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AN ORTHOSIS FOR MEDIAL OR LATERAL STABILIZATION OF ARTHRITIC KNEES

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THE PROBLEM

An orthosis may offer the only relief possible for patients suffering gross damage of the knee because of certain forms of arthritis. An orthosis is indicated when the knee requires support either for relief of pain or to give stability for preservation of function. These conditions may occur when a surgical approach is not appropriate, and when physiotherapy alone is not sufficient.

Because clinicians at the Canadian Arthritis and Rheumatism Society in Vancouver, Canada, wanted to be able to identify cases that might benefit from use of an orthosis, and then to be able to provide them with an appropriate orthosis, a knee clinic was established which included the authors as the Engineering Component. We were struck by the gross nature of the disabilities from which the patients were suffering, and found it difficult to sift out just what was pertinent in order to identify what was needed. The average age of the patients was about 70. They often had gnarled hands and feet. Sometimes, other joints were affected. The difficulties presented often had been present for a long time. Some cases had seemed to fall apart rapidly, often presenting insurmountable problems for those providing therapeutic assistance. The problems seemed to be in such a mixed-up array, as our untrained eyes saw them, that we were forced to isolate some specific malfunction as a point of entry into the problem of orthosis design.

It was decided that mediolateral knee instability would be the most likely malfunction to tackle for development of an orthotic solution.

THE APPROACH

Initially, we were observing only in order to become more familiar with those elements we could identify as common to the sorts of knee disabilities seen in the clinic. Soon we were willing to enter into a simple program of activities which would allow us to develop in whatever directions it took us. Two approaches became apparent. First, conventional "long leg braces" used on some of the patients included plastic laminate sleeves around the knees. Secondly, objective data were sought, initially through search of the literature, and subsequently by making direct goniometric measurements of motions about the ankle and knee in two planes as each patient walked. These data would be useful for defining the degree of motion occurring in the mediolateral directions, telling us when these motions were occurring in the walking cycle, and indicating how other joints were functioning in relation to the particular malfunction being observed. On the basis of practical application of known orthotic solutions and on the objective studies we had done on joint motion patterns, we outlined some criteria for orthosis design.

DESIGN CRITERIA

As we established our design criteria, we found that plastic laminate "splints" and conventional long leg "braces" were unsatisfactory solutions for the problem of mediolateral instability at the knee. Also, in the review of the literature we found only the "Michigan Brace" (*1*) to be designed specifically to control mediolateral knee instability for arthritics, and it, too, fell short of satisfying the criteria we had outlined. Because our own solution related directly to these criteria, most of them are satisfied by the design.

The criteria that were established and how the new design meets them are indicated in Table 1.

THE SOLUTION

A schematic diagram to show the application of forces supplied by the orthosis during the walking cycle for the patient with "knock-knee" is

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TABLE 1.

Criteria	*Results*
1. Light weight	Under a pound—.450 Kgms.
2. Weight evenly distributed	Note symmetry of orthosis in Fig. 2
3. Minimum area of contact with the body	Approximately 100 sq. in. (645 sq. cms)
4. Minimum interference with surroundings (clothes, furniture, etc.)	Not as good as with conventional or Michigan orthosis, but better than with the plastic-laminate splint.
5. Force application optimal for comfort	Improvement in size and shape of knee support is required, other elements are satisfactory.
6. Wanted joint motions uninhibited as unwanted motions are blocked	Hip and ankle function is normal. Knee flexion is not inhibited. There is some restraint of knee extension.
7. Acceptable cosmesis	Better than previous orthoses except for the plastic splint.
8. Easy to fit to the patient	Prefabricated, only strap adjustments that include sewing and riveting are required.
9. Easy for the patient to don	Easier than other orthoses, but needs improvement.
10. Adjustable	The adjustment strap which controls the position at which medial or lateral displacement is blocked allows the patient to set this for himself.
11. Safety for the patient	Pinch-proof. Catastrophic failure unlikely.
12. Reliability	Will not jam or catch, or disengage in action.
13. Minimal costs	Less expensive to make and maintain than the other types of knee orthoses used for this purpose.
14. Minimal skills needed for application	Prefabricated in two types and one size: valgus right side is also varus left side. Sometimes a heat gun is needed for adjustment of the plastic cuffs.

given in Figure 1. The force at the knee is provided to balance the forces required at mid-thigh and shank on the opposite side to keep the knee joint in a more normal mediolateral position. Forces would be applied in the opposite direction for correction of a varus, or bowlegged, deformity.

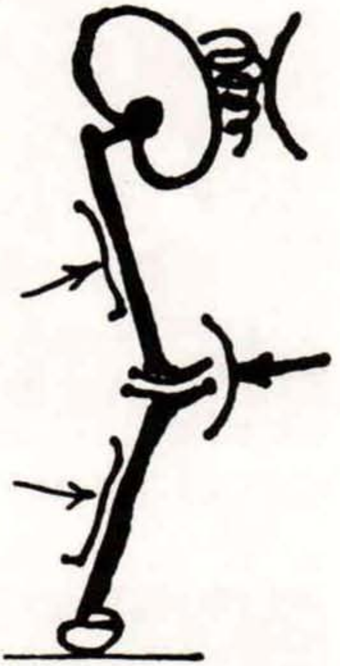

Fig. 1. Schematic showing application of forces by the experimental orthosis.

Fig. 2. Anterior view of the experimental orthosis applied for medial instability.

The orthosis used routinely is shown in Figures 2 through 6. The subject in this instance is a person without physical problems about the knee. Figure 2 shows the position of the orthosis for a knee which is unstable toward the medial side (valgus). The parts that stabilize the knee are the thigh and shank cuffs, which are made of transparent, rigid PVC; the knee cuff which is made of leather; and the telescoping tube assembly that connects the three cuffs. The knee cuff is triangular in shape, and is anchored to the shank cuff on one apex of its base and to the thigh cuff on the other apex of its base. The apex remaining is anchored to the telescoping tube assembly by a strap that crosses behind the knee. Thus, the needed forces are provided. Figure 3 shows how the orthosis would be used on a person with a later-

Fig. 3. Anterior view of the experimental orthosis applied for lateral instability.

ally displacing knee. Figure 4 shows the action of the telescoping assembly as it shortens to permit knee flexion, and displaces backward to relax the knee cuff. The plastic fixtures at the ends of the telescopic beam allow the plastic thigh and shank cuffs to tilt in any direction on the telescoping assembly, and the tubes of the assembly are free to rotate with respect to each other. Figure 5 shows how the knee cuff fits against the side of the knee to hold it against movement. Figure 6 shows how the strap links the telescopic assembly to the thigh and shank cuffs. A waist-band system secures the orthosis to the limb. Inside the telescoping tube an elastic cord prevents inadvertent separation when the orthosis is not being worn.

The universal hinge at the thigh cuff is shown in Figure 7. An identical unit is used at the shank cuff. The joint consists of a polypropylene molding with a threaded metal insert, a nylon bolt that screws into the insert to attach the joint to the cuff. The bolt is secured to the cuff by a nylon nut in such a way that the head of the bolt is inside

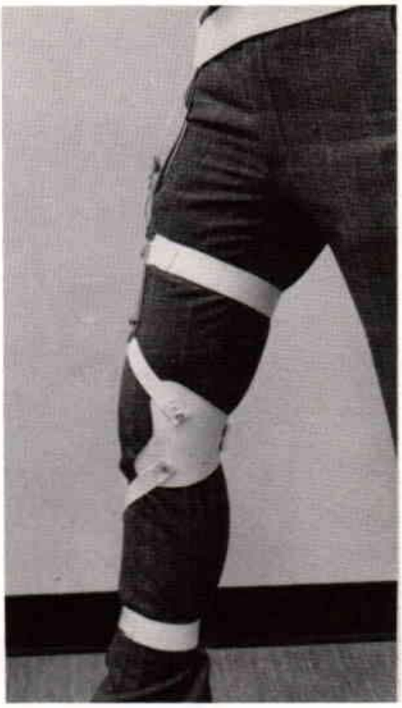

Fig. 5. Medial view showing placement of knee cuff when installed on medial side.

Fig. 4. Lateral view of experimental orthosis to show action of the telescoping assembly.

Fig. 6. Posterior view of experimental orthosis to show how the strap links the telescoping assembly to the thigh and shank.

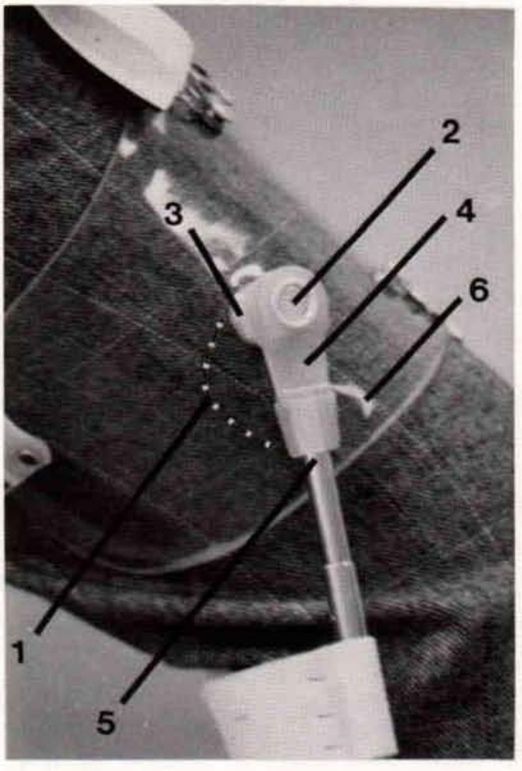

Fig. 7. The universal hinge used to fasten the telescoping assembly to thigh and shank.

the cuff, countersunk, and the lock is outside the cuff. Extra bolt is cut off after the polypropylene pivot is set at the best distance from the cuff by turning it on the threads of the bolt. The thin section of the polypropylene pivot allows abduction-adduction motions to occur (plastic spring effect). The tubing is "press fitted" into the base of the polypropylene pivot. A hole drilled through to the tubing along its axis allows installation of the elastic cord, which is secured by a knot. The tubes can rotate relative to one another. When not on the limb, the orthosis goes limp like an unheld puppet. When properly in place it stiffens to its task.

THE FUNCTION

Joint motion studies taught us that the knees we were trying to brace needed support mainly during the extension part of stance phase. Thus, we felt that what was needed was an orthosis which would exert an intermittent force active during extension, but not active during all other parts of the walking cycle, and completely inactive during sitting. When the knee is flexed, the telescoping beam of the orthosis moves posteriorly so that the tension on the knee cuff is reduced. Conversely, as the knee extends, tension in the strap is increased to give the required support. Telescopic action of the beam, coupled with the pivoting, flexing-joint system at both ends and the relative rotation of the tubes to one another, removes all but the constraining forces that are needed, except for contraint of extension—a factor that can detract from effectiveness of the orthosis for some patients. Quadriceps strengthening has been given for some of these cases, and others have been considered to be unsuitable users. If there is a tendency toward hyperextension at the knee, then this feature can be beneficial.

APPLICATION IN THE CLINIC

The procedure we use is nearly optimal. The patient is seen in the clinic, and a prefabricated orthosis is used as part of the assessment procedures. Various adjustments are made to control straps until it is necessary to adjust only the knee cuff strap so that the time difference can be determined between when the tension is on and when it is off. If, with tension on the strap, the patient indicates improvement, then he is held for completion of the fitting, which is done either during or immediately after the clinic. Improvement is indicated by a positive response from the patient and, more objectively, evidence of increased speed of walking or walking with the cane held up.

The biggest problem in adjusting the orthosis lies in getting the straps of the knee cuff at the required length. The straps are permanently fastened to the shank and thigh cuffs when they are set correctly. The posterior strap to the telescoping beam is left adjustable. After everything is fixed, and the excess part of the nylon bolt is cut off, the patient practices applying the orthosis and adjusting the back strap for a few times. If there are difficulties of remembering, or special tabs are needed, these matters are dealt with at subsequent therapy sessions. The whole process seldom takes an hour per patient, excluding time in the clinic.

RESULTS

Approximately 24 orthoses have been fitted to date. The longest period of use is just over a year (the original prototype). Approximately half the cases have had their orthoses for three months or more. It is the positive response of the patient and the increased speed of walking that give the most important clues to success. The deformity is not corrected necessarily, but comfort and function are improved because the orthosis prevents the knee from sagging into a painful position. Conditions which cannot be handled well using this orthosis include rotational instability and mediolateral instability coupled with knee extensor weakness.

More detailed results will be reported by clinicians responsible for patient care. Similarly, details of construction will be reported through a future report or publication by us and those involved in fabrication.

CONCLUSIONS

We have added not only a new orthosis to the list but a new principle through the use of the telescoping beam and the associated joint system. We already know that we can apply this concept to a number of orthosis types. In mind is a design which incorporates two such beams so organized that the orthosis will offer control of flexion and extension instabilities. We can envision the use of such beam-joint structures for improvement of the "Milwaukee Brace." We are in the early stages of applying it to fracture bracing. Our hope is that the processes we have gone through and the design we have developed will add scope to the work of others similarly involved. Our own plans are to make permanent molds for fabrication of the PVC cuffs, to develop a plastic knee cuff, to improve fastenings, to instrument the orthosis for monitoring forces, and to expand field testing outside the home area until we have results on approximately 200 applications.

We have named the orthosis the C.A.R.S.-U.B.C.[2] Knee Orthosis Valgus-Varus.

ACKNOWLEDGMENTS

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[2]Canadian Arthritis and Rheumatism Society—University of British Columbia.