I. INTRODUCTION

The University of California Biomechanics Laboratory (UC-BL) Dual-Axis Ankle-Control System was developed to answer the need for a more satisfactory method of ankle bracing than that afforded by the conventional short leg brace (1). The name was chosen because the device is essentially an external analog of normal motions about the two joint axes in the ankle complex. In this report, System designates the brace together with the equipment used for its alignment—to be described below—whereas Unit refers to the brace alone.

Early studies of human locomotion established the importance of the subtalar (talocalcaneal) joint (2) as well as of the ankle (talocrural) joint (3) for walking and other activities of daily living. The conventional double-upright short leg brace is supplied with one single-axis joint which is supposed to move with the ankle joint. There is no general agreement regarding the proper, or optimum, alignment of this brace-joint axis relative to the anatomic joint axes of the
ankle complex. Perhaps the most commonly recommended procedure at the present time is to try to align the brace-joint axis with the anatomic ankle-joint axis. Such an attempt is almost sure to fail—primarily because it ignores the subtalar joint. In addition, the brace-joint axis is usually made parallel with the floor and therefore cannot be coaxial with the ankle-joint axis, which has been shown to lie not horizontally, but inclined downward and posteriorly from the medial to the lateral end (4).

Any ankle brace is a compromise and provides, at best, an approximation of the various movements which can take place in the normal ankle complex. Investigation of the effects and limitations of the conventional brace has indicated that a somewhat more complex device, which provides a more precise approximation to normal motion by allowing movement at both the ankle and the subtalar joints, would be of significant benefit to the brace wearer.

Desai and Henderson developed a complex adjustable external mechanical analog of the ankle and subtalar joints to determine the locations of, and observe the motions about, these joints. This device, and the drop-foot brace based upon it, have been described in detail (1). The final model of the brace worked out by them was in all essentials the prototype of the present UC-BL Dual-Axis Ankle-Control Unit.

The UC-BL Shoe Insert (5), developed as an adjunct to the brace and usually used with it, is a plastic shell that grips the heel firmly and holds the foot in an improved functional position within the shoe.

The present model of the brace, without attachments, allows "normal" (unrestricted) motion at both the ankle and the subtalar joints. Attachments at one or both of the joints can be added to restrict, direct, or aid certain motions as desired. The brace is not, however, an all-purpose device. Developed originally for the correction of drop foot, it has also proved useful as an adjunct in the treatment of talipes equinovarus (clubfoot). In its present form it is not suitable for use as a weight-bearing brace, because it has not been designed to withstand heavy loads.

Considerable effort has been directed toward simplifying procedures for fitting and alignment without impairing the desirable features of the brace. For several years alignment has been accomplished by fitting an adjustable brace (a simplified analog with adjustable elements) to the patient; with this method, misalignments of the joints of the adjustable brace are systematically eliminated until optimum fit and alignment are achieved (6). Alignment duplication jigs are used to transfer the alignment to the final brace.

Recently, a further simplification in fitting was introduced which allows the orthotist to align and construct the Dual-Axis Unit in a frac
tion of the previously required time. This report describes the simplified technique, in which a plaster wrap cast is taken of the patient's leg and foot with his shoe on, and this cast is used as a basis for the alignment and construction of the final brace.

The new procedure is based on anthropometric studies of the foot and ankle which were completed within the last year by Isman and Inman (4). Many investigators (7, 8, 9) have in the past considered the ankle joint to be a multi-axis joint—notably Hicks (9), who believed that there were separate plantar-flexion and dorsiflexion axes. On the basis of their own studies, Isman and Inman (4) and Inman (10) state that the ankle joint is close enough to being a single-axis joint that for purposes of bracing it may be considered as such; they also determined that this axis could be approximately located as a line connecting points 3 to 5 mm. distal to the distal tips of the lateral and medial malleoli (Fig. 1).

The investigation of Isman and Inman further indicated that the average inclination of the subtalar axis is 41 deg. from the horizontal.d (most authorities agree that this inclination is approximately 40 deg.e)

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d In the following, the horizontal plane is the plane of or parallel to the floor or other standing surface.

e It should be pointed out that the angle of the subtalar joint of the brace will rarely be set at exactly 40 deg. from the floor. This is due to (1) variations in anatomy and (2) the necessity of placing the heel joint at the junction of the shoe's heel and heel counter, rather than at the actual point of emergence of the axis from the patient's foot.
and that it intersects or passes slightly below the ankle-joint axis approximately halfway between the tips of the malleoli (Fig. 2). For purposes of bracing, actual intersection can be assumed, in which case, of course, the two axes lie in a single plane. The relationship between the two brace-joint axes can be visualized by rotating this plane about the ankle axis until the axis of the subtalar joint within the plane is inclined to approximately 40 deg. (Fig. 3).

The method of making the brace may be briefly summarized as follows: The locations of the distal tips of the malleoli are marked with indelible pencil. A thin-walled plaster wrap is taken of the patient’s leg, with the wrap carefully molded to the shoe at the same time. When the wrap and the shoe are removed from the patient and the wrap is repaired and keyed back onto the shoe, a steel pin is inserted through the points on the wrap that mark the tips of the malleoli. The pin represents the ankle axis, and the cast, shoe, and pin provide a model with all of the necessary information for alignment.

The heel joint, which corresponds to the subtalar joint, is preset and fixed in a position 15 deg. medial to the long axis of the shoe. Adjustable components are now used to link the heel joint to the ankle joint in such a way as to hold them in the common plane referred to in Figure 3 and to maintain within that plane the relative angle formed by the two axes.

![Figure 3](image_url)

1 Although the ankle-joint axis passes through points approximately 3 to 5 mm. distal to the distal tips of the malleoli, an axis that passes through the distal tips is sufficiently accurate for purposes of bracing.

2 This line represents the projection of the subtalar axis on a horizontal plane. The discrepancy between this angle (15 deg.) and the average found by Isman and Inman (23 deg.) is explained by the fact that the long axis of the shoe runs approximately through the second ray and is thus closer to the line representing the axis of the subtalar joint than is the midline assumed by Isman and Inman, which runs midway between the second and third rays.
The alignment maintained by the adjustable components is transferred to permanent parts by means of special tools, i.e., protractor, bending jig, and alignment transfer jig. When the permanent parts are reassembled on the shoe and the sidebar and cuff have been bent to the shape of the wrap, the unit is complete. Fit is checked on the patient, and assists are added and subtracted as needed.

II. PARTS AND EQUIPMENT

Brace Hardware and Equipment

The UC-BL Dual-Axis Ankle-Control Unit (Fig. 4) comprises three basic links: the stirrup, yoke, and sidebar assemblies. Of these, the stirrup and the yoke require adjustable brace counterparts and alignment transfer jigs.

The stirrup assembly includes the channel which is attached to the shoe and the stirrup which is the link between the shoe and the heel joint. The stirrup slides into and out of the channel; this arrangement makes it possible to disconnect the brace from the shoe quickly. Parts: channel and stirrup. Tools: adjustable stirrup, stirrup-bending jig, and protractor.

The stirrup and the yoke are held together at the heel joint by a flanged nut, a flanged screw, a locking screw, and Nylatron washers (see Fig. 35). Tools: special spanner wrenches.

The yoke assembly consists of the tang which constitutes half of the heel joint and the tongue which constitutes half of the sidebar joint.
Parts: tang and tongue (which, when joined together, comprise the yoke) and one lacing hook. Tools: adjustable yoke, shortened sidebar-joint pivot nut, center-drilled ankle-joint-alignment machine screw, yoke alignment transfer jig, bending irons, and acetylene welding torch.

The yoke and sidebar are held together at the sidebar joint by a sidebar-joint pivot nut and a sidebar-joint screw.

The sidebar assembly consists of a standard commercially available aluminum or steel sidebar (which incorporates either a Klenzak joint or a free ankle joint) and a cuff which is the link between the sidebar joint and the shank of the leg. Parts: commercially available sidebar (the Klenzak joint has a setscrew, a steel toe-lift spring, and a steel ball which, for this brace, is replaced by a Nylatron reaction plug), cuff band made of 16-gage aluminum, 1 1/2-in. wide, leather, rubber (1/8-in. Kemblo Cel-flex) for the liner, Velcro or leather strap fasteners. Tools: bending irons.

To provide eversion assistance, rubber bands are stretched between a reaction stud in the heel and the lacing hook of the yoke. The reaction stud, a 1 1/2-in. #8 plated screw, is screwed into the heel, leaving a 1/8-in. space between the heel and the head of the screw.

In addition to the items listed above, a pair of suitable shoes must be provided by the patient. They will be used during the casting procedure and must be retained by the orthotist for use in fabrication of the brace. The shoes should be sturdy laced oxfords with metal shanks. For women, laced oxfords or nurses' type shoes are required; the heel must be no higher than 1 in.

**Stock Tools and Supplies**

It is assumed that fabrication will be done in an orthotics shop outfitted with standard equipment. Specific supplies for fabrication of the UC-BL Dual-Axis Ankle-Control Unit would include the following:

- 3/16-in. drill
- #3, #19, and #29 wire-gage drills
- #8–32 tap
- 8–32 flat head machine screws
- #10 standard brass rivets, 1 in. long
- #4829 Speedy rivet
- heel nails
- 7-in. bandage scissors or a cast cutter
- one pair 7-in. bow-spring outside calipers
- machinist’s square or similar right-angle instrument
- trisquare combination tool with two circle-bisecting attachments
- "C" clamps, 6-in. opening
leather punch
hand pump for inflating balloons
rubber bands, size 10 or 12 balloons (airship, colorless, manufactured by Ashland Rubber Products, Ashland, Ohio 44805, #836 for adults, #625 for children)
$1/4$-in. or $3/8$-in. rubber tubing, 24 in. to 30 in. long
$1/2$-in. double-sided adhesive tape
masking tape
indelible pencils
steel pin, $3/8$ in. in diameter and 9 in. long
lead strips, approximately $1/8$ in. x 1 in. x 8 in.
small scraps of leather for build-up on heel around channel
shoe glue, such as Sta-Bond
baby powder
grease or petroleum for rubber tubing
3-in. stockinet (2-in. for children)
4-in. rolls of fast-setting elastic plaster, Johnson and Johnson Orthoflex
conventional plaster bandage for cast repair

III. CASTING PROCEDURE

1. Place a clean sheet of paper on the standing surface, since any sharp bits of hardened plaster from previous casting procedures will easily tear the balloon that is used during casting.

2. Have the patient don his shoes without stockings. If he wears any device such as an arch support or shoe insert, it should also be worn during casting.

3. Seat the patient in such a way that he can comfortably hold his affected leg extended.

4. Place a $1/2$-in. strip of double-sided adhesive tape over the tip of each malleolus to help mold the balloon, and subsequently the cast, to these areas.

5. Powder the inside of an appropriately sized balloon; this is easily done by stretching the opening over the mouth of a small container of baby powder and shaking. Then inflate the balloon fully and place it with the closed end against the anterior end of the extended shoe of the patient (Fig. 5).

6. Push the balloon carefully onto the shoe past the heel. Release air gradually until the balloon is completely deflated (Fig. 6). To control the release of air and maintain control over the balloon, hold the open end of the balloon against the abdomen while using both hands to guide the balloon onto the foot. Trunk movement is used to control the rate of air release.
7. Pull on the projecting mouth of the balloon and cut it off as shown in Figure 7. Place the fingers of both hands under the cut edge; stretch the balloon and pull it up onto the leg (Fig. 8). The balloon is now inside out.

8. To secure the balloon's position, run masking tape around the leg on the balloon about 3 in. above the malleoli. Trim away excess balloon to top of tape (Fig. 9). Press the balloon onto the tape strips at the tips of the malleoli.

9. Pull a length of thoroughly wet 3-in. stockinet (2 in. for children), long enough to extend from the malleoli to the middle of the knee, into position, with the distal edge left approximately 1 in. above the malleoli. This can best be accomplished by rolling the stockinet into a doughnut-shaped ring, stretching the ring, and putting the foot through it. Once it is past the heel, the stockinet should be unrolled up the leg to the knee (Fig. 10).

10. Tape a long piece of lightly greased 1/4-in. or 3/8-in. rubber tubing
into place along the anterior aspect of the leg, extending from the knee to beyond the middle of the shoe (Fig. 11).

11. Encase the opposite shoe in a piece of stockinet to keep it free of plaster.

12. With the patient standing in a normal upright balanced position, palpate the distal ends of the malleoli and outline them on the balloon's surface with an indelible pencil (see earlier footnote D). Mark the top of the shoe and the junction of heel counter and the heel of the shoe in a similar manner (Fig. 12).

13. Set two 4-in. rolls of fast-setting Johnson and Johnson Orthoflex elastic plaster on end in cold water and soak them until air bubbles cease to rise.

14. With the patient standing, begin the wrap at the rubber tubing on top of the instep. The wrap is made by applying two layers from
the dorsum to the bottom of the heel (Fig. 13). Then begin an upward spiral wrap, with each successive layer overlapping the previous one by half the bandage width, or 2 in.

15. Continue the spiral upward to the popliteal crease (Fig. 14). Wrap twice around the crease and then make a downward spiral wrap similar to the previous upward one (with the same type of overlapping layers). The purpose of this controlled wrap is to provide a uniform thickness between the fibular head and the malleolar areas. The proper contour of the sidebar and fit of the cuff depend upon this uniform thin cast.

16. Smooth and mold the entire wet wrap into the areas around the malleolar tips and the top of the shoe counter.

17. Remove the rubber tubing after the cast has hardened. This will ex-
pose a cutting channel adequate to allow the use of a standard pair of bandage scissors or a cast cutter.

18. Remove the cast, retain the shoe, and dismiss the patient.
19. Repair the cast by closing its cut edges with short strips of conventional plaster bandage, taking care to avoid extending the patch to the lateral aspect of the leg, where a plaster build-up would hamper the achievement of a smooth brace sidebar contour. Let the cast dry naturally at room temperature or place it in an oven at 150 deg. F. for 1 hour.

IV. ALIGNMENT, FABRICATION, AND FITTING: DETAILED PROCEDURE

1. The marks made over the tips of the lateral and medial malleoli will be clearly visible on the inside of the cast. Transfer these marks accurately to the outside of the cast with a pair of 7-in. bow-spring outside calipers or a similar device (Fig. 15).
2. Drill a $\frac{3}{8}$-in. hole through the cast at each of the two malleolar marks.
3. Insert a pin, ½ in. in diameter and approximately 9 in. long, through the malleolar holes. This pin approximates the patient's ankle-joint axis.
4. Trim the cast to the line marking the junction of the heel and the heel counter.
5. Stuff the shoe with paper to prevent distortion.
6. Replace the cast on the shoe; key it along the top edge of the shoe counter, using the previously molded ridges.
7. With a machinist's square or similar right-angle instrument, establish and mark the medial and lateral points along the sides of the heel portion of the sole where vertical lines would bisect the lines marking the distal ends of the malleoli (Fig. 16).
8. Remove the cast from the shoe. Take the heel off the shoe. If a plastic spacer is present between the sole and the heel, remove and discard it, and sand the heel portion of the sole flat. Shoe construction varies, and in some cases a skived leather insert is present between the heel and the sole. If this insert comes off in the process of removing the heel, glue it back into place and lightly sand it to insure a flat surface.
9. Draw a connecting line (Fig. 17) on the flattened heel portion of the sole between the two marks made in Step 7.
10. Draw a center line (see earlier footnote g) along the length of the sole; to do this, use the rule of a trisquare combination tool which has two circle-bisecting attachments fitted to opposite ends, one cupping and bisecting the heel, the other cupping and bisecting the anterior end of the sole (Fig. 18). A "C" clamp placed at the heel will greatly assist in holding the rule in place while the line is drawn.

11. Using the point of intersection of the line drawn across the heel and the longitudinal line just drawn, draw another line passing 15 deg. medial to the longitudinal line on the forefoot portion (Fig. 19). This line approximates the axis of the subtalar joint projected on a horizontal plane (see earlier footnote g).
12. Drill two pairs of holes with a #29 wire-gage drill, one pair on each end of a channel—one set of holes 1 in. from one end and the other set of holes 1/2 in. from the other end. Tap these holes to #8-32 threads. Scribe a center line on the channel (Fig. 20).

13. Remove the paper and the heel liner from inside the shoe. Center the channel over the subtalar, or 15 deg., angle line, with that end of the channel that has the holes 1 in. from the end placed posteriorly and with the center of the posterior end 1/8 in. inside the heel margin (Fig. 21). Hold the channel in place with a "C" clamp.

14. Using one of the tapped holes as a drill guide, drill a hole through
the sole into the shoe with a #29 drill. Holding the channel in position temporarily with a rivet through this hole, drill the hole on the opposite corner. Again, place a rivet in the hole while the last two holes are drilled.

15. Remove the rivets and the channel and drill through all four holes in the shoe again with a #19 drill. Fix the channel in place with flat head machine screws inserted from the inside of the shoe and tightened until the heads are flush with the insole.

16. Invert the shoe and grind or file the tips of the screws flush with the
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channel surface. Trim and sand all protruding corners of the channel (Fig. 22).

17. Connect the adjustable yoke to the adjustable stirrup, and insert the stirrup into the channel (Fig. 23).

18. Replace the cast once again in the manner described in Step 5.

19. Place the shortened sidebar-joint pivot nut into the medial side of the hole in the tongue portion of the adjustable yoke, and screw the center-drilled ankle-joint-alignment screw into the nut (Fig. 24).

FIGURE 23

CHANNEL

TONGUE

ADJUSTABLE YOKE

FIGURE 24

ADJUSTABLE STIRRUP

FIGURE 25
20. With all of the adjustable components loose, adjust the yoke and stirrup until the ankle-joint pin can pass freely through the center of the machine screw and the holes in the cast which mark the ankle-joint axis; leave approximately \( \frac{1}{2} \) in. clearance between the projection marking the lateral malleolus and the inner aspect of the tongue. The tongue should be perpendicular to the ankle-joint pin (Fig. 25).

21. Lock all of the adjustable components and bend a strip of lead to follow the contour of the shoe from the heel joint to the sidebar joint; it should be at a uniform distance of approximately \( \frac{1}{2} \) in. from the shoe and the cast (Fig. 26).

22. Invert the shoe and, with a \#29 drill, drill a hole through both the channel and the shoe. The pilot for this stirrup alignment hole is in the base of the adjustable stirrup (Fig. 27).

23. Remove the cast, the adjustable yoke, and the adjustable stirrup.

24. Measure the angle between the heel-joint surface of the adjustable stirrup and its base (Fig. 28).
25. Place a stirrup blank in the bending jig with the narrower side up and clamp it to the base in a centered position. Then bend the blank (Fig. 29) to the angle measured in Step 24.

26. Align the transfer jig to the adjustable yoke and lock all of the jig’s adjustments (Fig. 30).

27. Remove the adjustable yoke from the jig. Put a yoke tang into the stirrup-bending jig and bend it to a 45 deg. angle. This is done because the initial bend of the yoke tang is so close to the bearing sur-
face that bending irons would not work and a vise technique might damage or warp the machined bearing surface. Install the bent tang and a tongue blank in the yoke transfer jig in their appropriate positions (Fig. 31).

28. Bend the two components (Fig. 32) until they mate and approximate the contour of the lead strip (Step 21). (Bend the tang first and then bend the tongue as necessary to mate with it.)

29. Mark the tang for proper length, allowing for an overlap of \( \frac{1}{2} \) in.

30. Remove the tang and the tongue from the jig, cut the tang to length, and sand or grind a bevel on each of their overlapping ends.

31. Replace the tongue and the tang in the transfer jig, and silver braze their mating surfaces together (Fig. 33). To prevent metal-burn, it is good practice to braze the beveled edges first and then the side surfaces. Cool the yoke, remove it from the jig, and clean and polish it.

32. Attach a lacing hook to the inner aspect of the yoke, approximately midway between the sidebar joint and the heel joint, with the opening upward (Fig. 34).
33. Assemble the stirrup and the yoke to form the heel joint as follows: Place a Nylatron washer over the flanged nut. Insert the flanged nut through the yoke and place another Nylatron washer over the nut as it emerges from the yoke. Now insert the flanged nut through the stirrup and place a third Nylatron washer on it. Then firmly hold the flanged nut with a spanner wrench and screw the flanged screw into it. Tighten with a second spanner wrench so that all of the play is removed between the joint surfaces without restricting free motion. With the two spanner wrenches still in place, screw the locking screw into the flanged screw, expanding the threads against the flanged nut and firmly locking the two pieces together (Fig. 35).

34. Install the stirrup in its proper position (as far as it will go) within the channel. With the shoe right side up and with the previously drilled stirrup alignment hole as a drill guide, drill a hole through the stirrup (Fig. 36).

35. Remove the stirrup/yoke assembly, invert the shoe, and fill in the area on either side of the channel with leather of a thickness equal to the height of the channel (Fig. 37).
36. Reattach the heel and replace the stirrup/yoke assembly. Secure the assembly in position by inserting a rivet from the inside of the shoe through the previously drilled alignment hole. Replace the heel liner in the shoe.

37. Replace the cast on the shoe by the procedure described previously.

38. On the cast of the leg, mark the position of the cuff, which is located posteriorly, \(\frac{2}{3}\) of the way around the leg, with the top edge about 1 in. below the base of the head of the fibula. Bend a lead strip to conform snugly to the cast at the marked position. Then bend an aluminum cuff blank to the same shape as the lead strip. Cut this band to the desired length and tape it in place on the cast (Fig. 38).

39. If a Klenzak joint is used, remove the adjustable screw, the toe-lift spring, and the steel ball.

40. Anneal the sidebar blank by blackening the entire surface with an acetylene gas flame and then, using a neutral flame, heat the metal until the carbon film dissipates.
41. Using the ankle-joint-alignment machine screw, attach the sidebar blank to the yoke.

42. Insert the ankle-joint pin through the malleolar holes and the ankle-joint-alignment machine screw.

43. Bend the sidebar with bending irons into a snug fit over the contours of the cast and the cuff (Fig. 39).

44. Mark the sidebar where it crosses the proximal and distal borders of the cuff band (Fig. 40). Mark the position of the sidebar on the cuff band.

45. Remove the sidebar. Drill and tap two holes in the sidebar for #8-
32 machine screws, one \(\frac{1}{4}\) in. below the proximal cuff margin mark and the other \(\frac{1}{4}\) in. above the distal mark.

46. Cut the sidebar to length at the proximal cuff margin, sand and polish it, and refit it into the sidebar joint using the permanent sidebar-joint pivot nut and sidebar-joint screw instead of the shortened sidebar-joint pivot nut and the center-drilled ankle-joint-alignment machine screw.
47. Mark the positions of the two #8-32 tapped sidebar holes on the cuff band. Remove the band and drill two holes with a #3 wiregage drill. Also with a #3 drill, drill a hole in the opposite end of the band, centered 1/2 in. from the end (Fig. 41).

48. Using 1/8-in. Kemblo Cel-flex or a similar suitable material, make a cuff liner the shape of the inside surface of the cuff band allowing for a 1/8-in. overlap on all sides. Enclose this liner with a light horsehide cover. Glue the completed liner to the inside surface of the cuff band, and punch three holes in the liner through the three holes in the cuff band.
Figure 38

Figure 39

Figure 40
49. Center and glue a strip of Velcro hook the same length as the cuff to the outside surface of the cuff; punch holes in this, also, over the three cuff band holes. Fix a #4829 Speedy rivet in the single hole on the medial side of the cuff.

50. Cut a strip of Velcro pile in a length adequate to encircle the leg. Press the end of the strip on to the lateral side of the cuff band so that it is \( \frac{1}{4} \) in. posterior to the pair of holes, and punch it over the holes. The long part of the strip will now extend anteriorly (Fig. 42).

51. Pass two #8-32 machine screws through the liner, cuff band, Velcro hook, and Velcro pile and tighten them in the tapped #8-32 holes on the sidebar. This arrangement holds all of the materials firmly in place.

52. Make a pretibial pad of Naugahyde or leather approximately the width of the cuff opening, with webbing slots to receive the strip of Velcro pile. Thread the strip of pile into the pretibial pad. The sidebar assembly is then complete.

53. Screw the reaction stud into the lateral side of the heel portion of the sole, at approximately the anterior end of the heel (as shown on the completed brace in Figure 43).

54. The overall heel heights in both shoes should be checked to make sure that they are equal.

55. Summon the patient and fit him with the brace. Mount a few rubber bands between the reaction stud on the shoe and the lacing hook on the yoke to provide eversion assistance. When a Klenzak sidebar is used for the patient requiring toe-lift, replace the steel ball with the special Nylatron reaction plug. Re-install the toe-lift spring and the adjustment screw. Ask the patient to walk. After observing his gait, add or subtract rubber bands and adjust the toe-lift spring screw as required for optimum assistance at each joint.

56. Should damage or general wear require duplication of a particular brace at a later date, refitting of the patient is unnecessary.
tion of a completely new brace is very simple if the cast has been retained by the patient and the orthotist has kept a record of (1) size, model, and manufacturer of the shoe; (2) the angle of stirrup bend; (3) the angle formed by the two arms of the yoke alignment transfer jig; and (4) the distance from the pivot point of the transfer jig to the center of the bolt holding the tang in place, and the distance from the pivot point to the center of the bolt holding the tongue in place. Separate replacement of either the stirrup or the yoke is also conveniently accomplished with use of these data.

V. CLINICAL EXPERIENCE

Clinical experience with the UC-BL Dual-Axis Ankle-Control Unit has not yet included a great variety of conditions, nor has the sample of subjects been large enough to allow a valid statistical analysis. The conclusions and comments reported here have been compiled from patient records maintained by physicians and orthotists at the Biomechanics Laboratory.

The brace has been prescribed primarily for patients who, as a result of poliomyelitis or peripheral nerve damage, have flaccid paralysis of the musculature of either the anterior or peroneal compartments of the
lower leg, with little or no bony abnormality. This is the type of deformity with which we have had the most experience and for which this brace has proved most successful.

Originally, another important area of application was thought to be the correction of bony and soft-tissue defects. In an attempt to bring the foot into a corrected position and maintain the correction, the combination of the UC-BL Shoe Insert and the UC-BL Dual-Axis Ankle-Control Unit was used on children with talipes equinovarus deformities. The initial group of subjects were children who had a recurring highly resistant type of clubfoot with limited ranges of joint motion. As stated earlier, the corrective forces applied by the brace are transmitted through the shoe and the insert to the foot, and in this group of patients these forces usually proved to be so great that breakdown of the skin over bony prominences resulted.

However, when used as an adjunct to standard early orthopedic treatment, such as serial wedge castings or serial castings, the shoe insert/brace combination has proved much more successful. In patients with clubfoot which has recurred after serial wedge castings, a new series of casts is applied in order to achieve a slight overcorrection and a flexible foot. The final cast is removed in a bivalve manner and the casts for both a shoe insert and a brace are made. The bivalve cast is reapplied as a holding mechanism until the brace and shoe insert can be fabricated and fitted to the patient. Although regression occurred in some of these patients with highly resistant clubfoot, their feet have remained much more flexible than those of patients who have not worn the insert/brace combination. Because the brace is rarely considered for such patients until several serial castings or serial wedge castings have been applied without success, it is difficult to estimate the true value of the insert/brace combination. When used as a postsurgical supplement to such procedures as plantar stripping, ankle capsulotomy, and Achilles-tendon lengthening in children for whom such procedures are required to correct fixed deformities, the combination has proved to be successful.

Some experience has also been gained with patients with other disabilities. The brace has been fitted to two patients with mild cerebral palsy, several with hemiplegia, and several with progressive peroneal atrophy. Success has been mixed. It would appear that, as has proved to be the case with patients with clubfoot, a screening study, by a team of physicians and orthotists, is necessary to identify the specific types of disability which could be successfully treated with the UC-BL Dual-Axis Ankle-Control Unit.
Before discussion of the limitations and advantages of the UC-BL Unit, it should be emphasized that the conventional drop-foot brace serves a number of useful purposes. The UC-BL Dual-Axis Ankle-Control System should be considered an added component in the orthotics armamentarium.

Patient response to the UC-BL Unit has been quite interesting. Some patients who have previously worn a single-axis drop-foot brace feel insecure with the increased freedom of motion and without the heavy toe-lift spring action provided by a double-sidebar toe-lift brace (although the UC-BL Unit with its single sidebar produces an adequate toe lift). Others adapt immediately without any difficulty. For many patients, the convenience of a heavy toe-lift spring pick-up during level walking is offset by the inconvenience that the conventional brace causes during all the other activities of daily living.

In its present form, the UC-BL Dual-Axis Ankle-Control Unit is not a weight-bearing brace, nor can it be used with the anterior or posterior stops employed to simulate the action of the muscles which prevent toeslap and assist toe-off. A stop to limit excessive inversion is currently being tested, but its influence on the brace and the patient has yet to be determined.

The design of the UC-BL Dual-Axis Ankle-Control Unit is such that the wearer must exercise considerably more care in its use and handling than is necessary with the conventional short leg brace. For instance, if a patient repeatedly bumps the heel joint during walking down stairs, misalignment may result. Shoes must be kept in good repair, because misalignment of the heel joint may also occur as a result of a worn-down heel, which can cause the heel joint to be exposed and struck against the walking surface. The rubber bands eventually deteriorate and should be replaced by the patient as necessary. Children, unaccustomed to the added freedom of motion afforded by the brace, may fall during running and playing, thereby often bending and misaligning the joints of the brace.

Within these limitations, a number of advantages of the UC-BL Dual-Axis Ankle-Control Unit have become apparent through both patient response and investigator observation. It is obvious to the trained observer that patients with a unilateral disability walk with a more symmetrical gait when they use the Dual-Axis Unit. In most cases, there is a diminished tendency to circumduct the leg, which indicates that careful placement of the foot on the ground is less critical, since the foot can adjust to the angle created between the leg and the walking surface. In some instances, excessive knee flexion has also been diminished, probably because toe-lift is not merely a function of dorsiflexion about the
ankle axis but is accomplished by a combination of such dorsiflexion with eversion about the subtalar axis. This becomes more apparent when a patient with isolated peroneal weakness and relative drop-foot is fitted with the dual-axis brace without a toe-lift spring in the sidebar joint. Eversion is the only assistance supplied for patients in this instance, and they walk exceedingly well.

In general, patients indicate that with the Dual-Axis Unit their activity level and endurance are greatly improved. In a nonlaboratory atmosphere, however, any changes in energy expenditure resulting from a more symmetrical and efficient gait are difficult to assess. Because the Dual-Axis Brace is considerably lighter than the conventional single-axis drop-foot brace, one might assume that expenditure of energy would be less than that resulting from the use of a single-axis brace. This assumption is supported by data from studies by Ralston, which showed that addition of weights to an extremity without restriction of joint motion produced substantial increases in energy expenditure (11).

The patients' most consistent praise for the Dual-Axis Unit applies to activities which require more subtalar motion than is involved in straight and level walking. Some of the patients' comments follow; they are listed roughly in order of frequency.

There is a great increase in the ability to walk through crowded areas in which one must continually change directions.

It is easier to walk up and down stairs and on uneven terrain.

It is easier to get into and out of a car.

It takes less effort to move the right foot from the gas pedal to the brake and back to the gas pedal.

It is possible to adopt a sitting or squatting position in any manner and still have the braced foot flat on the ground.

Running and playing (in children with isolated muscle weakness) is accomplished without the halting gait which interrupts the smoothness of their activities.

It is easier to ride a bicycle.

Children with isolated muscle weakness have, in fact, completely rejected a return to a standard brace after a few days of use. Numerous other responses which relate to variations in an individual's occupation and manner of living have also been reported.

Some patients with newly fitted Dual-Axis Units tend to rush into activities which they previously avoided. Injury and further incapacitation may result unless the patient is cautioned to diversify his activities slowly. Only gradually does he understand the limitations imposed by his disability and the restraints he must exercise even with an effective, carefully fitted brace. However, with reasonable care of the brace and
with gradual testing of the additional activities that can be undertaken, the patient will soon enjoy the new freedom of movement allowed by the UC-BL Dual-Axis Ankle-Control Unit.

**REFERENCES**


\(^{h}\) Reprinted in this issue of the Bulletin.

\(^{j}\) Printed in this issue of the Bulletin.