Orthotics and Prosthetics, Vol. 30, No. 2, pp. 3–11, June 1976

FABRICATION AND FITTING OF THE CARS-UBC KNEE ORTHOSIS

R. Wassen[1], R. Hannah[1],
J. Foort[1], and S. Cousins[1]

The CARS-UBC Knee Orthosis (Fig. 1) which was described in the December 1975 issue of Orthotics and Prosthetics (*1*) is specifically designed to hold a medially or laterally unstable knee from moving into a painful position of deformity while the knee is in extension, and bearing weight. This paper covers fabrication and fitting procedures.

In the early phase of development, a plaster cast of the affected limb was made with the knee in a nearly corrected position. A positive model of the limb was made, and plastic laminate cuffs were made over it. Since then, we have developed prefabricated kits (Fig. 2). The cuffs are preformed of polyvinylchloride, a transparent thermoplastic with reasonable impact resistance and sufficient rigidity, and are fitted individually after being heated slightly.

The joint system (Fig. 3) includes the polypropylene joint head and the nylon bolt which serves as a pivot. The nylon is locked onto the PVC cuffs with a thin nylon nut which has been countersunk to fit approximately the shape of the underside of the flat head nylon bolt. The PVC, countersunk in the molding process, is clamped between the head of the bolt and the thin nut. When the hinge, which is threaded to mate the bolt, is screwed on, excess bolt is cut off to finish the joint system.

The telescopic beam plugs into the polypropylene joint head. The telescopic feature permits unrestrained flexion of the knee. The fit of the steel tubes permits the units to slide freely with respect to each other without rattle. One end of the knee sling is anchored to this beam so that the required pull toward the beam is achieved. The other ends of the knee cuff are fastened to the PVC cuffs (Figs. 4 and 5).

[1]Division of Orthopaedics, Department of Surgery, Faculty of Medicine, University of British Columbia, Vancouver 9, B.C., Canada.

The knee sling (Fig. 6) is made of leather. It is triangular in shape so that one corner can be anchored to each cuff and one to the telescopic beam in such a way that the three forces on the knee sling balance out the displacing force within the knee. The knee sling, the straps which hold it to the rest of the orthosis, and the straps that hold the orthosis on are the most handcrafted parts of the orthosis. Most of the fitting required involves adjusting the straps to achieve the required balance between the three parts of the orthosis: the thigh cuff, the shank cuff, and the knee sling. Included in these adjustments is adjustment of the waist band suspension system which holds the orthosis in place vertically, and adjustment of the straps which hold the shank and thigh cuffs in position when the whole system relaxes with flexion of the knee and hip.

FABRICATION

THE TELESCOPIC BEAM

Table 1 provides specifications for the seamless, mechanical steel tubing, (Standard Tube, Canada Ltd.) used to fabricate the telescopic beam (Fig. 3). The tubing is cut into seven-inch lengths using a standard type of tubecutter. These lengths will be cut shorter later if necessary to permit sufficient telescoping as the patient sits. An additional piece of 3/8-in. tubing 1-in. long is cut to insert into the 7/16-in. tubing so that 3/8-in. protrudes to plug the 7/16-in. part onto the polypropylene hinge. The 1-in. piece is attached to the 7/16-in. tube by a pop rivet through a hole approximately 3/16-in. from the end of the 7/16-in. tubing. The cut ends of the 7/16-in. tubing are deburred, and the telescopic beam assembly is nickle plated. The completed telescopic beam is shown in Figure 3.

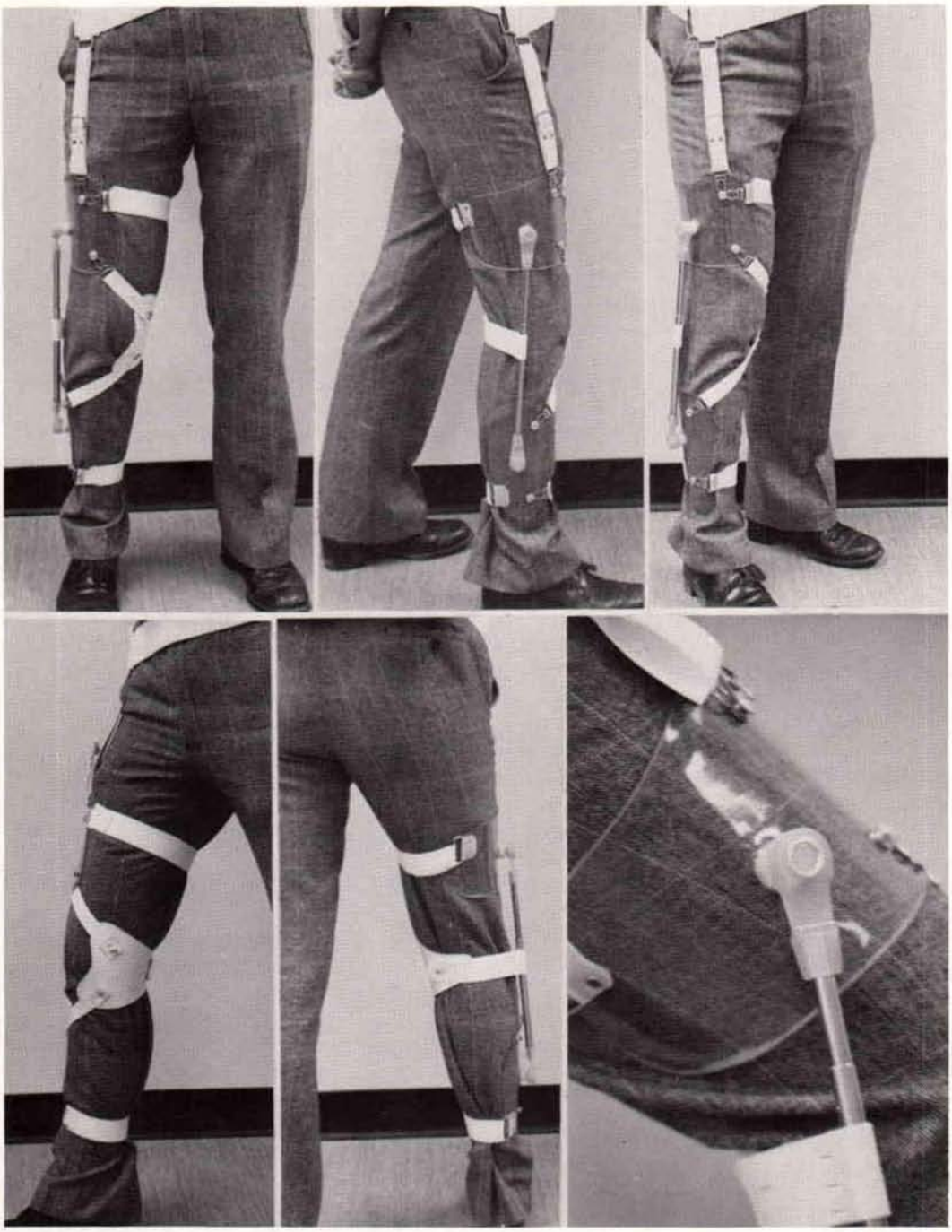

Fig. 1. Various views of the CARS-UBC knee orthosis for arthritis. These views show the orthosis fitted to provide for lateral instability. It can be fitted just as easily with the telescoping bar on the medial side of the knee to provide for medial instability. Although shown here being worn on the outside of trousers the orthosis may be worn next to the skin or simply with a stockinet over the knee.

TABLE 1. SPECIFICATIONS ON THE SEAMLESS MECHANICAL TUBING

O.D.	Wall Thickness Gauge	Dec.	I.D.	Length	Yield Str.	Finish	Type
3/8 in.	17	0.058	0.259	7 in.	60,000 min.	Nickel	4130
7/16 in.	22	0.028	0.318	7 in.	60,000 min.	Nickel	4130

THE JOINT-PIVOT SYSTEM:

Dimensions of the polypropylene joint head, which is injection molded by a local fabricator, are shown in Figure 3. An aluminum insert at the bearing area is provided to eliminate the effects of shrinkage of the polypropylene after molding. The insert is made of 5/8-in. aluminum round stock drilled and tapped for a 1/2-in. N.C. thread. The outer surface is knurled to key it to the polypropylene.

Attachment of the nylon bolt to the PVC cuff is shown also in Figure 3. The head of the bolt

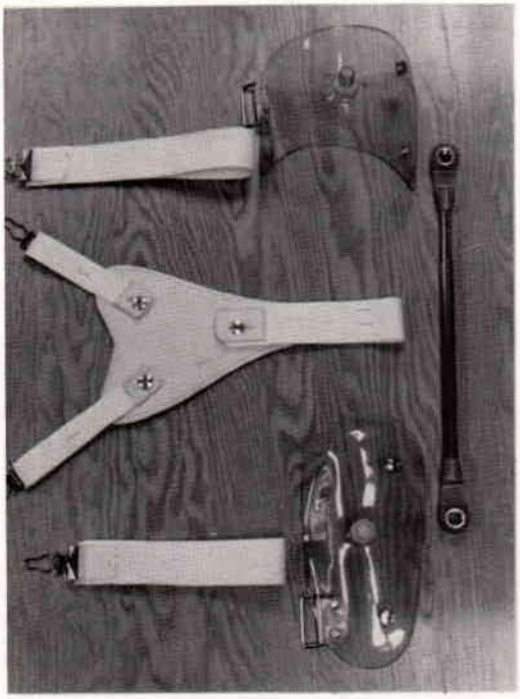

Fig. 2. The parts of the kit for the CARS-UBC knee orthosis.

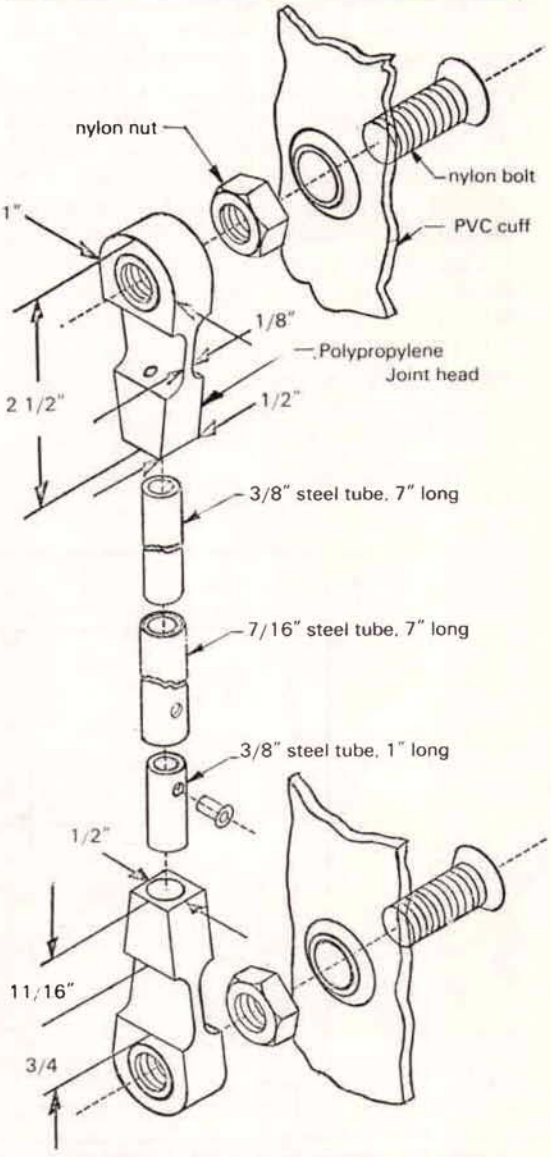

Fig. 3. The components of the telescoping joint system.

is shaved off to remove the screw driver slot, and a nylon nut, which is used to clamp it to the PVC, is thinned to approximately 1/4-in. and countersunk on the side which fits against the PVC. The nylon flat head bolt has 1/2-in. N.C. threads. The polypropylene joint head is screwed onto the nylon bolt to the required position. The advantages gained by using a threaded pivot-bearing system include the ability to position the joint head closer or further from the body for optimizing comfort and cosmesis, and keying of the joint head to the pivot in a direct and simple way.

Assembled, the joint system provides more than adequate pivoting action without significant joint head shift because the degree of pivoting required is only about 45 deg. The thin section of the joint head is designed to provide a flexing hinge which acts at right angles to the pivot. The flexing hinge can allow shifts of about 30 deg. off the axis of the telescopic beam in either direction. If it should flex beyond the yield point, it will not break, but continue to function as a springless hinge. Since the forces act inward against the PVC cuffs, all tendencies favor the system. Furthermore, because the telescopic beam allows relative rotation between the 3/8-in. and 7/16-in. tubing, it is virtually impossible to load the whole system adversely.

THE PVC CUFFS

When it was recognized that prefabricated cuffs were practical, plaster molds (Fig. 7) were established for the thigh cuff and the shank cuff. Each cuff is a mirror image of it's mate and so these are not really left and right cuffs, but varus and valgus cuffs. Thus, the shape of the valgus right is the shape for the varus left. The surface of the mold is shaped to give a flare to the edge of the cuff and to produce a conical elevation for the screw to recess into.

The cuffs are made of 1/16-in. PVC. The material is water clear, and therefore allows direct inspection of fit against the body. When adjustments are required, they can be made with a heat gun. The dimensions for the thigh and shank cuff bands are shown in Figures 4 and 5.

Molding and Finishing Procedures.

1. Soften the PVC pieces in an oven at approximately 400° F for at least 30 sec.
2. Prewarm the molds sufficiently to allow the needed working time.
3. With gloved hands, remove the PVC piece from the oven and work it down against the mold until it mates. Vacuum forming of course can be used.

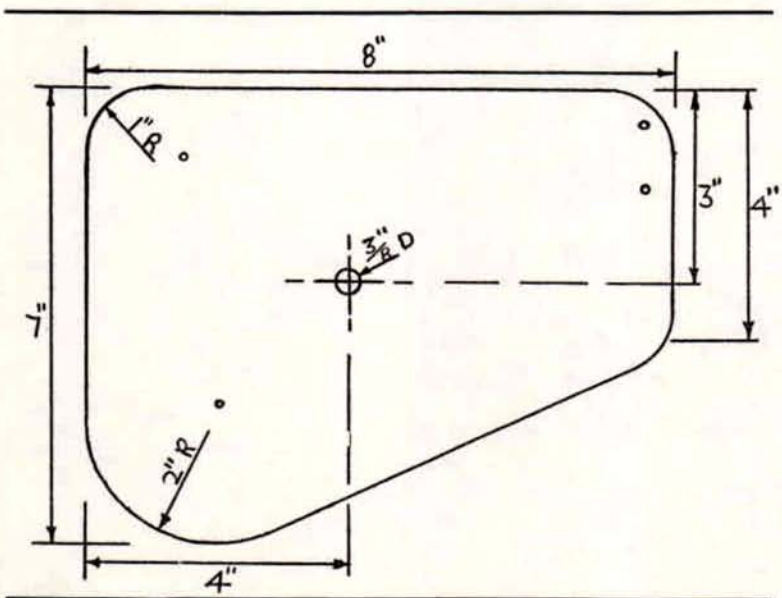

Fig. 4. Outline of the thigh cuff band. Transparent polyvinylchloride has proven to be a satisfactory material for the cuffs.

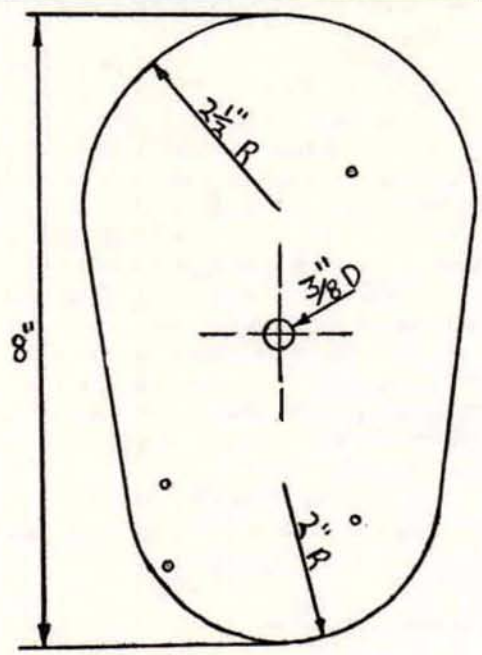

Fig. 5. Outline of the shank cuff blank. Transparent polyvinylchloride has proven to be a satisfactory material for the cuffs.

4. Remove the cooled part. Grind the edges with a disc sander and polish the edges with a felt buffer. Avoid fumes during all operations.

5. Using the disc sander, grind the tip off the conical elevation until a hole is made large enough to receive snugly the 1/2-in. nylon bolt.

6. Drill holes for straps and buttons as indicated on the template sketch using a No. 8 drill (Figs. 4 and 5).

STRAPS AND FASTENING

Because there is no attachment to the shoe, and the whole apparatus is so loosely interlinked within itself, a waist band suspension system is required. Figure 8 shows the 1 5/8-in. belt end, made of leather, to which two shapes and the 1 1/2-in. cotton webbing waist band are attached. The steps involved in making the straps are:

1. Make a leather belt end for attaching the metal shapes and waist strap per the pattern in Figure 8.

2. Use Velcro, attached at the time of fitting, for securing the belt.

3. Make the 1-in. Dacron webbing loop as indicated in Figure 9. The clip fastens to the

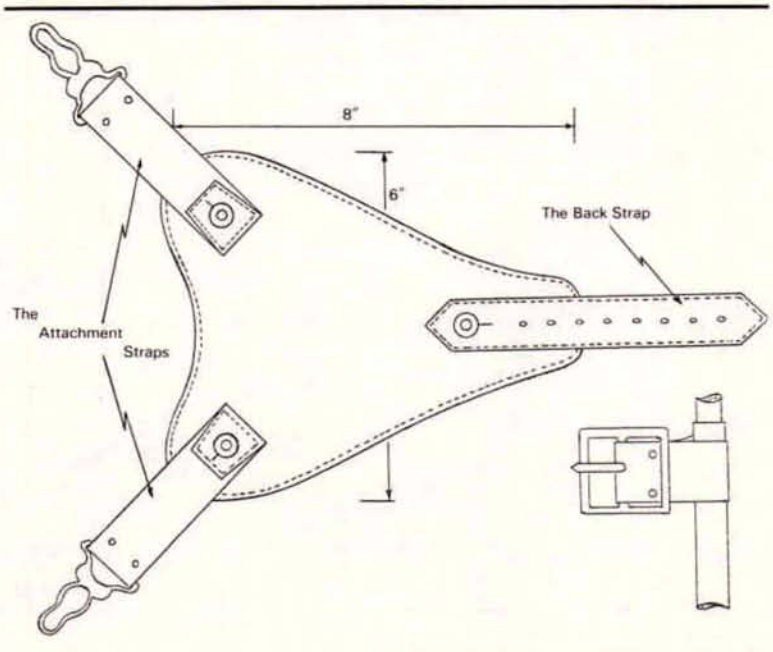

Fig. 6. Basic dimensions of the leather knee sling.

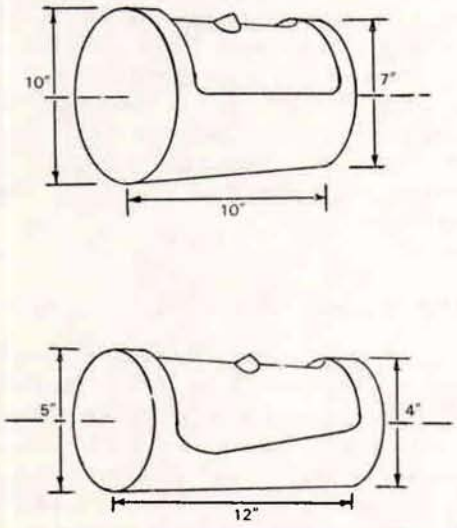

Fig. 7. The molds for the cuffs. The upper figure is for the thigh cuff mold, and the lower for the shank cuff mold. Only one mold for each level is required to provide left and right, varus and valgus because each cuff is a mirror image of its mate and because of the material used it can be reversed.

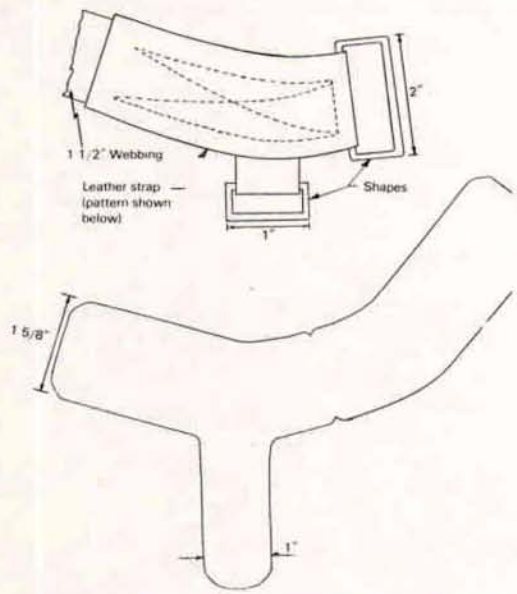

Fig. 8. Upper figure shows the end of the suspension belt. The lower figure is the pattern for the leather portion of the belt end.

button that is attached to the top-front end of the thigh cuff.

4. Make two 1 1/2-in. cotton webbing straps per Figure 10. These are attached to the thigh and shank cuffs and looped around the limb to stabilize the cuffs. The thigh cuff attachment strap is at the top edge, and fits onto the same button as the suspension strap, but goes on second to prevent disconnection of the suspension loop when there is no tension in the system. The shank attachment strap fastens to the lower edge of the shank cuff in the same way.

5. The knee sling is made according to the pattern shown in Figure 6. Attachment points for the three buttons are indicated and these are pop-riveted to the sling. Small copper washers are used for reinforcement.

6. Webbing attachment straps for the knee are shown also in Figure 6. Like other straps they are

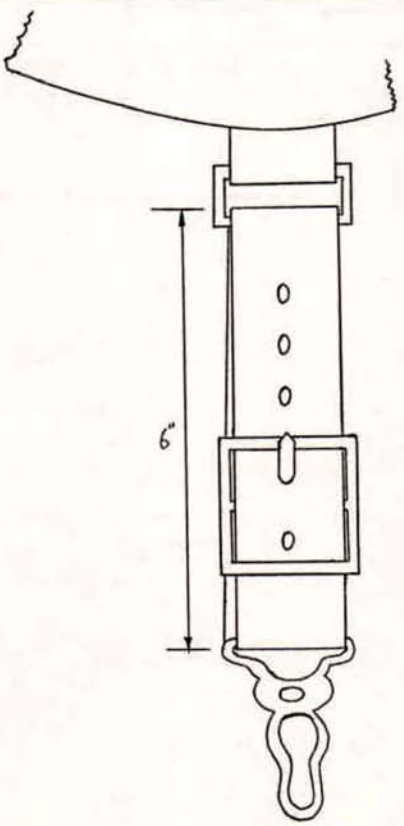

Fig. 9. The suspension strap.

made overlength and cut to the required length after trials on the patient.

7. The posterior knee strap is shown also in Figure 6.

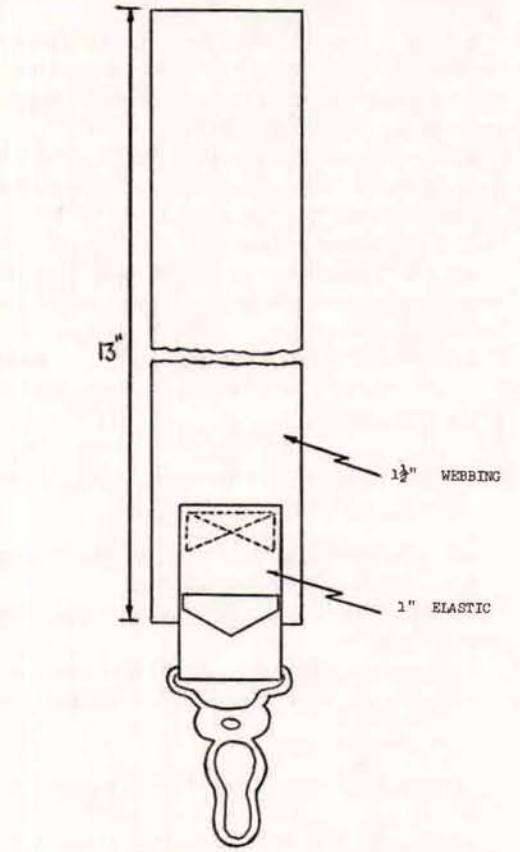

Fig. 10. The cuff strap. Two are required.

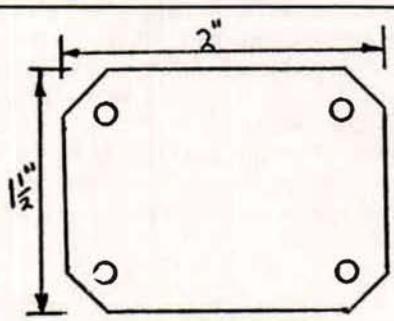

Fig. 11. The Polyethylene Link.

8. Straps are connected to the PVC cuffs by 1 1/2-in. shapes. These are attached by means of polyethylene links (Fig. 8) to the PVC cuffs.

9. Rayon elastic cord, 1/8-in. in diameter is fitted inside the tubing, extending through the polyethylene joints through 1/8-in. holes drilled into the joints along the axis of the tubing as indicated in Figure 3.

FITTING PROCEDURE

With the patient seated and the knee flexed the following steps are carried out:

STEP 1: THE WAIST BELT

- Apply the waist belt so that the suspension strap hangs down the anterior midline of the affected limb.
- Adjust the belt for comfort and sew Velcro on to fasten the belt.

STEP 2: THE THIGH CUFF

- Position the cuff at mid-thigh; on the lateral side for correcting a valgus deformity; on the medial side for correcting a varus deformity.
- For a snug fit, warm the cuff lightly with a heat gun or over a hot plate, and gently bend it to fit the leg. (Practice with a strip of scrap PVC is recommended.)
- Fit the thigh cuff securing strap by adjusting it through the ring on the cuff. It should pass around the leg to fasten onto the top button on the front of the cuff. This strap should hold the cuff securely in place but not restrict circulation. Sew or rivet the strap to the ring and trim off the excess.

STEP 3: THE SHANK CUFF

- A good fit is also important for the shank cuff.
- Fit it mid-way between the knee and the ankle on the medial or lateral side as was the case with the thigh cuff.
- Shape the cuff by warming it and flare the lower edge, if necessary, by pressing the warmed edge against a bench.
- Adjust the securing strap so that it fastens onto the bottom button on the cuff and holds the cuff securely in position.

● Check that the strap is not restricting the circulation, and rivet, or set it, to length.

STEP 4: THE TELESCOPIC TUBE

● Remove the cuffs from the leg and screw the plastic screws into the joint heads of the telescopic tube.

● The narrow tube should be at the top.

● The screw should not protrude from the joint head and the joint should rotate freely.

● Replace the cuffs, now connected by the telescopic tube, on the leg.

STEP 5: THE SUSPENSION STRAP

● Fasten the suspension strap clip (hanging from the belt) to the top button on the front of the thigh cuff.

● Fasten the thigh cuff securing strap back on *top* of the suspension strap clip on the top button.

● Have the patient stand. Adjust the length of the strap, with the patient standing, so that it supports the thigh cuff but does not pull the waist belt down uncomfortably on the hips. Have the patient sit and the suspension strap will go slack.

● Squeeze the suspension strap clip, only, permanently in place on the button with pliers.

STEP 6: THE KNEE SLING

This is the most important part of the fitting procedure because it is the knee sling that pulls the knee into a comfortable position.

● With the knee flexed, fasten one clip on the knee sling to the lower button on the thigh cuff and fasten the other clip to the top button on the shank cuff.

● Adjust the straps through these clips until the knee sling is positioned snugly on the side of the knee, but not restricting the patella.

● Pass the posterior leather strap of the knee sling behind the buckle of the telescopic tube.

● Extend the knee with the patient sitting. The knee sling should pull firmly against the side of the knee. If the anterior straps are pulling the cuffs out of position, they are too short. If adjustment on the posterior strap is insufficient the anterior straps are too long.

STEP 7: HAVE THE PATIENT WALK

● If the thigh cuff is rotating anteriorly, loosen the strap connecting the knee sling to the thigh cuff and tighten the posterior strap of the knee sling.

● Do the same to the shank cuff if it is also slipping anteriorly.

● When the best length of the two straps linking the knee sling to the cuffs has been determined, rivet or sew the straps and squeeze the clips permanently to the buttons with pliers.

● Have the patient take off the orthosis and put it on again a number of times to ensure independence. Establish that the patient can follow the written instructions given him.

● If the telescopic tube is too long, (i.e. restricting flexion), it may be shortened using a tube cutter or hacksaw.

● If the skin is in good condition the orthosis may be worn next to the skin, otherwise a stockinette may be worn.

Points which indicate that the fitting of the brace is successful are:

● the patient feels less pain in the affected knee

● the speed of walking is increased

● there is increased stability and mobility in the stance phase

● the patient feels more secure and confident

● there is less dependence on any walking aid

INSTRUCTIONS FOR THE PATIENT

● The orthosis is most easily put on when the patient is sitting with the knee flexed.

● Put the waist belt on with the buckle just in front of the hip.

● Position the cuffs on the side of the leg.

● Fasten the top cuff on by clipping the strap to the top button of the cuff.

● Fasten the bottom cuff on by clipping the strap to the bottom button.

● Now that the cuffs are fastened to the leg, fasten the knee sling. Do this by pulling the strap around and behind the knee and fasten it to the buckle on the tube.

Check:

1. When standing, the knee sling should give firm support at the side of the knee.
2. *If it is too tight* sit down and slacken the buckle on the tube.
3. *If it is too slack* sit down and tighten the buckle on the tube.

To take the orthosis off:

1. Unfasten the strap behind the knee.
2. Undo the strap at the bottom.
3. Undo the strap at the top.
4. Take off the waist belt.

LITERATURE CITED

1. Cousins, S., and James Foort, *An orthosis for medial or lateral stabilization of arthritic knees,* Ortho. and Pros., 29:4, December 1975.