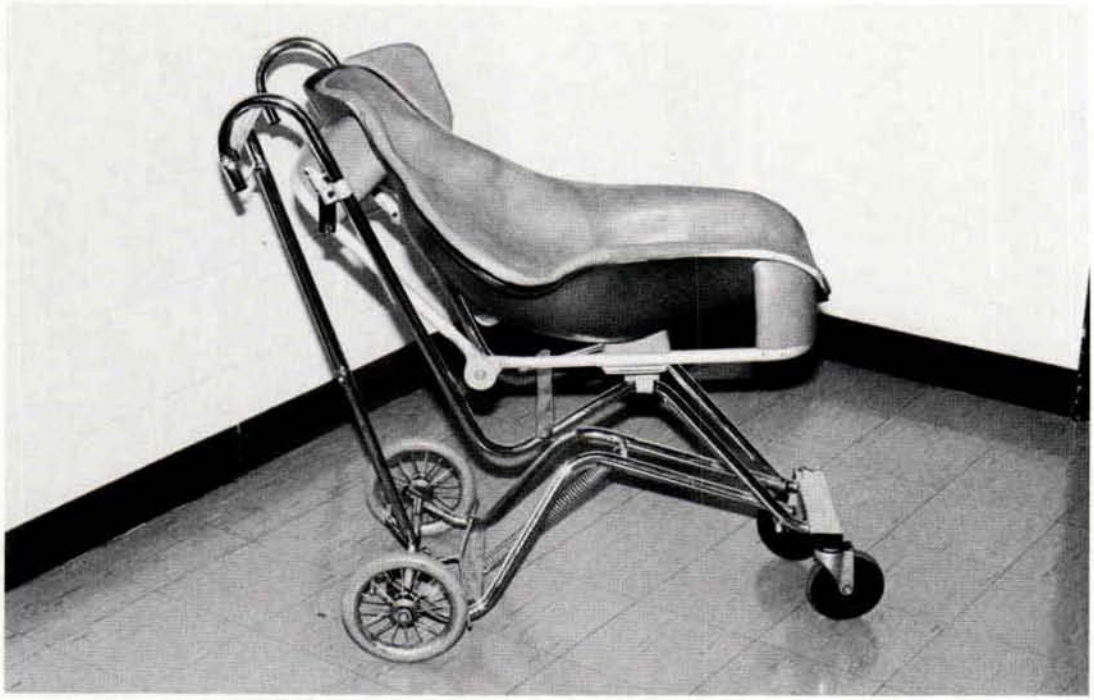

**Fig. 7B – Lateral view. In this case, independent mobility was not a consideration.**

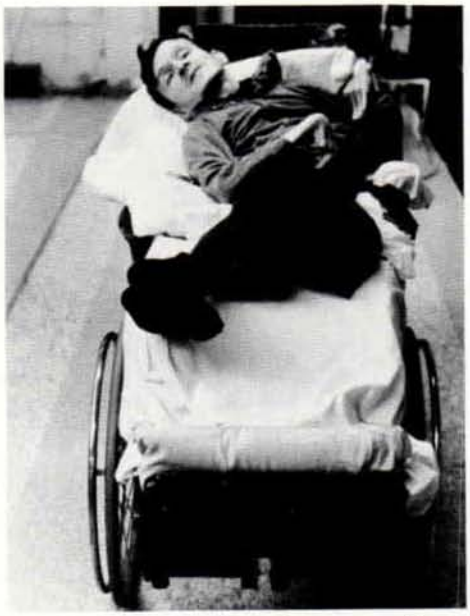

Fig. 8A – The system the patient was previously using was large, cumbersome and heavy.

are secured to the frame of the wheeled base by metal attachment brackets. By manipulating the positions of the outriggers and brackets the position and angle of inclination of the seat can be modified. At either end of the UTI a metal bracket is secured for attachment of a foot rest and headrest. For this particular application these brackets were removed and plywood platforms secured in their place. The seat was mounted in the proper alignment on these platforms temporarily and the void between the platform and the surface of the seat filled with rigid foam. A similar platform sitting on the frame of the UTI and under the pelvic area of the seat was devised. Once an initial fitting was performed and the orientation of the seat relative to the UTI verified, the outer surfaces of the three platforms were covered with scrap Naugaform® to present a finished appearance (Fig. 6).

Selection of an appropriate wheeled base may be constrained by the need or desire to use what the individual already has (Fig. 7a,b). If it should prove appropriate to select

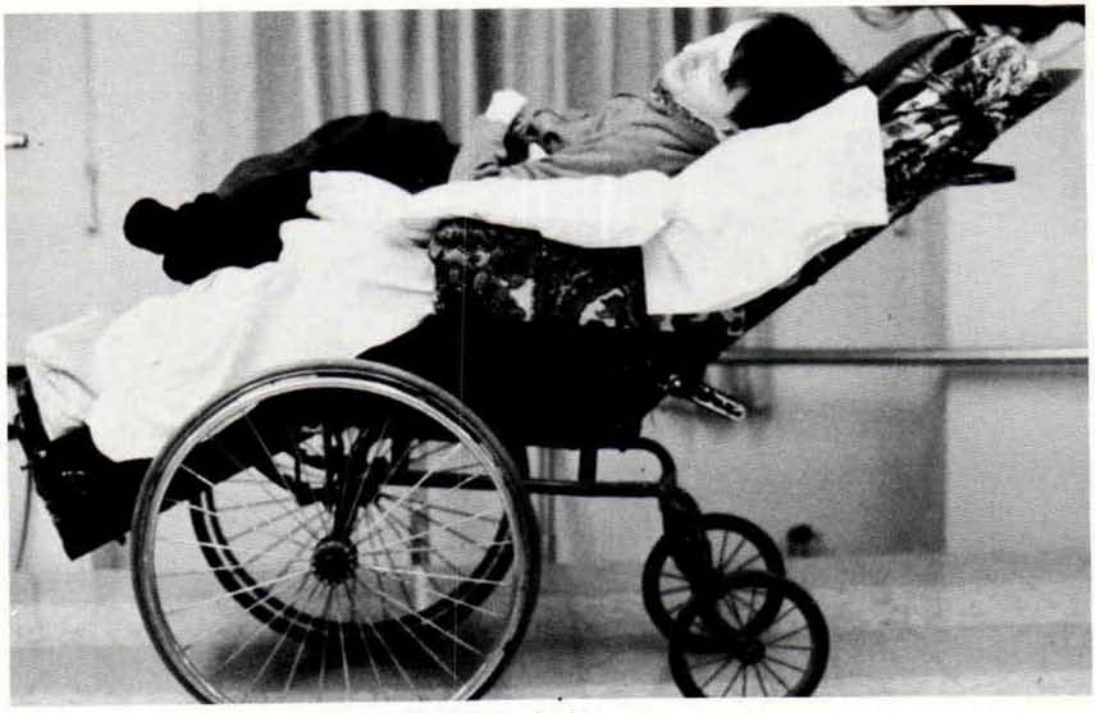

Fig. 8B – Wheelchair wheels were not necessary.

**Fig. 9—The new seating system is light, less bulky and has a more pleasing appearance than the system previously used.**

a new wheeled base every consideration should be given to obtaining one that is as small, lightweight, and inexpensive as possible. In particular, it should be kept in mind that such alternatives to wheelchairs as the Pogon (McClaren) buggy and strollers have proven quite satisfactory (Fig. 8a,b).

## FITTING AND FINISHING

It should be anticipated that two fitting sessions following the casting session will be necessary. The first fitting is to verify details of fit and alignment and plan any changes. A second session is then required to check the accuracy of any changes made and to deliver the completed seat to the individual (Fig. 9). Followup either in person or by telephone with the responsible clinician involved with the patient should be conducted in about six weeks.

## CONCLUSION

In conclusion, a method has been described for providing custom molded seats. It should be readily apparent that very little, if any, of the method is original, but is rather a synthesis of various methods used by others. It should also be apparent that the method is neither simple, inexpensive, nor quick. Therefore, it is felt that this method should be reserved for those individuals so severely involved that it is the most reasonable solution to a very difficult problem. For those individuals with greater flexibility and less deformity, considerably less complicated solutions to their seating needs can be devised, such as solid seats and backs, the MPI, or spinal orthoses. It should also be borne in mind that the use of such a seating technique with limited padding may be inadvisable for those with spinal cord injury due to the lack of sensation and the potential of decubitus ulcers.

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### Footnotes

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# The Chicago Insert: An Approach to Wheelchair Seating for the Maintenance of Spinal Posture in Duchenne Muscular Dystrophy

**Irwin M. Siegel, M.D.**
**Oscar Silverman, C.O.**
**Michael Silverman, C.O.**

## INTRODUCTION

Scoliosis is a complication of wheelchair confinement in Duchenne muscular dystrophy.[4] Such curves are rapidly progressive and are convex toward the side of the dominant hand because the patient usually leans toward the nondominant side to support the dominant arm.[3] A variety of external spinal containment systems have been described which retard the rate of scoliotic progression by maintaining the spine erect. Wilkins and Gibson, studying 62 wheelchair-confined Duchenne dystrophics, noted that although many developed marked scoliosis and kyphosis, those with hyperextended spines and rigid paraspinal contractures had comparatively little lateral curvature.[5] Locking of vertebral facets in exaggerated lordosis apparently inhibits the development of scoliosis. Wilkins and Gibson recommend orthotic management of wheelchair-confined patients to keep the pelvis level and the spine extended. This can be accomplished with a firm wheelchair seat and either circumferential or three-point torso support, preferably fabricated from orthoplast or Pelite-lined polypropylene or polyethylene. Alternatively, a spinal containment orthosis in the form of a modified wheelchair seat may be used.[2] This method features a fiberglass shell, lined with custom-carved polyurethane foam upholstered with a modified urethane foam and a tricot double-knit covering. The patient's pelvis is snugly fitted and his thoracolumbar junction extended. The lumbar lordosis thus created is bolstered by the backrest, which also incorporates lateral flanges to support the sides of the chest. To further encourage lumbar extension, the backrest is inclined backward 15 degrees. Although offering a viable option in the prevention of scoliosis in wheelchair-confined Duchenne dystrophies, cost and availability of this system limit its wide application.

A wheelchair seating insert, referred to as the "Chicago insert", was developed by the authors. The insert was modeled on the design of Wilkins' and Gibsons' "Toronto spinal support system", and is prescribed when a patient with Duchenne muscular dystrophy is first wheelchair-bound (Fig. 1). For those who have already developed slight scoliosis, the device can correct seating imbalances to reduce lateral leaning. In can be fitted to any standard wheelchair.

**Fig. 1—The Chicago insert fits in a wheel chair. The back is designed to hyperextend the lumbar spine. Lateral pads prevent leaning and do not interfere with arm movement.**

## FABRICATION AND FITTING

Measurements include the width of the wheelchair, vertical height at the waist with the patient seated on a flat surface and a snug measurement at the waist. A plaster mold is not required. Construction begins with a hinge spring steel frame, over which wide bands of rubber are stretched. A block of ethafoam, a close-cell polyurethane, is used for the seat and is cut to give a 15 degree posterior tilt. One inch Temper foam is glued to the seat for comfort. The entire seat is then covered with plastic. (Fig. 2). The back of the insert is angled posteriorly 15 degrees superior to waist level in order to provide thoracolumbar hyperextension. Lateral control pads attach at the hinge of the seat, flaring upward with the apex at waist level and the superior border at the level of the lower two ribs. These are formed using 3/16" polypropylene as a base, with carved ethafoam for shape and, again, one inch Temper foam for comfort. The entire orthosis is then covered with nylon tricot, which does not restrain the conforming actions of the foam.

**Fig. 2—Fabrication of the seat. Wide rubber bands are stretched across the back. Ethafoam and temper foam are used to pad the seat and lateral pads.**

During fitting, the lateral control pads must be adjusted so they do not impinge on the arms. The height of the apex of the pads and correct placement of the extension bend should be checked. Usually, a slack back has to be applied to the patient's existing chair to allow full extensions of the insert.*

Posterior tilt of the seat fits the patient against the back of the device, encouraging extension and guiding the lumbar spine into lordosis, thus locking the lumbar facets. The firm seat keeps the pelvis level, while the lateral control pads help center the patient in the chair and discourage lateral leaning. The "Chicago insert" provides some of the benefits of the "Toronto spinal support system" and is more cost effective.

*Further fabrication and fitting details available from North Shore Orthopedics, 2041 Green Bay Road, Highland Park, Illinois 60035.

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# Pressure Applied By Elastic Prosthetic Bandages: A Comparative Study

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## INTRODUCTION

Edema of the residual limb following amputation is a universal problem. The accumulation of this edema is due to several factors; handling of the tissues during surgery, post-operative inactivity and lack of muscle tone in the residual limb. As prosthetic fitting is not possible without reduction and control of edema in the immediate post-operative phase following amputation, edema must be kept to a minimum. Edema can be an additional problem for a patient who has a prosthesis but who does not use the prosthesis for several days because of some medical or prosthetic problem.

Current methods used for reduction of edema include elastic bandaging, elastic shrinkers, pneumatic shrinkers and rigid dressings in the immediate post-operative phase. Of these, elastic bandaging is the most commonly used method.

On reviewing the literature very little has been written about the ideal external pressure which should be applied to reduce edema. A number of studies[1,3,4,5,6,18] have examined the effects of external pressure on venous and skin flow and also edema reduction in the whole limb. J. B. Redford[16] compared the effects of pneumatic and "Tubigrip" (elastic) shrinkers and concluded that both devices result in satisfactory reduction of edema although pressures were not measured under the residual limb in his study. Isherwood, et. al.[8] compared the pressure exerted by an elastic wrap, a pneumatic bandage and "Puddifoot dressing" in amputees. The "Puddifoot dressing" is an elastic stocking applied over a polyurethane foam lining.[15] These investigators found that there was great variation in range of pressure applied by elastic wrap and the pneumatic bandage. Pressures ranging between 15 to 25 millimeters of mercury were reported. The "Puddifoot" stocking applied a lower pressure of 10 to 12 millimeters of mercury.

Prior to this project, we reviewed several studies on the effect of external pressure in both reduction of edema and venous return.[1,3,4,5,6,18] From this review we concluded that an ideal pressure range should be around 20 to 25 millimeters of mercury and a range of 15 to 30 probably acceptable. With the help of one of the manufacturers of elastic shrinkers we developed an elastic stocking which would maintain this "ideal pressure" for a prolonged period of time. We compared the pressure applied by the elastic

bandage and another elastic shrinker currently available.

## MATERIALS AND METHOD

Lower limb amputees were selected from among the patient population from the Kansas University Medical Center, Kansas City, Kansas and the Veterans Administration Medical Center in Kansas City, Missouri. A total of 41 amputees were studied ranging in ages from 15 to 55 years. The length of time post amputation varied from two weeks to two years—the average being less than one month.

The circumference of the residual limb was measured in two different places and an average was computed. Below knee amputees were measured 2 inches and 4 inches below the medial tibial plateau. In above knee amputees, with the anterior superior iliac crest as the reference point, measurements were made at 4 inches and 7 inches distally.

Three different types of pressure bandages were used.

- Elastic Wrap.
- Elastic shrinker which is currently available on the market (Product 1[2]).
- A new elastic shrinker modified by the manufacturer depending on the efficacy of the compression (Product 2[1]).

We tested 6 different types of elastic shrinkers manufactured the same company. The final version was the one that met the following criteria:

- Pressure exerted was within the acceptable limits.
- Sustained pressure was applied for a long period of time.
- No change in pressure was noted with repeated washing.
- Acceptance by patients.

## INSTRUMENTATION

A number of instruments are available to assess pressure applied to the skin.[2,8,14] The instrument we used for the measurement of pressure consisted of a pressure switch, a solid state pressure transducer (Microswitch, Honeywell, 120 PC Series), a liquid crystal readout in millimeters of mercury and associated electronic circuitry (Fig. 1). The pressure switch was similar to the pressure sensory described by Isherwood, et. al.[8] It consists of a flat silicone rubber envelope with internal switch contact. When the pressure on the envelope exceeds the pressure between the skin and stocking material, the contact separates and switches off an indicator located in the solid state pressure readout. At the instant the indicator is off, the pressure is read. We repeated this several times to obtain an average pressure reading. Four pressure sensors were attached to the residual limb; two on the anterior surface approximately two inches and five inches from the distal end of the limb, and the remaining two were located under the posterior surface at the same distances.

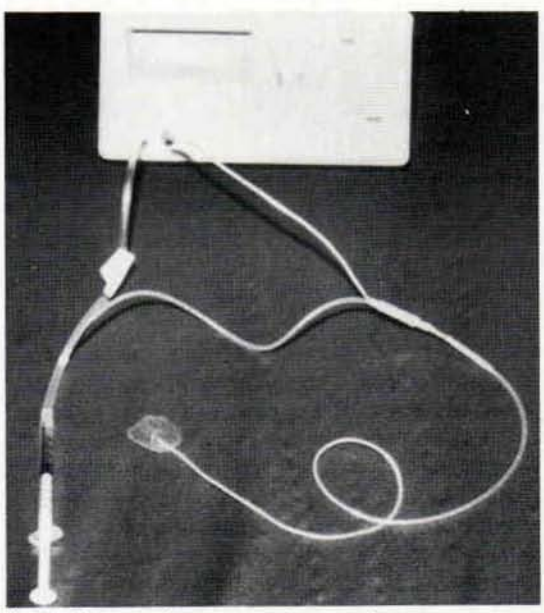

**Fig. 1—Pressure instrumentation used to measure pressure applied to the skin by prosthetic bandages. The instrument consists of a pressure switch, a solid state pressure transducer and a readout in millimeters of mercury.**

**Fig. 2A – A single layer of elastic wrap is pulled over the limb and a plastic ring is pulled snugly against the skin.**

The pressure under the elastic wrap was measured after application by both patient and staff. The pressure underneath the elastic shrinkers were measured under single layer and double layer wraps. (Figs. 2 A&B)

Pressure sensors underneath the new elastic shrinkers (Product 2) were in place for a long period of time and pressure was checked at periodic intervals. Pressures were also tested after repeated washings of the elastic shrinker.

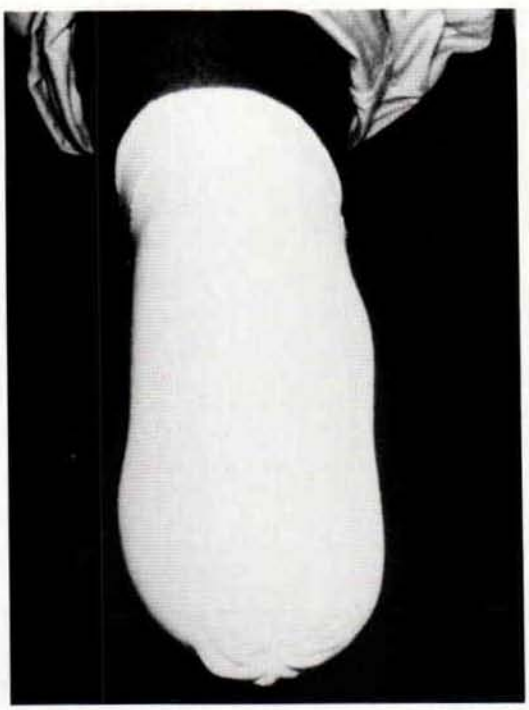

**Fig. 2B – The wrap is then doubled back to provide two layers of compression.**

## RESULTS

The results of the pressure versus stump circumference measured with three different types of stump bandages are shown graphically in Figures 3, 4, 5, 6 and 7 namely: Elastic wrap, Product 1 (shrinkers 6" circumference) and Product 2 (6,8–10" circumference). The area between the two straight lines represents the acceptable limits of applied pressures. Figure 4 shows the pressure versus limb circumference for the elastic wrap on 13 patients for circumferences sizes varying from 15 to 65 millimeters of mercury with only 5 measurements in the ideal range.

Seven patients using the elastic wrap had pressure greater than 40 millimeters of mercury. There was a large difference in the applied pressure depending on whether the wraps were applied by skilled or unskilled persons. In follow-up measurements with prolonged usage, the elastic bandage tended to loosen and decrease the pressure exerted.

Figure 4 shows the average pressures measured with Product 1 on six patients. The residual limb circumference varied between 10 and 14 inches. As measured, a single layer exerted less than 10 mm/Hg over a 14 cm. residual limb. When doubled the same elastic bandage exerted pressure in the lower acceptable limits for only 3 patients and less in others.

Twenty patients were tested with Product 2 with shrinkers in single and double layers. In most, the pressures were below acceptable levels when a single layer was used, but when doubled 18 out of 20 showed an increase in pressure to within acceptable limits. Following repeated washing of Product 2, there was no decrease in the pressure exerted underneath the elastic shrinker. Figures 5, 6 and 7 show the results obtained with 6", 8" and 10" unstretched diameter elastic shrinkers. The corresponding ranges of limb diameters are also shown on the figures.

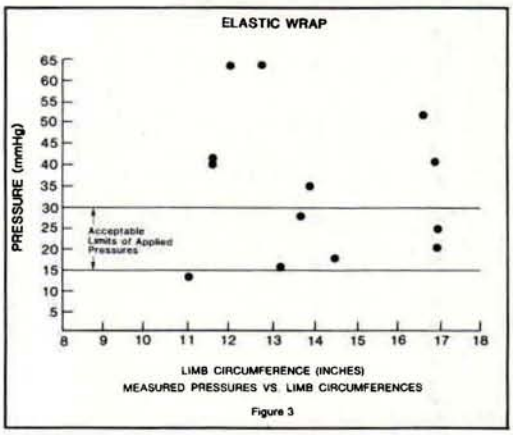

Figure 3

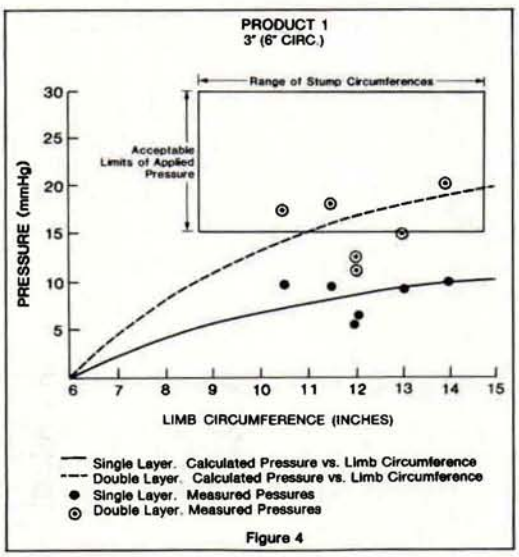

Figure 4

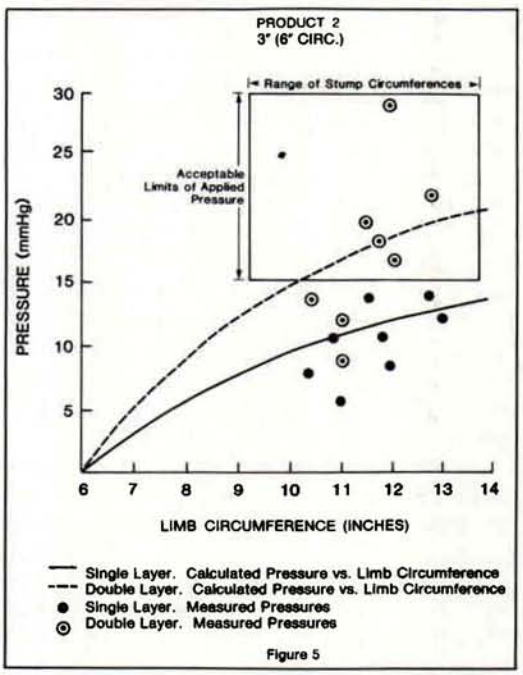

Figure 5

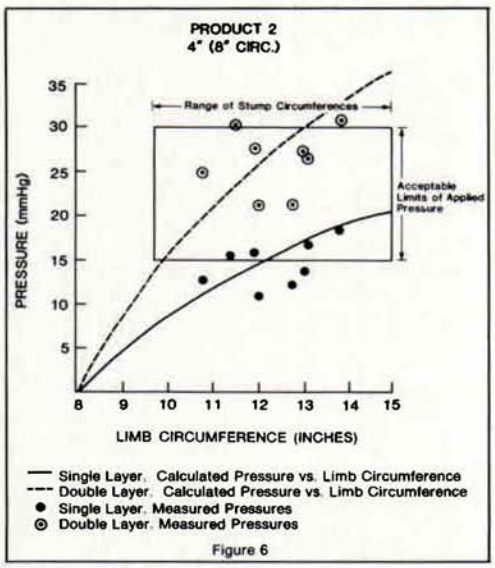


Figure 6

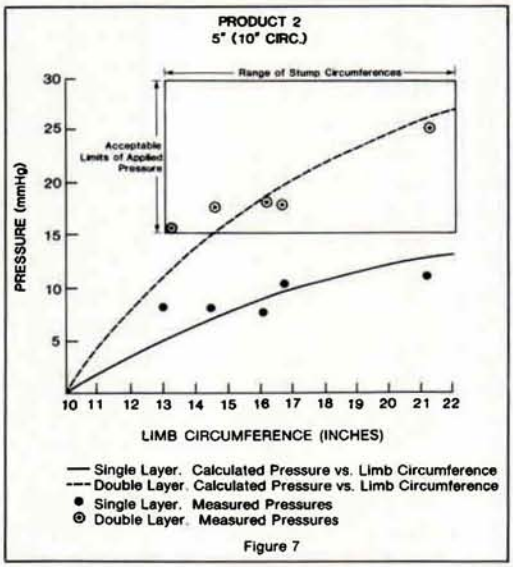


Figure 7

# DISCUSSION

One of the important factors in edema control is equilibrium between the intra and extracellular fluid compartment.[16,17] At the arterial end of the capillary, the net forces favor exudation of fluid into the interstitial space with outward positive pressure of 7 millimeters of mercury. While at the venous end the net forces favor resorption of the fluid from the interstitial space in the venous capillary with a negative pressure 7 millimeters of mercury. Use of external compression can raise the extra-vascular hydrostatic pressure. This in turn decreases exudation of fluid at the arterial end of the capillary while increasing the resorption at the venous end. External compression also increases venous return. External pressure is especially important to control edema in an amputated limb which has virtually no muscle contraction to aid venous return.

A number of previous studies have examined the effect of external compression on venous return and reduction of edema. Allan Holloway, et. al., studied skin blood flow with Xenon clearance.[4] This study showed that the skin flow decreased when external pressure applied was less than 5 to 10 millimeters of mercury and also when pressure was above 30 millimeters of mercury. H. E. Groth, et. al. evaluated the effects of elastic stockings on saphenous and femoral venous flow by Doppler study.[3] Groth concluded that elastic stockings increase the venous flow velocity by 32 to 52 percent. Mueller, et. al. as quoted by Isherwood, studied the effect of elastic compression on femoral venous flow and concluded that the external pressure in excess of 0.04 kilogram per centimeter squared (25 millimeters of mercury) was potentially harmful.[8] Makin recommended an external pressure of 20 millimeters of mercury to be optimal.[10] Husni, et. al. showed that air splints inflated with 20 millimeters of mercury offered excellent compression in the lower extremity without compromising the venous circulation.[7] Several other studies,[9,11,12,19] all showed that external compression reduced edema. Based on these studies we concluded:

- Elastic compression helps in reduction of edema and increased venous return.
- External pressures of less than 15 millimeters of mercury are ineffective in increasing venous return but external pressures of more than 30 millimeters of mercury may cause harm. Therefore the

ideal pressure exerted by elastic compression stocking should be between 20 and 25 millimeters of mercury.

- The compression stocking should be capable of sustained pressure over a prolonged period of time.
- The pressure should be graded so that it should be more at the distal limb than the proximal limb.

The rigid dressing is still considered the most efficient method of reducing residual limb edema in the immediate post operative phase.[13] Unfortunately, use of the rigid dressing after amputation is not widely accepted by surgeons. It also requires a special team to provide the maximum benefit in its usage. Therefore, in spite of proven value, application of rigid dressing does not appear to be very popular. Wrapping the limb with an elastic bandage appeared to be the most convenient and perhaps the most popular method, but the elastic bandage has definite disadvantages as discussed above. The elastic shrinker tested in this study appeared to be easier for the patient to apply and, more importantly, to be more efficient in the reduction of edema. Manella, K. J. has also reported that elastic shrinker is more effective than the elastic bandage.[11]

Additionally, we found that with the "Compressogrip" the pressure was maintained for a long period of time and repeated washing did not affect the elasticity of the fabric used for the shrinker.

Based on our study the following are the advantages and disadvantages of the elastic shrinkers:

## Advantages of Elastic Shrinkers

1. (a) With a temporary prosthesis during the night.
   (b) When rigid dressing can not be used.
   (c) When patient can not use permanent prosthesis due to repair or illness.
2. Ease of donning.
3. No special skills needed.
4. Pressure exerted close to ideal range.
5. Constant pressure over prolonged period of time.

## Disadvantages of Elastic Shrinkers

1. Can be painful to apply and wear immediately post-operatively.
2. More expensive than the elastic bandage wrap.
3. Rolling of the elastic proximal border is a problem in A/K amputees.

# SUMMARY

We have reviewed the literature to determine the ideal pressure to exert on residual limbs to successfully reduce edema. We tested the currently popular methods, measuring pressure under elastic bandage wraps and two types of elastic shrinkers. The elastic wrapping was shown to be less expensive than either of the elastic shrinkers. Pressures underneath the elastic wrap were found to vary widely depending on who applied the wraps. Both types of elastic shrinkers were easier to apply than the elastic wrap and any patient or family member could learn to apply these properly. Upon comparison there existed a significant difference in the pressure exerted between the types of elastic shrinkers used in this study. We therefore developed and recommended an elastic shrinker (Compressogrip) which exerts a pressure in the ideal range as demonstrated in this study.

**Footnotes**

[1]Knit Rite Corporation, Kansas City, Missouri (Compresogrip)
[2]Jobst Corporation

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# The Berkeley Endoskeletal Below Knee Modular System

**Timothy Staats, M.A., C.P.**

## INTRODUCTION

Endoskeletal systems for lower limb amputees are increasingly used as a means of efficiently fabricating, aligning and finishing prostheses. Early work with pylon systems was done by Wheeler (1947) in an experimental prosthesis for Northrup Aircraft (1). Hammontree et al (1965) described a temporary pylon used as an early fit system for geriatric below knee amputees (2). Foort and Hobson (1965) revolutionized many of the concepts of below knee pylon systems by their development of a prefabricated receptacle system with alignment features built into the pylon at the socket and ankle levels (3). Goldner et al (1966) from Duke University used temporary plaster and plastic pylons as a preparation for fitting permanent above knee and below knee prostheses (4). Staros and Gardner (1969) presented the concept of direct forming of below knee sockets using thermoplastic materials. Adapting that technique, they utilized the United States Manufacturing Company's Adjustable Pylon System (5). Wilson (1969) detailed the existing pylon systems in a comprehensive overview of below knee prosthetics (6).

## DESCRIPTION OF COMPONENTS

The Berkeley Endoskeletal Below Knee Modular System* (Fig. 1), or Berkeley pylon

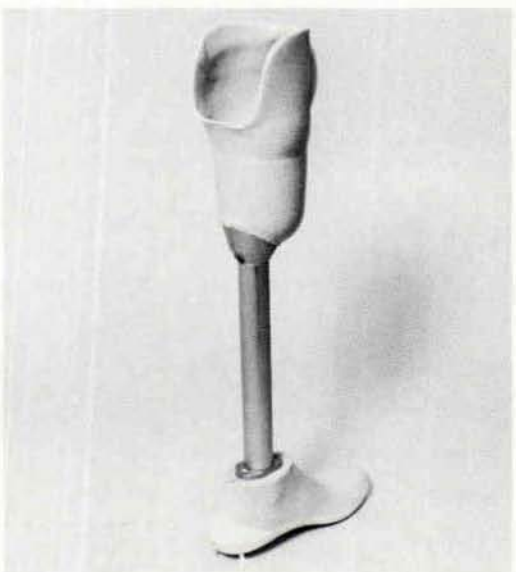

**Fig. 1 – A below knee socket which has to be aligned on the Berkeley pylon and then finished with a reinforcing lamination.**

is a vertical pylon alignment coupling and endoskeletal foundation for the below knee prosthesis. The Berkeley pylon offers a light weight, easy to fabricate and simple design pylon for use as a temporary or intermediate pylon. The Berkeley pylon was developed at the University of California at Berkeley, Biomechanics Laboratory under contract with the Veterans Administration. The Berkeley pylon may be used as a definitive prosthesis only if the system is duplicated from an aligned socket on an adjustable leg using standard prosthetic fabrication methods. The Berkeley pylon system can also be adapted to commercially available ankle rotators.

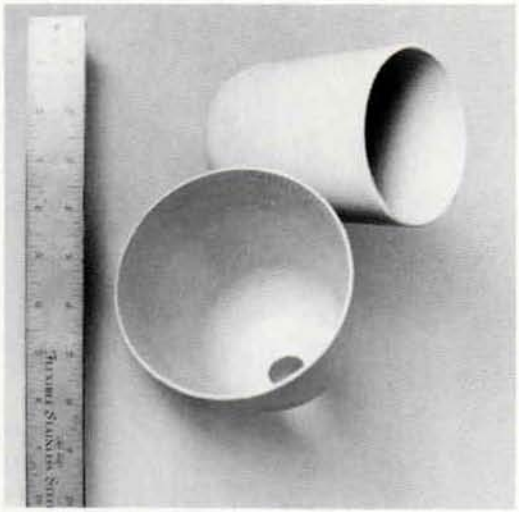

**Fig. 2A – The flexible socket attachment cups are fabricated from polyester resin and come in two sizes.**

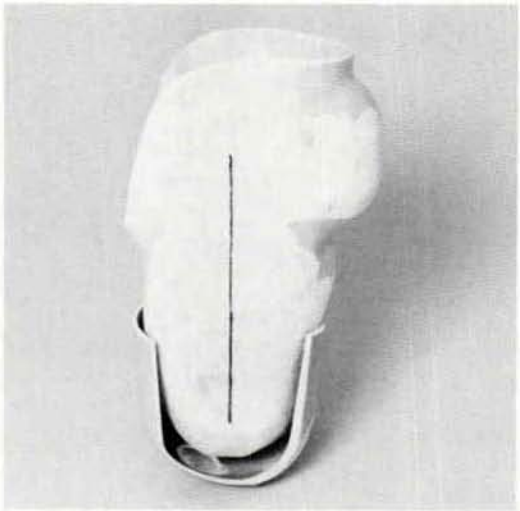

**Fig. 2B – The socket attachment cup is heated, molded and trimmed to provide contact and then epoxied to the socket.**

The Berkeley pylon weighs 18 ounces, and consists of five component parts:

- Socket cup
- Spherical alignment coupling
- Internal proximal clamping component
- Pylon tube - 1⅜" O.D.
- Internal foot clamping component

The socket cup is a receptacle for the below knee socket (Fig. 2A). The socket cup is heated to allow the below knee socket to be press fitted into the cup. The socket cup is available in two sizes, regular (4" diameter) and large (5" diameter). The semi-flexible cup is presently fabricated with nylon and fiberglass polyester laminate. When heated, the cup may be trimmed to adequately receive the below knee socket. A clearance space of ½" minimum (Fig. 2A) is necessary between the distal end of the socket and the cup when the pylon is used as a temporary or intermediate prosthesis. For a definitive prosthesis, the socket can be pressed into the bottom of the cup during essentially standard duplication procedures.

The spherical alignment (Fig. 3A and 3B) coupling attaches the below knee socket and socket cup to the pylon system via a coupling retainer and $^{5}/_{16}$" hex bolt, which passes through the posterior aspect of the coupling housing. The lower end of the spherical alignment coupling is called the Internal Proximal Clamping Component (Fig. 4A). The pylon tube slides over this assembly and is secured by tightening the hex bolt on the distal end of the clamping component using an extension socket wrench (Fig. 4B). The internal expanding tube clamp utilizes the full strength of the pylon to assure rigid connection. *Care must be taken not to over tighten the internal tube clamp. Optimal wrench torque is 15ft./lbs.*

The Internal Foot Clamping Component

**Fig. 3A – The spherical alignment coupling allows angular adjustment by loosening the hexagonal bolt on the posterior aspect.**

can be used with any wooden keel SACH foot (Fig. 5). The foot should be attached to the clamping component with a ⅜" -16 hex bolt and two wood screws to secure the assembly to the top of the foot. The foot is attached to the pylon by tightening the foot bolt (Fig. 5). *The Berkeley pylon system is designed for and requires a minimum of 5-½" between the bottom of the socket and the top surface of the SACH foot.*

## INITIAL ASSEMBLY AND ALIGNMENT

Select the proper size socket attachment cup in which to fit the below knee socket. The upper edge of the socket attachment cup must fit snugly against the below knee socket. It is usually necessary to heat and trim the socket attachment cup to achieve this intimate fit. Scribe or draw an alignment center line on the posterior aspect of the

**Fig. 3B – The serrated edges in the spherical alignment coupling that lock alignment adjustments in place.**

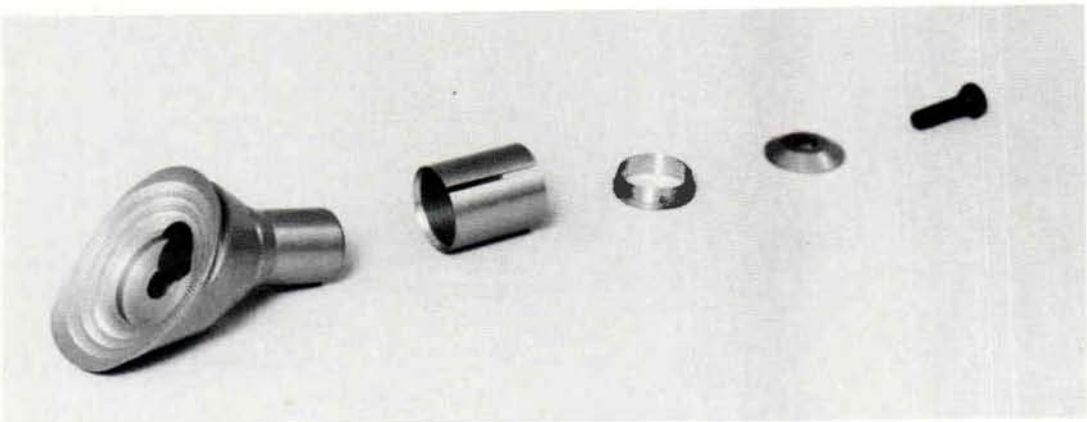

**Fig. 4A – The internal clamping component. The pylon slips over this component and is held in place by the expansion of the component when the bolt is tightened.**

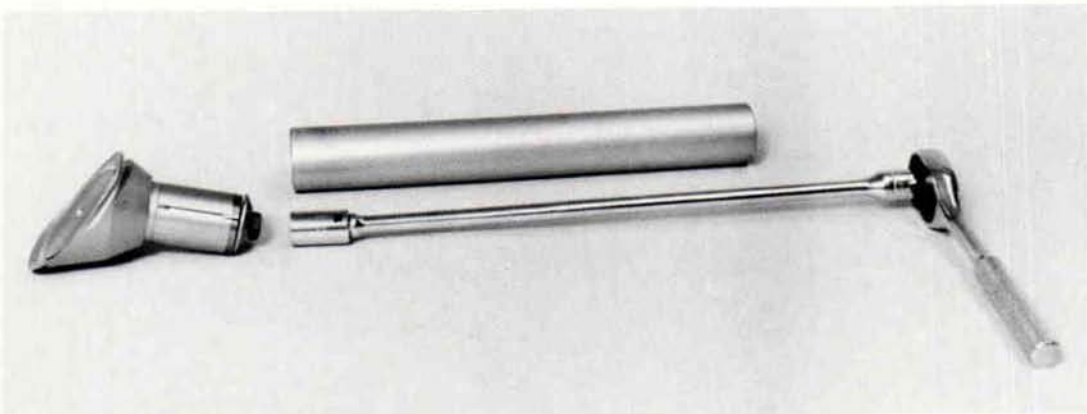

**Fig. 4B – An extension socket wrench is required to reach in the pylon and tighten the bolt.**

socket. This will allow the socket to be removed from the socket attachment cup and accurately replaced. Bond the socket to the attachment cup using epoxy or a similar adhesive.

Static alignment of the Berkeley pylon requires accuracy in negative impression casting and positive mold modification techniques for the best results. It is suggested that the negative impression casting techniques and prealignment lines described by Hampton (1965) in the "Northwestern Suspension Casting Technique" (7) be considered to aid in establishing angular and linear references prior to static alignment. Generally, if reasonable care is taken to establish good flexion and adduction angles, socket foot positioning with the Berkeley pylon is adequate for temporary and intermediate prosthesis designs. Basic dynamic alignment for temporary or intermediate prostheses is performed by loosening the alignment coupling retainer bolt and tilting the socket cup and socket to the new position. Changes in flexion or extension, adduction or abduction in tilt angles of $\pm$ 10° and unlimited rotation are possible. Exaggerated socket flexion/extension adjustments will affect the toe and heel levers. Similarly, adduction or abduction maneuvers will affect foot inset or outset. Changes in

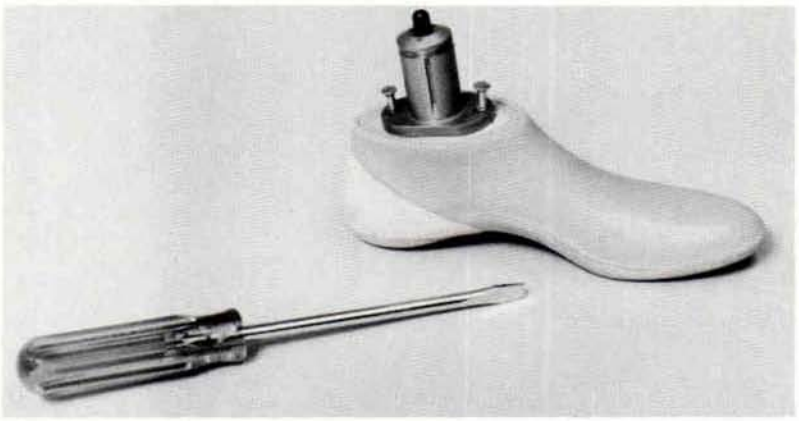

**Fig. 5 – The internal foot clamping component functions in the same manner as the component on the spherical alignment coupling. There must be a minimum of 5½" between the distal socket and the top of the foot to use this system.**

these angles are enhanced by the socket attachment cup's 30° angle attachment to the alignment coupling. If radical angle changes are performed and unwanted lever arm conditions are encountered, the socket can be loosened from the socket cup and repositioned to accommodate the situation. When precise alignment of the prosthesis is required, it is suggested that the prosthesis be aligned on the V.A.P.C. adjustable pylon and the Berkeley pylon be duplicated into position during finishing. All adjustments are made prior to the final lamination as a lamination tie off groove will permanently fix the socket attitude when the final lamination is performed.

The following guidelines should be followed when adjusting the pylon:

1) Mark initial position of the alignment coupling by a pencil ring mark on single piece alignment coupling to adjust the Berkeley pylon.
2) Loosen the alignment bolt if angular adjustments are required after walking trials. Make the alignment change and tighten the bolt.
3) Adjustments should be made as viewed from the rear. A space of ⅛" represents an angular change of three degrees (Fig. 6).

## FINAL ASSEMBLY AND FINISHING

The finishing technique for the Berkeley pylon involves procedures that are generally used in other pylon systems. Certain steps are necessary to insure proper results:

- Scribe an alignment line on the posterior aspect of the socket. This will allow the socket to be removed from the cup and replaced accurately (Fig. 7A).

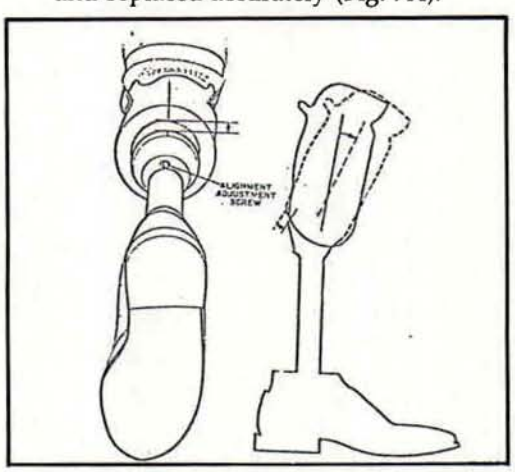


**Fig. 6 – Angular adjustment of the socket is made by loosening the alignment adjustment skrew. Ten degrees of rotation are available in the sagittal and frontal planes. Unlimited rotation is available. The 30° set angle to the pylon enhances the effect of the angular adjustments.**

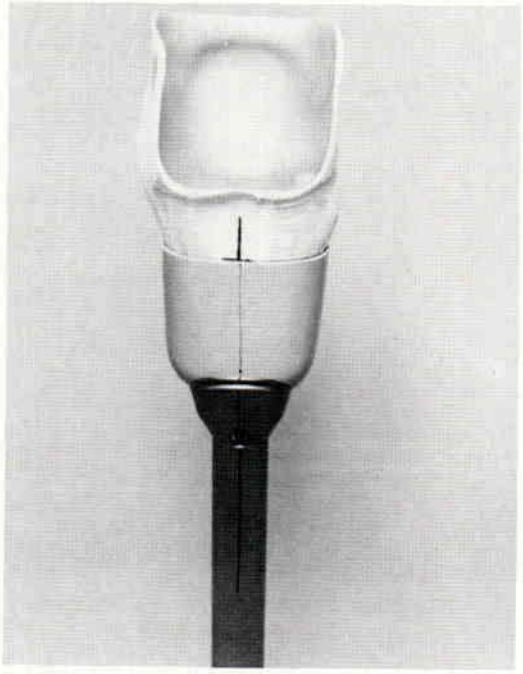

Fig. 7A – Permanent fastening of the socket to the attachment cup. Mark the alignment and remove it from the socket by breaking the temporary bond used for alignment.

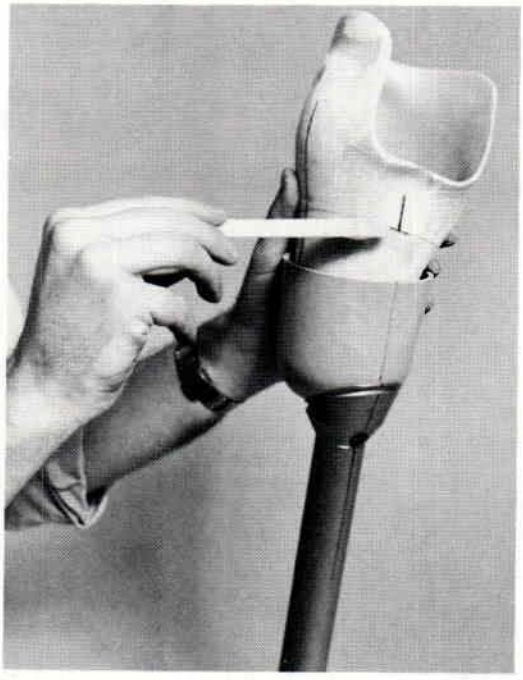

Fig. 7B – Rough up the socket and the attachment cup and epoxy all surfaces. Replace the socket.

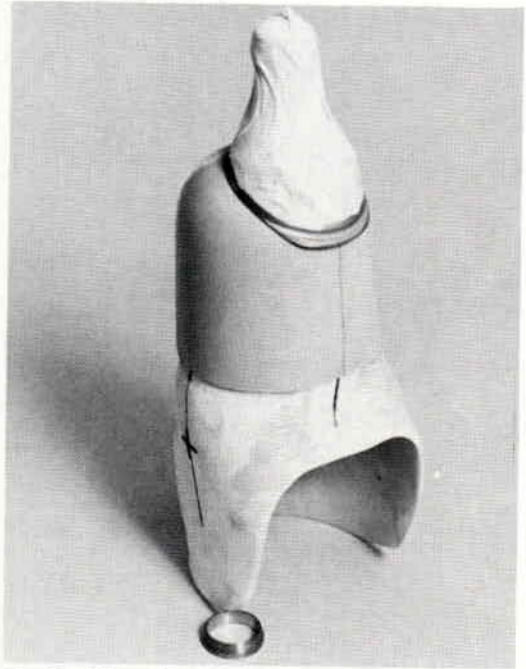

Fig. 8 – All machined surfaces are protected from the laminating resin.

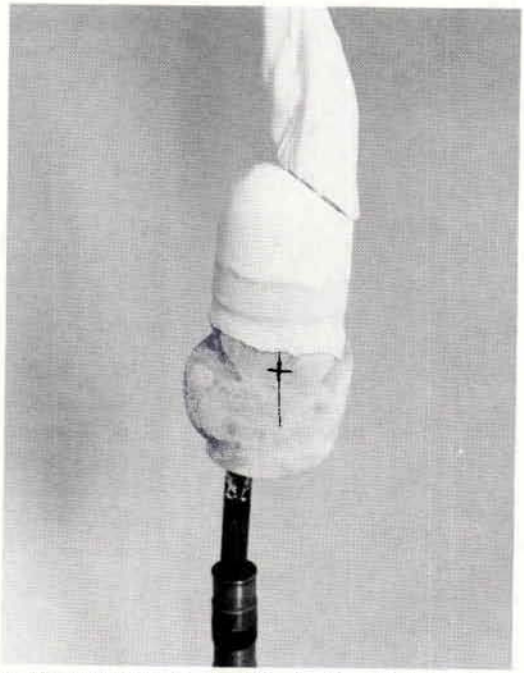

Fig. 9 – Layup for the final lamination. Nylon is staggered on the socket and pulled into the tieoff groove with wire.

- Sand the inside proximal edge of the cup and the socket for good bonding. Apply epoxy bond (Epibond) or suitable adhesive resin to the spherical alignment coupling retainer inside the cup and bond the socket to the cup. Replace to alignment lines previously described (Fig. 7B).
- Mark the toe-out position before removing the pylon system from the socket-coupling assembly. The base of the foot coupling should be permanently attached to the foot with two wood screws, as well as the ⅜" bolt provided with the foot.
- All loose parts are removed from the socket-coupling system for final lamination. All machined surfaces are masked off (Fig. 8). *Do not remove the alignment coupling retainer bolt for final lamination.*
- Pull one layer nylon stockinette over the socket-coupling until the leading edge is ½" above the cup socket joint. Pull the second nylon stockinette layer over the first layer until the leading edge is ½" below the cup-socket joint (Fig. 9).
- Important: Secure the two layers of stockinette into the tie off groove with three or four wraps of lockwire (type 302 temper soft stainless steel, 0.20" diameter).
- Reflect the second nylon back and trim at 1" below the cup socket joint, then reflect the first layer back over the brim of the socket and laminate as usual.

## PROSTHETIC FOAM COVER

For a definitive prosthesis a soft foam cover will be applied to the pylon and the socket. For a smooth transition between the foot and the foam cover, the following steps provide a simple method to achieve this result:

- Measure the approximate length of the foam cover from the top of the foot to the upper boundary on the socket.
- Wrap the upper boundary of the socket with lead wire to determine the shape of the entry to carve inside the foam cover.
- Insert the socket-pylon system into the foam cover. Check the socket attachment for tightness and attach the foot as per previous instruction.
- Fit the foam cover to the socket and to the foot (Fig. 10). Sculpture the foam cover as desired beveling it into the foot and the socket leaving minimal transition lines.
- Apply cosmetic hose or suitable cosmetic cover over the sculptured prosthe-

**Fig. 10 – Foam cover shaped over the Berkeley pylon.**

sis. In some finishing techniques, resin is used to bond the socket brim and cosmetic hose together at the ½" brim line. The location of suspension cup studs are coated with resin to prevent stockings from running.

## ACKNOWLEDGMENTS

Professor Charles Radcliffe[2], Steve Lamb[3], George Irons, C.P.O.[4], Melinda Galgoul and Barbara Brown are specially thanked for their participation in the development and preparation of this report.

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1. Technical Director for the United States Manufacturing Company
2. Professor of Mechanical Engineering at the University of California at Berkeley
3. Research Engineer for the University of California at Berkley
4. Research Director for the United States Manufacturing Company

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*Available from the United States Manufacturing Company.

# Modifications of the Switch Control for a Powered Hand on an Elbow Disarticulation Prosthesis

John P. Spaeth, M.S., C.P.

## CASE PRESENTATION

We were presented with a twelve year old girl who was a congenital amputee. The patient, although functionally an elbow disarticulation, had three digit remnants present on the distal residual limb. These digits were not mobile and essentially not functional.

The patient had been attempting to wear a conventional prosthesis from approximately age eight. She could generate enough cable excursion to operate the elbow (i.e. full flexion and extension), however, she could not operate the conventional terminal device. The patient's parents found themselves forcing the child to wear the prosthesis against her will. Of course, the parents could not enforce the wearing time while the child was away from home with, for instance, school, play. The patient's parents found themselves having to deal with a common problem in upper extremity prosthetics—prosthesis rejection.

The physician, when faced with providing the patient with her third prosthesis, wanted to forego the prescription in hopes of circumventing another rejection. In interviewing the child, he found that she had two reasons for rejecting her prosthesis. First, she could not operate the terminal device, so that the prosthesis became to her a non-functional burden, and, second, the appearance of the terminal device was not cosmetic.

Subsequent to the patient interview, the physician requested that the child be provided an elbow disarticulation prosthesis which utilized a myo-electrically controlled hand.

## THE PROSTHETIC PRESCRIPTION

The prosthetic evaluation concluded that the patient had no usable myo-electric potential at the level of either her biceps or triceps. The deltoid muscle exhibited a usable potential at the level of both the medial and anterior fibers. It was decided that the placement of electrodes over the deltoid muscle was undesirable because of the high proximal socket trimline required to mount the electrodes.

It is conceivable that with proper preprosthetic training the patient could have developed some myo-electric potential in either the biceps or triceps muscle.

The patient lived approximately 100 miles from the nearest therapeutic training facility and transportation was a problem, making training impractical.

Potential volume changes of the residual limb were also considered. A myo-electrically controlled prosthesis could not be worn with a prosthetic sock. In addition, use of surface electrodes necessitates an intimate socket fit. With these factors in mind, the prescription was changed from a myo-electric control system to a switch control system.[1]

The definitive prescription called for a hybrid system, utilizing a conventional elbow disarticulation socket, Dorrance E-2500 child size outside locking hinge, Variety Village 127-00 pull switch, Variety Village 6V dc-220 ma power supply, Otto Bock 6¾ externally powered hand, with Otto Bock quick disconnect wrist.

## BIOMECHANICAL CONSIDERATIONS

Body powered control of an elbow disarticulation prosthesis is typically achieved from shoulder girdle movement harnessed so that gleno-humeral flexion and scapular abduction creates enough excursion of the control cable to flex the forearm. Shoulder depression with gleno-humeral extension and abduction then controls elbow joint lock. When the elbow is locked, additional pulling of the control cable will operate the terminal device.

Because of the nature of these control factors, operation of a pull switch to control the powered hand was a problem. All of the "normal" harnessing to allow for operation of the forearm and elbow joint had to be retained, and an additional movement for control of the pull switch to operate the hand had to be located and harnessed. The only other control movements considered to be functional were shoulder elevation or chest expansion. Even though the excursion needed to operate the pull switch was small (approximately 12mm), it was determined that these two control movements were too inaccurate for the fine cable control needed to operate the hand with precision. In addition, shoulder elevation and chest expansion are cumbersome movements, and conspicuous, and should be avoided if possible.

The solution seemed to be a connection from the terminus of the control cable directly to the pull switch, instead of the terminal device (Fig. 1). This allowed for full elbow flexion, however, the force on the cable terminus required to flex the forearm caused the switch to be activated before the forearm was locked into its desired flexed position.

## DESIGN AND PULL SWITCH MODIFICATIONS

The pull switch had to be modified so that it would provide enough opposition to the control cable force to allow for forearm flexion and yet, once the elbow was locked, the opposition had to be small enough to allow activation of the switch.

The Variety Village 127-00 pull switch seemed most suitable for the needed modifications (Fig. 2a).

The forearm flexion attachment was moved distally to lessen the force needed to flex the forearm. Flexion of the 11 inch forearm with the Otto Bock 6¾" hand attached, requires 4.7 pounds of pull. Because more force would be required to flex the forearm while lifting objects, the spring tension of the pull switch was increased to 10.5 pounds.

The Variety Village switch 127-00 has a single cam type shaft which moves laterally in the switch housing. This shaft protrudes on one end of the housing for attachment to the control cable. The cam shaft is spring loaded internally so that the shaft retracts to the "off" position when not in use. The internal spring was removed and an external spring of greater tension was added. To aid the external spring, an opening was made in the switch housing for the cam shaft opposite the end which already protrudes (Fig. 2b). A 4mm length of 2mm bar stock was brazed to the end of the cam shaft as an extension. A spring generating 10 pounds of tension was attached to the cam shaft extension and the entire assembly was mounted in the forearm cavity. The switch was mounted with two machine screws, which threaded into the body of the switch. The spring was

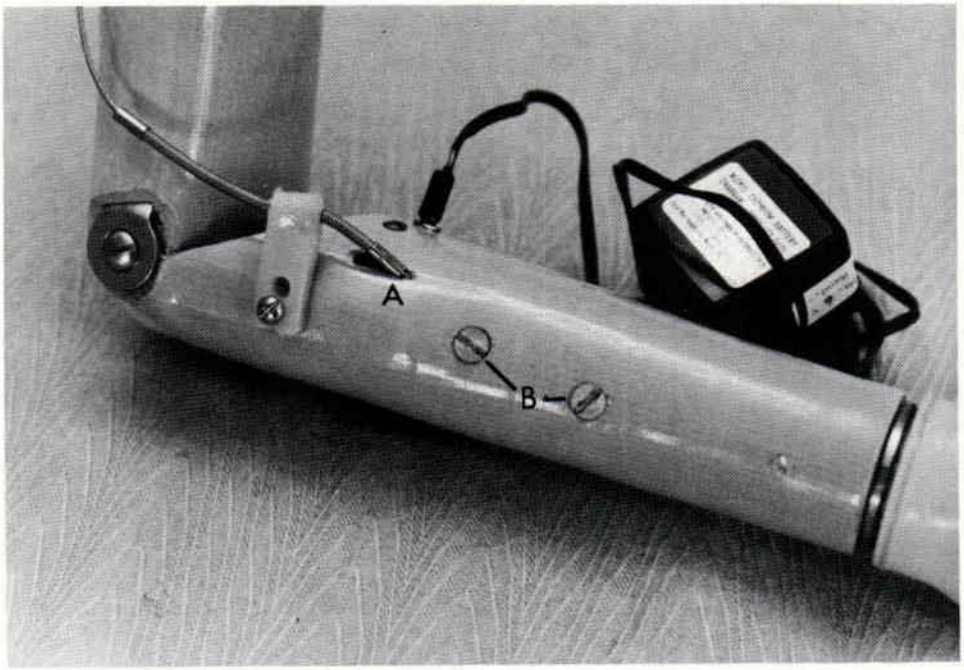


Fig. 1 – A) Control cable terminus; B) Pull switch mounted inside forearm cavity.

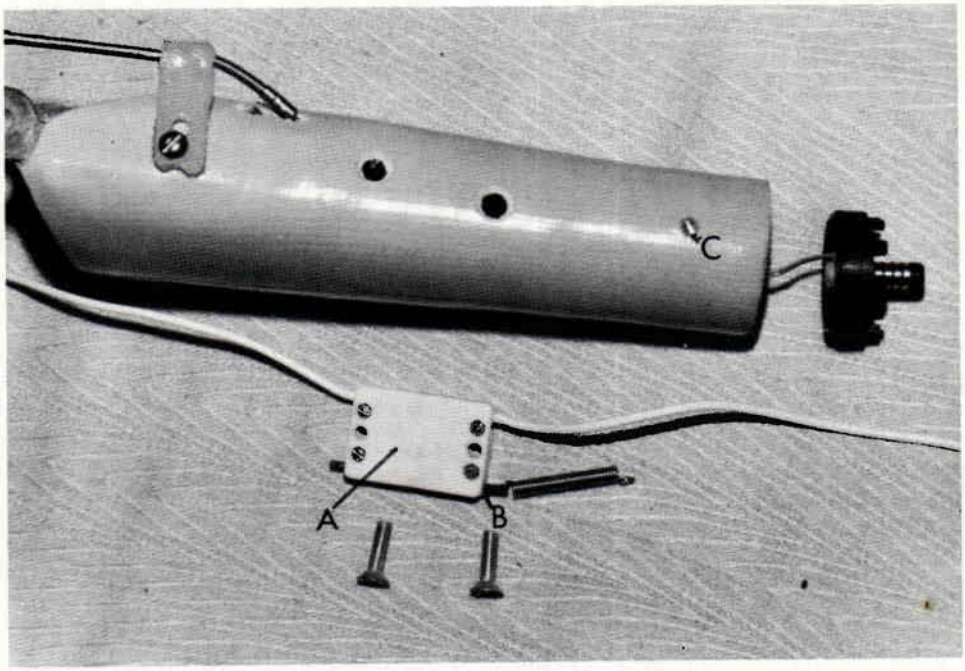


Fig. 2 – Disassembled forearm A) Variety Village 12700 pull switch; B) New opening and cam shaft extension with spring attached.

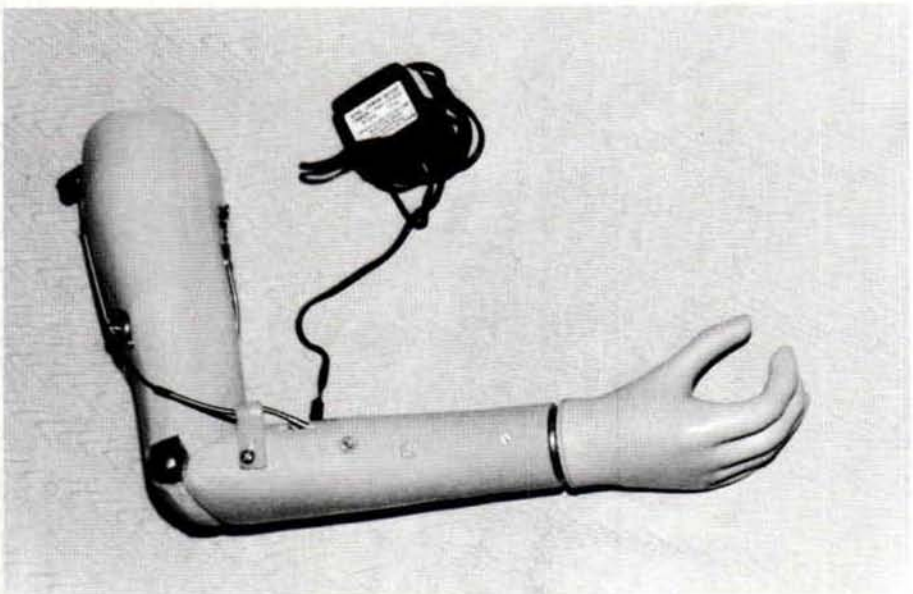

**Fig. 3—Finished prosthesis with battery charger.**

attached distally by means of a nut and bolt (Fig. 2c).

Once assembled, the entire switch assembly and power supply fit into the arm cavity. The batteries were mounted permanently so a jack was provided proximally for the battery charger. The proximal location is used so the cosmetic glove does not have to be rolled down for charging.

The finished prosthesis does not require any cables distal to the switch control on the forearm. (Fig. 3).

## TRAINING AND FOLLOW-UP

The patient had been seen by an occupational therapist one time for therapy. The movements for control were essentially the same as for her conventional prosthesis. It took approximately 40 minutes for the patient to learn the fine control movement needed to find the different positions of the pull switch. At the close of the therapy session, the patient could open and close the hand with 100% accuracy. We anticipate that the speed with which she operates the prosthesis will improve with practice.

Approximately 12 months have passed since the delivery of this prosthesis. The patient's earlier signs of prosthetic rejection have been remediated. Thus far the initial reaction has been a positive one on both the part of the patient and the parents. To date we have not had any mechanical failure on the hand or modified switch.

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*Technical Note:*

# Prosthetic Applications of Methylmethacrylate Acrylic Plastic

**Scott Hornbeak, C.P.O., B.S.**
**Richard J. Boryk, C.P., B.A.**
**Timothy B. Staats, M.A.C.P.**

Methylmethacrylate, or acrylic, is a plastic material used extensively in dentistry for dental plates and repairs of dental work. Sterile methylmethacrylate is used as bone cement for total hip and knee replacements in orthopedics, and has also been used as a structural replacement for bone in certain cervical spine surgeries.

The prosthetic and orthotic applications of methylmethacrylate have been clinically tested for two and a half years in the UCLA Prosthetic-Orthotic Laboratory. The unique qualities and versatile applications of this plastic have shown it to be superior to polyester resin mixed with Solka Floc or Micro Balloons. Methylmethacrylate is now used routinely to attach laminated sockets to wooden end seals, to repair and fill socket cracks, pits, or rough areas, to replace suction socket valve housings, and to bead or build up sharp edges or insufficiently rolled socket brims (Fig. 1). The material is particularly useful in shaping or recontouring below knee and above knee plastic sockets (Fig. 2). The time necessary to complete socket fills or adjustments has been reduced on the average from one hour down to twenty minutes when compared to typical polyester resin techniques.

Methylmethacrylate is a two component, cold cure, acrylic plastic, the type used consisting of a fine powder and a liquid monomer. This material is available in a fast or

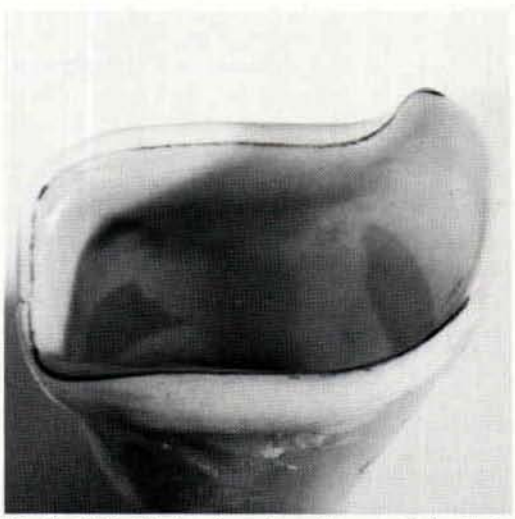

**Fig. 1 – Rolled brim of an above knee socket adds to patient comfort (methylmethacrylate unpigmented and outlined).**

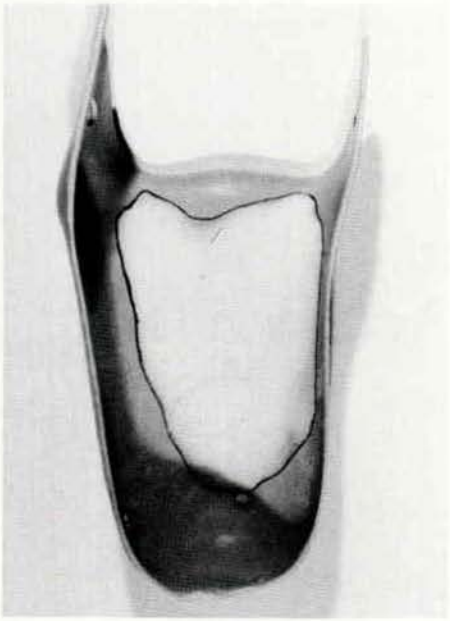

**Fig. 2—Split below knee socket illustrates a fill in the gastrocnemius area (outlined area).**

regular set time. The fast set cures in approximately five to ten minutes and the regular cures in fifteen to twenty minutes.

Acrylic laminating resin, which is also in the methylmethacrylate family, is a different material and cannot be used in the same manner as the methylmethacrylate described.

Methylmethacrylate is mixed to different consistencies for different applications. By varying the ratio of powder to liquid monomer the user may mix a thin liquid or a stiff paste. Methylmethacrylate increases in viscosity as it cures until it reaches a moldable, dough-like consistency which can be shaped and smoothed using fingers or a brush with a small amount of liquid monomer.

## PRECAUTIONS

Some cases of contact dermatitis in dentists and surgeons from use of methylmethacrylate monomer have been reported (1). It is advisable to wear gloves whenever working with methylmethacrylate. The long term effects of using this material directly against skin before it has cured are unknown. If sensitivity to the liquid monomer is noticed, further use should be discontinued. After methylmethacrylate has cured, contact with the skin is safe.

## METHOD

The procedures used when working with methylmethacrylate are divided into five steps:

- Surface preparations
- Mixing
- Molding
- Smoothing
- Polishing

### *Surface Preparations*

Methylmethacrylate bonds well with polyester resin, acrylic resin, epoxy, and wood surfaces. Roughen the surface to which methylmethacrylate will be applied with 80 to 120 grit sand paper to achieve good bonding. Prime the roughened surface with an application of a small amount of liquid monomer.

### *Methylmethacrylate Mixing Procedures*

Combine two to three parts methylmethacrylate powder with one part liquid monomer by volume to obtain a workable consistency of methylmethacrylate. Add powder to liquid when possible. If the mixture is too thin, methylmethacrylate monomer can be added to thicken it, and conversely if the mixture is too thick, liquid monomer will thin the mix. One or two drops of standard lamination pigment adequately colors methylmethacrylate. The proper consistency for most applications is a thick putty-like mixture. A thick mixture is advantageous for three reasons: first, with a putty-like consistency, it is easy to apply and shape complex curves and contours; second, the mixture will cure quickly when mixed to a thick paste allowing rapid shape modification; and third, thin mixtures have a tendency to bubble and pit during the curing process.

Fig. 3 – Methylmethacrylate (unpigmented for illustrative purposes) is added to the outside of a below knee check socket to provide room to grind over the fibular head.

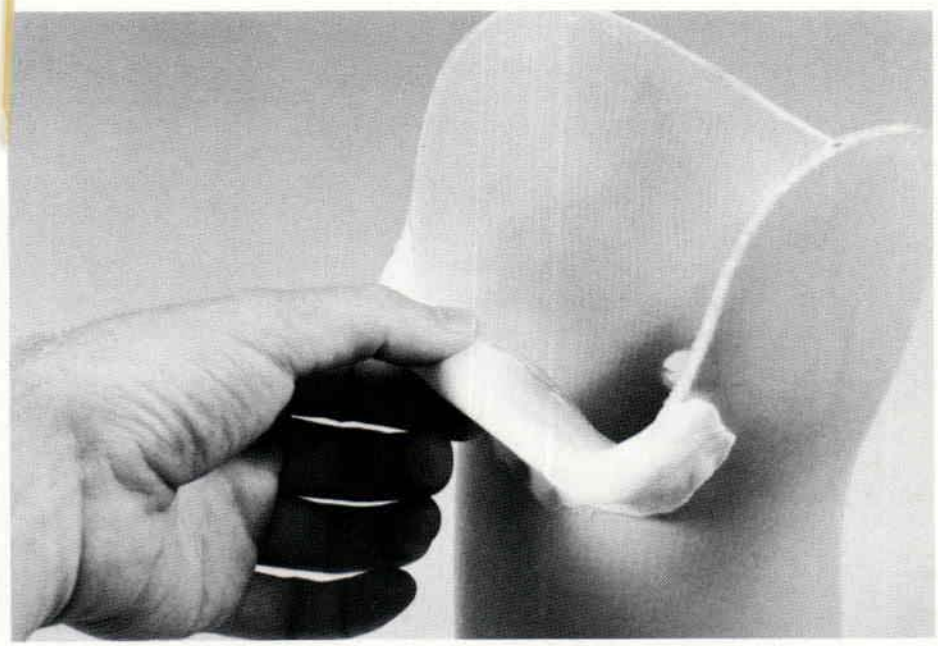

Fig. 4 – Methylmethacrylate being shaped to lengthen the posterior shelf of a PTB socket.

For normal laboratory procedures fill two eight ounce cups with approximately three quarters of an ounce of liquid monomer in each. One cup will be used for mixing the methylmethacrylate powder. The second cup of monomer will be used as a smoothing agent as the plastic begins to cure.

## *Molding*

Apply the methylmethacrylate mixture on the prepared surface with a tongue depressor (Fig. 3). The surface should be wet from the application of monomer as a primer. When applied, the mixture will be somewhat tacky to the touch and not easily molded. The methylmethacrylate is spread over the roughened surface to insure good bonding. After thirty seconds to one minute the material can be molded and shaped by hand without plastic sticking to the fingers (Fig. 4). Any plastic that does adhere to the skin or gloves is easily removed during the curing process.

## *Smoothing*

Smoothing of the methylmethacrylate can be initiated after the buildup is no longer tacky and the general shape has been obtained. Monomer liquid is used to feather the margins and to even any bumps on the methylmethacrylate buildup. By moistening the fingers or a small brush in the liquid monomer, the buildup can be rubbed or brushed to provide a smooth transition on to the socket (Fig. 5). The liquid monomer acts as a lubricant at this stage of the curing process. Note: Curing methylmethacrylate generates an exothermic reaction which may be slowed down by placing a cool towel or water on the hardening plastic, thus further avoiding pits and bubbles. With practice, a smooth, finished buildup can be completed at this stage without the further grinding, shaping, or coating common to polyester resin techniques.

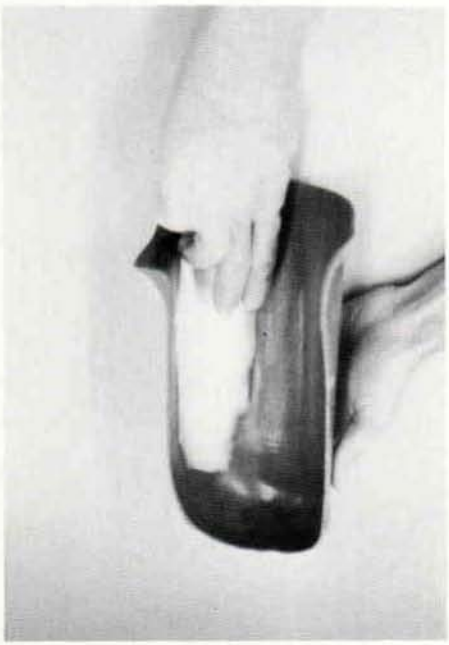

**Fig. 5 – Smoothing the methylmethacrylate with liquid monomer.**

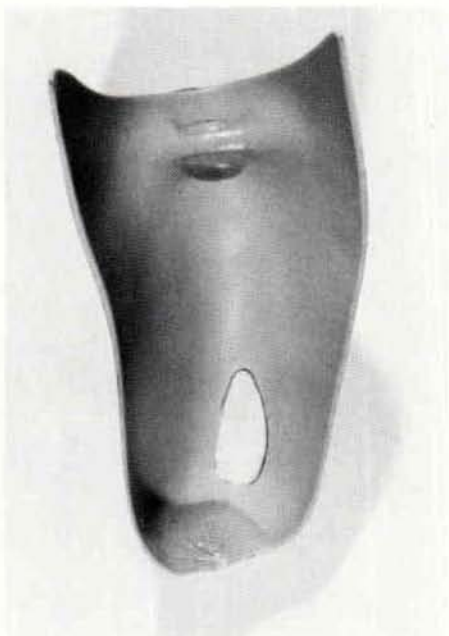

**Fig. 6 – Methylmethacrylate added to the outside of a below knee socket allows grinding for an anterior-distal tibial relief.**

## *Polishing*

Should sanding or polishing be necessary, ridges and bumps are quickly removed by grinding with a 120–220 grit cone on the router. Initial grinding is followed by wet or dry sanding with 220 grit Durite and final polishing is done with 400 to 600 grit wet or dry sand paper. A felt cone is used to buff any rough edges along the trimlines, socket edges or filled rivet holes.

Approximately five quarts of monomer are required to set off twenty five pounds of powder. Methylmethacrylate powder is generally sold by the pound. Liquid monomer is sold by the quart or gallon.

## SUMMARY

The advantages of using methylmethacrylate over polyester resin techniques are that it is moldable as it cures, it does not require fillers to create a thick paste, it sands quickly to a smooth gloss, and provides almost immediate compatibility for the socket-skin interface. Methylmethacrylate bonds well to polyester and acrylic laminates and is hypoallergenic when cured. Methylmethacrylate allows the prosthetist to make changes in socket size and shape in about twenty minutes as compared to other plastics that normally take over sixty minutes before the patient can wear the prosthesis. The ability to change shapes rapidly also provides an extremely useful diagnostic tool when using laminated check sockets (Fig. 6). Although it is more expensive per volume used when compared to polyester resin, clinical experience with methylmethacrylate has shown it to be technically advantageous in terms of application and time saved.

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# New Publications

## *A Manual of Orthopaedic Terminology,* 2nd. Edition, by Carolyn T. Blauvelt and Fred R. T. Nelson; C. V. Mosby Co., St. Louis/Toronto/London, 1981. 257 pp., index; $19.95, paperback.

This book is intended to serve as an introduction to the language of orthopaedics for anyone, professional or layman, involved in treatment of disorders of the neuro-musculoskeletal systems. It provides a quick ready reference giving brief, concise definitions of unfamiliar words and phrases. It is not organized alphabetically, but rather by subject area and each chapter begins with a brief description of the subject area. The book therefore, gives an overview of the field itself. Some idea of the scope of the book may be gained by scanning the chapter titles:

1. Classification of fractures and dislocations
2. Musculoskeletal diseases and related terms
3. X-ray and scanning techniques
4. Orthopaedic tests, signs, and maneuvers
5. Laboratory evaluations
6. Casts, splints, dressings, and in-house traction
7. Prosthetics and Orthotics
8. Anatomy and surgical intervention
9. The hand
10. The foot
11. Physical medicine and rehabilitation: Physical and occupational therapy
12. Musculoskeletal research

Appendix A. Orthopaedic abbreviations
B. Human skeleton
C. Anatomic positions and directions

In encompassing so broad a territory the authors have called upon the assistance of a long list of consultants and contributors. Of particular note is the fact that the chaper on prosthetics and orthotics was compiled by Wilton H. Bunch, M.D., Ph.D. and Steven Kramer, C.P.O. The results are excellent giving a brief and accurate description of the two fields and of specific devices.

Anyone with any depth of knowledge about orthopaedics might consider the book superficial and redundant. It should however, be evaluated in light of its avowed intent, which it fulfills. The purpose is not to supplant such traditional references as dictionaries and textbooks, but rather to supplement them. For clerical or technical personnel or for someone reading the literature who encounters an unfamiliar word and who wants a quick answer, it should serve a useful purpose.

Charles H. Pritham, C.P.O.

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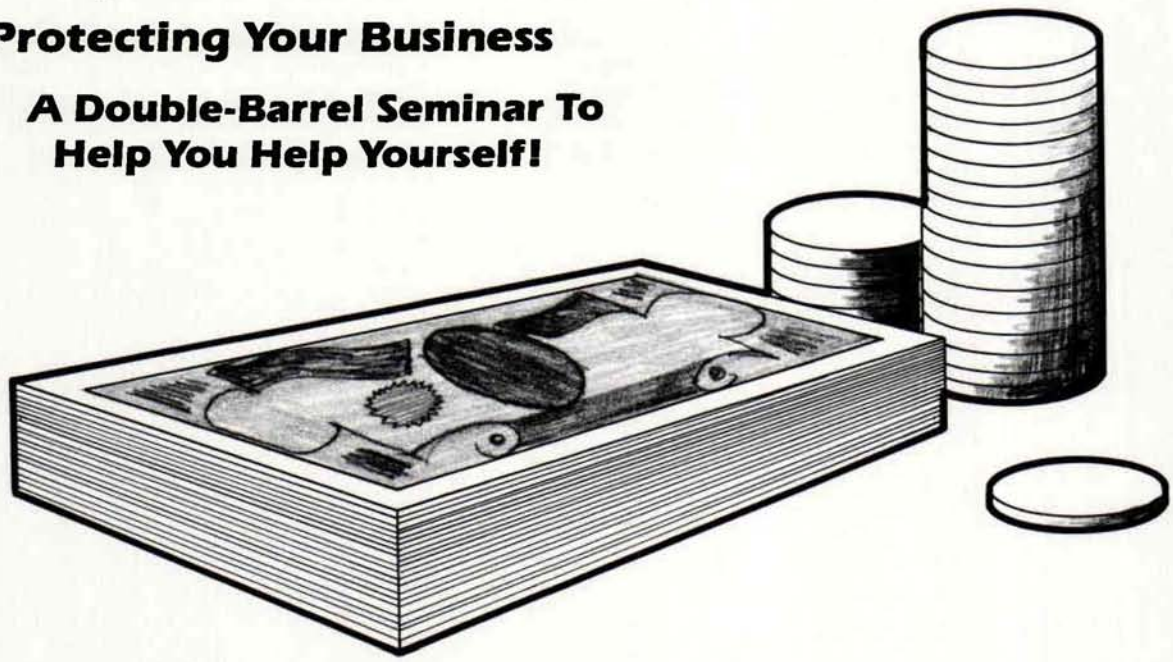

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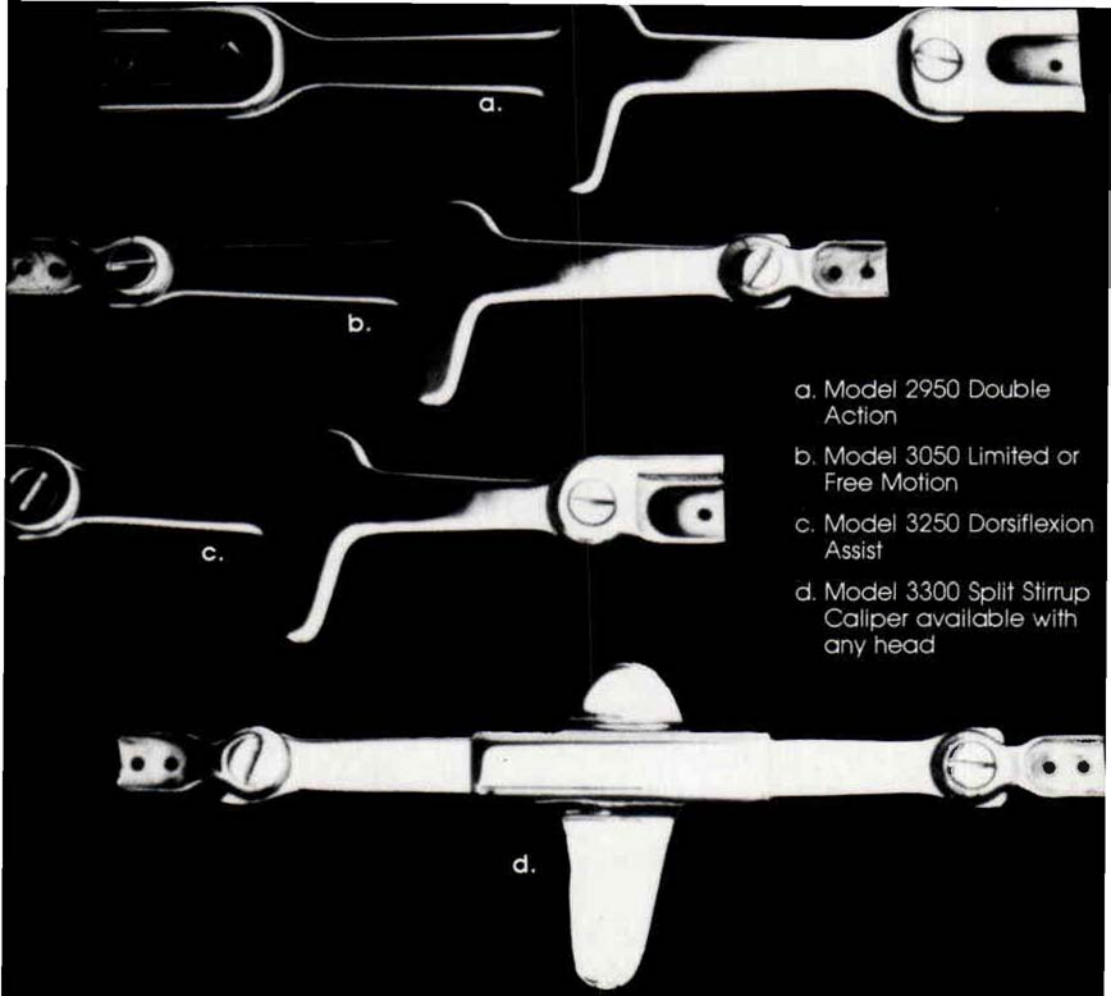


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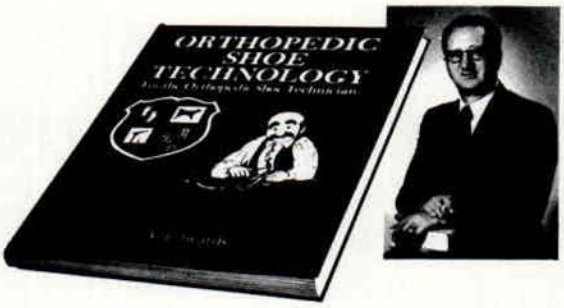


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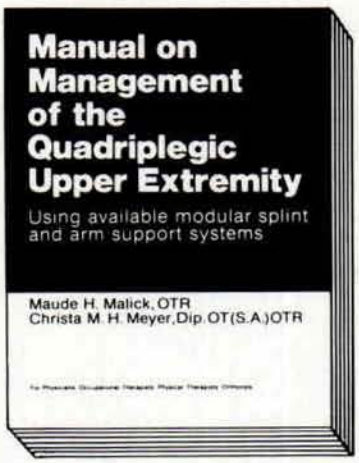


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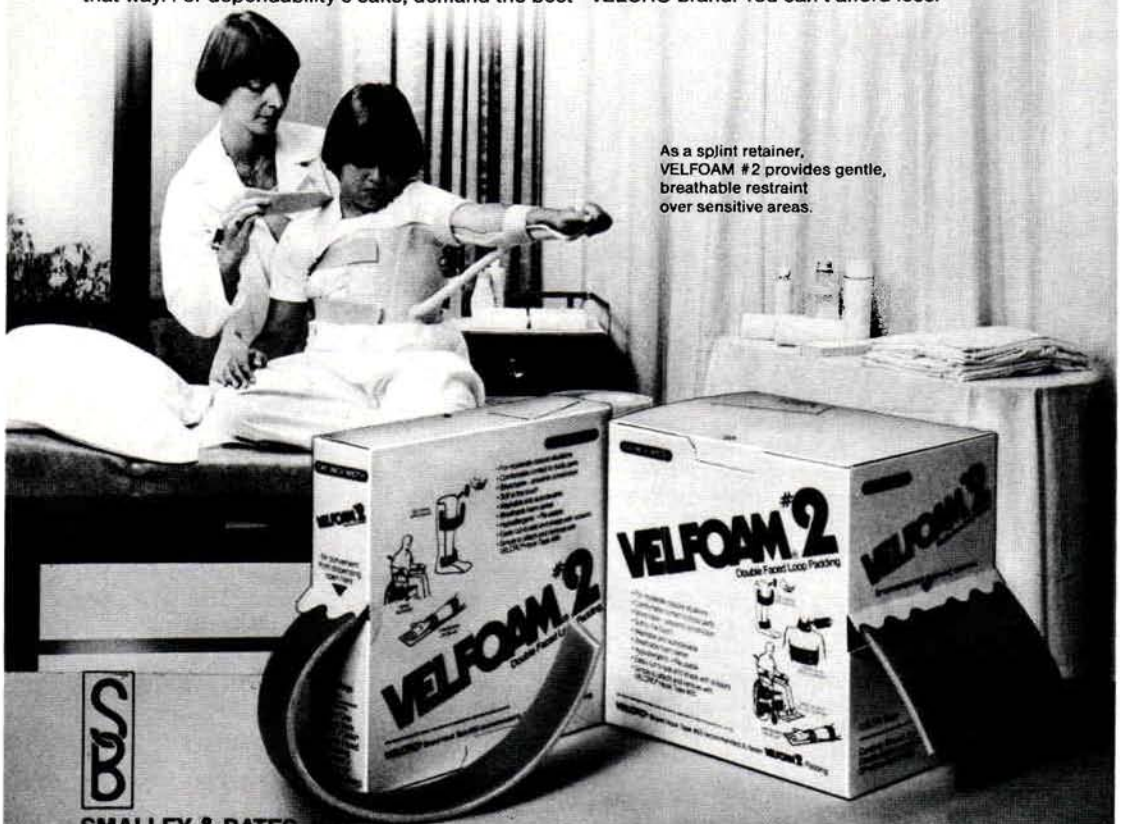


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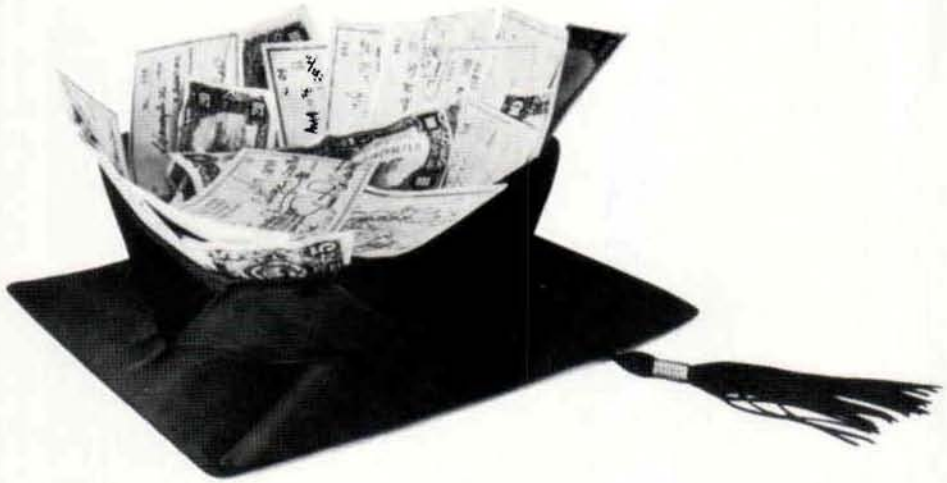

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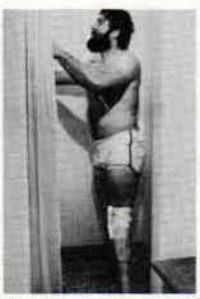

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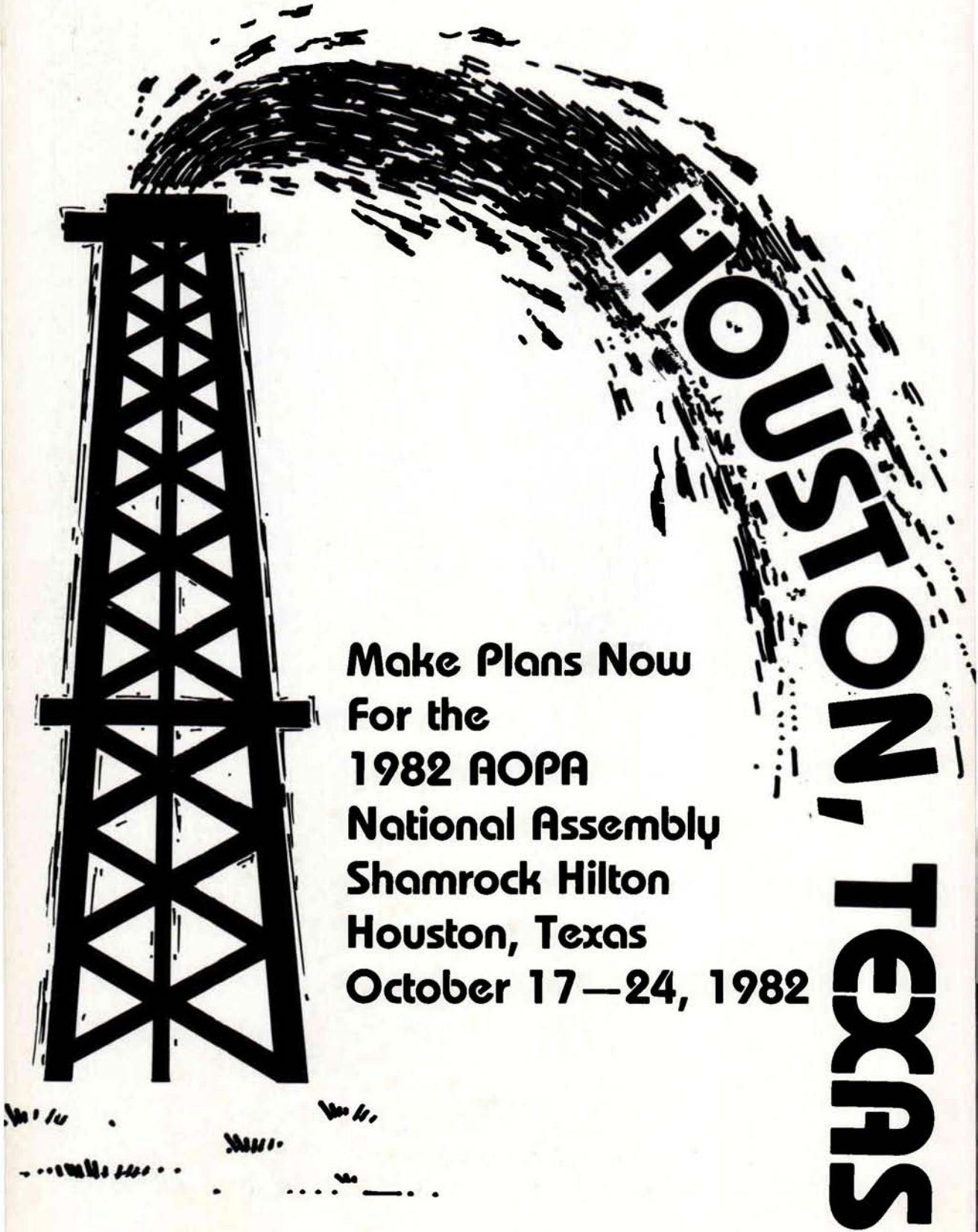


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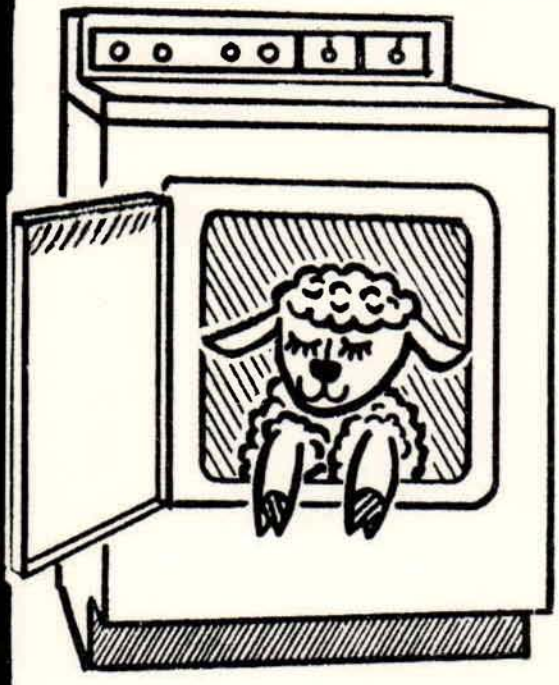

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