Improvement in function after valgus bracing of the knee

AN ANALYSIS OF GAIT SYMMETRY

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The use of a valgus brace can effectively relieve the symptoms of unicompartmental osteoarthritis of the knee. This study provides an objective measurement of function by analysis of gait symmetry. This was measured in 30 patients on four separate occasions: immediately before and after initial fitting and then again at three months with the brace on and off. All patients reported immediate symptomatic improvement with less pain on walking. After fitting the brace, symmetry indices of stance and the swing phase of gait showed a consistent and immediate improvement at 0 and 3 months, respectively, of 3.92% ($p = 0.030$) and 3.40% ($p = 0.025$) in the stance phase and 11.78% ($p = 0.020$) and 9.58% ($p = 0.005$) in the swing phase. This was confirmed by a significant improvement at three months in the mean Hospital for Special Surgery (HSS) knee score from 69.9 to 82.0 ($p < 0.001$). Thus, wearing a valgus brace gives a significant and immediate improvement in the function of patients with unicompartmental osteoarthritis of the knee, as measured by analysis of gait symmetry.

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Osteoarthritis of the knee occurs more often in the medial compartment,¹ presumably due to its increased loading during gait. The load on the knee during the stance phase is a combination of compression due to body mass and, with the exception of a fleeting abduction at initial stance, an adduction moment.¹ The consequence of this external moment is that the centre of pressure within the knee

moves medially, increasing the load on the medial compartment.

Traditional conservative methods of treatment, such as weight loss, walking aids, wearing a heel wedge^{2,3} and analgesia, may temporarily ameliorate symptoms improving function and walking distance, but they fail to address the underlying pathology. Many of these patients will ultimately require total knee arthroplasty. Although osteoarthritis can be treated surgically, there are many patients for whom this is inappropriate, because of medical comorbidity, old age or other circumstances. In young patients it is desirable to delay primary arthroplasty. The object of other surgical treatments, such as high tibial osteotomy or unicompartmental arthroplasty, is to transfer the load to the less affected lateral compartment.⁴⁻⁷ Such procedures carry the usual surgical risks, increase the possibility of complications for the subsequent arthroplasty⁸ and are not suitable for patients of all ages.⁵

The concept of a valgus brace is to apply, during stance, an external abduction moment to the knee, which directly opposes the usual adductor moment and should unload the degenerative medial compartment. The term 'valgus brace' derives from this applied abduction, or valgus, moment.

Horlick and Loomer⁹ and Pollo et al¹ have shown that symptomatic relief can be provided by these braces and Lindenfeld et al³ found that valgus braces could reduce the adductor moment around the knee. It is clear that wearing a valgus brace may delay the requirement for surgery in relatively young patients.^{1,3,9} The study of Kirkley et al¹⁰ compared the results of a prospective, randomised clinical trial using three types of treatment: medical treatment only or with a neoprene sleeve or a valgus brace. Their results indicated that patients who have osteoarthritis of the medial compartment may benefit significantly from the use of a knee brace in addition to standard medical treatment. The group with valgus braces had, on average, significantly better outcome scores than that with neoprene sleeves.

In these studies no objective measurements of function when using a valgus brace were made. This was the aim of the present study. The relatively new technique of gait symmetry analysis (GSA)¹¹ uses a treadmill with left and right forceplates under a belt to record consecutive steps (usually between 20 and 60). Several parameters can be calculated from each step, including the duration of stance

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Fig. 1a

Fig. 1b

Photograph (a) and diagram (b) showing the valgus brace.

and swing phases. The measured parameters are then used to compare the braced with the contralateral limb. A direct ratio, the symmetry index, has been found to be the most useful and easily understood method of presenting the results. It defines perfect symmetry and shifts either towards or away from it. An important advantage over functional scoring such as the Hospital for Special Surgery (HSS) knee score, is that GSA can measure changes rapidly.

Patients and Methods

The patients were measured and assessed immediately before fitting the brace. All had received conservative treatment only. These data were taken as the control for each patient and consequently, paired comparisons between visits were possible, allowing the use of more sensitive statistics (paired Student *t*-test). This trial was therefore a prospective controlled comparison of function before and after use of the brace.

We excluded patients who were over 70 or under 35 years of age and those who had a varus deformity greater than 12° or a fixed flexion deformity greater than 10°, significant hip, back or contralateral leg symptoms, an arthroscopy of the knee within the preceding six months and physical or mental inability to comply with the requirements of wearing a brace.

There were 18 men and 12 women with a mean age of 56.2 years (35 to 70) who attended a specialist knee clinic between October 1997 and May 1999. They had radiologically demonstrable osteoarthritis of the medial compartment of the knee (Larsen grades II to IV) on anteroposterior and Schusse radiographs with relative sparing of the lateral compartment (Larsen grade 0 to I) which was consistent with their symptoms.

Each patient was fitted with a custom-made valgus brace, the GII ADJ Unloader (GII Orthotics Europe, Belgium). This comprises two semirigid plastic shells, for the thigh and calf, linked by a polyaxial medial hinge set at 4° of valgus. An adjustable tension strap crosses the lateral aspect of the knee from below, posterolaterally to above, anteromedially, from the calf to the thigh shells (Fig. 1).

The same technician obtained the negative casts, fitted the braces and instructed the patients in the proper use and care of the brace. The patients were measured and assessed before and immediately after fitting the brace and again after continuous wear of the brace for three months.

Instrumented treadmill. A standard running machine (PowerJog 200; Sport Engineering, Birmingham, UK) was modified to house two independent forceplates, one placed on the left and the other on the right of the bed. Each plate was supported at each corner by an electrical resistance strain-gauge transducer designed to be sensitive only to the vertical component of force. The signals from each transducer were amplified and digitised by a standard laboratory system (National Instruments Corp, Austin, Texas). A program written within LabView (National Instruments Corp) on a personal computer recorded the signals for later analysis.

Walking tests were performed only if the subject felt confident enough to start and complete the exercise. Subjects were asked to walk on the instrumented treadmill, wearing their normal shoes (Fig. 2). Both the subject and the operator were in a position to operate the controls at all times. During the first test, patients selected their own preferred walking speed; this was recorded and used for all subsequent testing of that patient. Four tests were performed, one immediately before and one immediately after the initial fitting of the brace; the other two were performed consecutively, and within minutes of each other, with and

Fig. 2

GSA walking test (using a modified, standard running machine).

without the brace, after three months. Each test lasted for one minute, during which time between 20 and 60 steps were recorded.

Analysis began with a visual inspection of the data to remove any invalid steps if the patient had faltered. A macro was incorporated into the system which marked for scrutiny, and possible exclusion, any step that exceeded two

sds of the mean for any measured parameter.

A series of Visual Basic macros in Microsoft Excel was used in the analysis. They automatically detected the heel strike and toe-off, thereby isolating each step. After this the stance phase and swing times, among other parameters, were calculated for each step, both left and right. Symmetry indices (SI) were then calculated for the stance and swing phases. An SI is defined as the ratio of the means of the parameter measured from the affected limb divided by that of the unaffected limb. These can be calculated for any measurement; those for stance and swing phase alone were used in this study.

Any change in an SI can easily be seen and understood. An SI of 1 indicates a perfectly symmetrical gait. A shift towards 1 with time indicates an improvement, whereas a shift away indicates deterioration.

Clinical assessment. Patients were assessed clinically using visual analogue pain scores for resting, standing, walking and climbing stairs. A modified HSS knee score, activity questionnaires and requirement for analgesia were also recorded. The radiological grade of osteoarthritis in each of the three compartments was noted and the mechanical femorotibial axis was determined from full-length weight-bearing radiographs.

GSA compared with HSS score. In order to validate the use of GSA, HSS scores were calculated initially and after three months. The initial score before bracing was compared with the SI taken at the same time. The scores at the second visit were assessed from activity during the previous three months in which the brace was worn. Consequently, comparison at this point was with the SI while wearing the brace and with that at the first visit. It can be seen in Figure 3 that the three outcome measurements show an improvement; in all cases this is significant ($p < 0.05$). Although the greatest change in the mean improvement

Fig. 3

Validation of symmetry indices by comparison with HSS score (mean $\pm$ sd).

Table I. Mean ($\pm$ sd) stance- and swing-phase symmetry indices

	Initial visit		Three-month visit	
	No brace	Braced	No brace	Braced
Stance phase	0.97 $\pm$ 0.11	1.02 $\pm$ 0.10 $p = 0.030$	0.97 $\pm$ 0.11	1.01 $\pm$ 0.12 $p = 0.025$
Swing phase	1.13 $\pm$ 0.32	1.01 $\pm$ 0.17 $p = 0.020$	1.12 $\pm$ 0.29	1.02 $\pm$ 0.18 $p = 0.005$

appears in the HSS score, the differences at three months between the measurements are not significant ($p > 0.05$). It was felt therefore that the SI had a similar capacity to detect any underlying change in function as the HSS score. The advantage of GSA was that it could be performed immediately before and after fitting the brace, whereas the modified HSS scoring system requires the passage of time between tests.

Results

At the initial examination the mean modified HSS score was 69.93 (47 to 87). All patients reported moderate to severe pain on walking, with a mean of 7.57 on the ten-point visual analogue score for this activity. The mean score for resting and standing was less at 2.30 (0 to 7) and 4.00 (0 to 7), respectively. All patients had Larsen grade II or III (24 and 6, respectively) in the medial compartment and grade 0 or I (16 and 14, respectively) in the lateral compartment. All patients except one had an abnormal varus mechanical axis at the knee (one patient had a valgus mechanical axis of 2°) with a mean of 4.82° of varus ranging from -2° (valgus axis) to $+12^\circ$. All patients reported subjective improvements in their symptoms, with less pain on walking on the treadmill with the brace fitted.

With an antalgic gait, it can be expected that the subject

will tend to spend less time on the affected limb. This will lead to a stance-phase SI of below 1 and a swing-phase SI above 1, both of which have been observed in this study. A more symmetrical gait, which is assumed to be an improvement, will result in each SI shifting towards 1. This is summarised in Table I and clearly demonstrated in Figure 4; the change in both indices is significant ($p < 0.05$). The mean HSS score also improved significantly from 69.93 (± 9.90 sd) at the initial visit, to 82.04 (± 10.65 sd) at the three-month visit.

Discussion

Patients with unicompartmental osteoarthritis of the knee can be helped by the use of a valgus brace. Clinical studies of this^{2,9,10} have relied on subjective scoring systems. The objective outcome measurements made in our study support these previous findings and show that the improvement in function begins as soon as the brace is worn. Figure 4 clearly shows this improvement, with a significant shift towards a value of 1 (perfect symmetry) for both the stance and swing phases of gait. This effect is detectable at the first fitting and is maintained three months later.

Although this shows that this design of brace is clinically effective, it sheds little light on the mechanism. It is clear that without the brace our patients tend to bear weight for longer on the unaffected limb, while sparing the affected limb for longer. This is typical of an antalgic gait. The return to a more symmetrical pattern indicates less discomfort.

There are, however, many parameters other than pain which may also disturb the pattern of gait. These include changes in proprioception and a lack of confidence in the affected limb. Despite the fact that our study does not

Fig. 4

Symmetry indices with and without valgus brace (mean $\pm$ sd).

explain the mechanisms which are responsible for improving symptoms, it does add objective evidence that valgus bracing for unicompartmental osteoarthritis of the knee is clinically effective.

Further work is required to determine if the effectiveness of this type of brace is reduced with time, to investigate the alteration in internal load of the knee when the brace is worn and to determine whether there are biological consequences of unloading a degenerative area of articular cartilage.

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