The effect of wedged insoles on the thrust of osteoarthritic knees

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Summary. *We describe a method of quantifying the lateral/medial thrust of the knee which occurs in the early phase of walking. We have used this method to evaluate the effects of wedged insoles on the lateral and medial thrust for normal knees and knees with unicompartement osteoarthritis (OA). A laterally elevated (valgus) insole decreased the lateral thrust of both normal and osteoarthritic knees. A medially elevated (varus) insole increased the lateral thrust. In 50 symptomatic knees with medial compartment OA, decreasing the lateral thrust with a valgus insole reduced pain on walking in 27. Patients whose pain was reduced by valgus insoles tended to have earlier OA and to have a significantly greater reduction in the lateral thrust than in the 23 remaining unaffected knees. A varus insole was effective in decreasing the medial thrust and reducing pain in all ten knees with lateral compartment OA. We recommend the use of valgus insoles for patients with painful early medial compartment OA and the use of varus insoles for lateral compartment OA.*

Résumé. *Les auteurs présentent une méthode d'évaluation quantitative, avec mesure par un accéléromètre, des écarts internes ou externes qui se font au niveau du genou dans la première phase du pas. Ils ont étudié les effets dynamiques et l'utilité clinique des semelles à coin valgisant ou varisant pour les genoux atteints d'arthrose unicompartimentale. Une semelle à coin externe (valgisante) diminue l'écart externe ou augmente l'écart interne que subit le genou normal ou arthrosique. L'effet*

est inverse pour une semelle à coin interne. Sur 50 genoux atteints d'arthrose interne avec écart externe, la semelle à coin valgisant diminue les douleurs à la marche dans 27 cas et est inefficace dans 23 cas. Les genoux pour lesquels les semelles valgisantes sont efficaces ont une réduction significative de l'écart externe par rapport à ceux pour lesquels ces semelles sont inefficaces. La semelle valgisante est plus efficace en cas d'arthrose du genou débutante qu'en cas d'arthrose évoluée. La semelle varisante est active pour les 10 genoux avec arthrose compartimentale externe et écart interne.

Introduction

In knees with medial compartment osteoarthritis (OA), lateral thrust is a sideways movement of the knee which occurs suddenly in the early stance phase of gait [3] and is caused by sudden collapse of the joint into the position of varus deformity. The movement is limited by the restraining force of the lateral collateral ligament of the knee. In knees with lateral compartment OA, there is a medial thrust. Similarly this is limited by the action of the medial collateral ligament.

In Japan laterally elevated (valgus) insoles have been widely used for the relief of symptoms associated with medial compartment OA of the knee [10]. The devices are commonly called “wedged insoles” due to their shape on coronal section. Wedged insoles are often plastic and custom made.

We hypothesised that the pain due to OA knee, and progression of the OA itself, was exacerbated by lateral and medial thrust. This would account for the reduction in symptoms experienced by patients using canes, knee braces and wedged insoles.

There are few objective studies linking the clinical and biomechanical effects of wedged insoles. In this study we applied accelerometers to subjects' knees to quantify lateral and medial thrust in the early stance phase of walking. We studied both normal and OA knees, both with and without wedged insoles, and correlated the dynamic effects to the relief of pain.

Patients, materials and methods

Subjects studied

We assessed a total of 100 knees in 88 subjects. For the purposes of this study they were divided into three groups.

- Normal knees: There were 40 subjects (30 females and 10 males) with an average age of 60 years (45–75 years). None had a history of knee pain or knee disorders.
- Medial OA: There were 38 subjects with a total of 50 knees affected by OA and demonstrating lateral thrust. This group was composed of 25 females and 13 males. Their average age was 62 years (51–72 years). All these patients had been treated with a valgus insole for at least one month prior to commencement of the study.
- Lateral OA: There were 10 subjects with a total of ten afflicted knees all demonstrating medial thrust (7 females and 3 males). Their average age was 63 years (53–71 years) and all had been treated with a varus insole for at least one month prior to commencement of the study.

Radiographic grading of osteoarthritis

The radiographic appearance of the OA was graded using a standing anteroposterior view of the knee in a single leg stance [8] as follows:

- Grade 1: less than 50% loss of cartilage space in the afflicted compartment.
- grade 2: from 50%–100% loss of cartilage space in the afflicted compartment.
- grade 3: osseous destruction of the tibia and/or femur.

Fig. 1. The wedged-insoles

Fig. 2. The unidirectional accelerometer, used in the study

Of the 50 knees with medial OA, the distribution of grading was Grade 1, 15 knees; Grade 2, 27 knees and Grade 3, 8 knees. Of the 10 knees with lateral OA the distribution was: Grade 1, 2 knees; Grade 2, 5 knees and Grade 3, 3 knees.

The insoles used

We used insoles made of ethylene-vinyl-acetate, the upper surface being flat and covered with leather.

Table 1. Effect of wedged-insoles on the first peak of lateral/medial acceleration of normal knees

Thrust pattern (number of knees)	No insole	Valgus insole	Varus insole
Lateral thrust (<i>n</i> = 20)	6.87 ± 2.29 (m/s ²)#	5.23 ± 2.09**	9.29 ± 2.29**
Medial thrust (<i>n</i> = 5)	5.39 ± 1.25	7.00 ± 1.24*	3.04 ± 0.73*
Unclassifiable (<i>n</i> = 15)	–	–	–

mean ± SD; ** *P* < 0.001; * *P* < 0.01

Fig. 3. Accelerographs of a normal knee showing the lateral thrust pattern in which the first acceleration peak (FP) appears in the lateral direction after the heel strike followed by the second peak (SP) in the medial direction. Note that the FP was reduced with a valgus insole and increased with a varus insole

Fig. 4. Accelerographs of a normal knee showing the medial thrust pattern in which the first acceleration peak (FP) appears in the medial direction after the heel strike followed by the second peak (SP) in the lateral direction. Note that the FP was increased with a valgus insole and decreased with a varus insole

The valgus insole had a wedge under the lateral heel and forefoot. A coronal section of such an insole shows the upper surface to be inclined at 5–10 degrees medially (Fig. 1). Varus insoles used in this study had medial wedging and, in addition, an arch support.

Wedges of varying sizes were used for both the varus and valgus insoles. Patients with small feet experienced discomfort at the ankle if they used large wedges. We therefore measured the subjects foot size to determine the wedge used. We did not base the wedge size on the deformity at the knee or severity of OA. Wedges of 6–8 mm were used for small feet and wedges of 9–12 mm for larger feet. Most wedges used in this study were in the 8–10 mm range.

Measurement of thrust at the knee

We used a technique described by Wosk et al. [12] to evaluate the lateral and medial thrust of the knee. We have previously demonstrated the repeatability and accuracy of this method [6]. A unidirectional accelerometer (Type 1823, NEC San-ei, Tokyo) was attached with adhesive tape to skin overlying the subjects' tibial tubercle. This registered the horizontal medial-lateral component of acceleration whilst walking (Fig. 2) [4, 8, 12]. From each test walk an accelerograph was derived and the lateral or medial thrust calculated.

To assess the time of heel strike, a strain gauge was attached to the skin on the sole of each of the subjects' heels. Signals from the above two devices were recorded on a computer via a telemeter.

Fig. 5. Accelerographs of a normal knee showing the unclassifiable pattern

For data collection each subject walked for about 10 gait cycles on a flat, level walkway at their normal speed and wearing their own shoes. Care was taken that subjects maintained an even gait. For data analysis only the middle three gait cycles were used.

Patients with normal knees were monitored three times: with no insole, with a valgus insole including a 10 mm lateral wedge and with a varus insole including a 10 mm wedge. Patients with medial and lateral compartment OA undertook two test walks each, both with and without their appropriate insoles.

Artefactual motion

Skin motion artefacts are common if accelerometers attached to skin are used to gather data [5]. We attempted to reduce these artefacts to a minimum by preloading the accelerometer against the skin as described elsewhere [4, 6, 9].

Results

Normal knees

We observed three patterns in the accelerographs obtained from the 40 normal knees in the study:

- **Lateral thrust pattern:** this was found in twenty knees (50%). The first acceleration peak (FP) after heel strike is in a lateral direction followed by a second peak (SP) medially (Fig. 3). The amplitude of the FP was significantly reduced with a valgus insole (Students' *t*-test: $P < 0.0001$) whereas this was significantly increased with a varus insole ($P < 0.0001$) (Table 1).
- **Medial thrust pattern:** five knees (12.5%) demonstrated this pattern. The FP is in the medial direction followed by a laterally directed SP (Fig. 4). A valgus insole had the effect of increasing the FP ($P < 0.01$) which was reduced by a varus insole ($P < 0.01$) (Table 1).
- **Unclassifiable pattern:** this was found in 15 knees (34.5%) (Fig. 5).

Fig. 6. Accelerographs of a knee with medial compartment OA showing reduction in the first peak of lateral acceleration (FP) with valgus insoles. Note that the rate of reduction in the FP was greater with a valgus insole of 10 mm wedge than 7 mm

Fig. 7. Diagram showing effects of clinically effective and ineffective insoles on the first peak of lateral acceleration of osteoarthritic knees

Knees with medial osteoarthritis

In all 50 knees the lateral thrust pattern was found. In all knees the amplitude of the FP was decreased with the use of valgus insoles ($P < 0.001$) (Fig. 6). The mean reduction in the FP amplitude with the use of insoles was 23.7% (standard deviation 16.5%). Pain was reduced in 73% of Grade 1 knees, 59% of grade 2 and 0% of Grade 3 knees. The 27 knees showing clinical improvement had a significantly larger FP without insoles and significantly greater FP reduction with insole use

Fig. 8. Accelerographs of a knee with lateral compartment OA showing marked reduction in the first peak of medial acceleration (FP) with a varus insole

compared to the 23 knees showing no improvement (Fig. 7, Table 2). Generally, a reduction in pain due to the use of insoles was noticed within one week of commencement of their use.

Knees with lateral osteoarthritis

All ten knees demonstrated a medial thrust pattern on their accelerographs. FP amplitude was smaller ($P < 0.001$) whilst walking with varus insoles in all 10 knees (Fig. 8). With insoles the mean reduction in FP was 48.7% (standard deviation 11.5%). Pain was reduced in all 10 knees irrespective of the grade of OA. Again, pain reduction began soon after use of the insoles was started.

Discussion

In normal knees, 50% had a lateral thrust pattern and 12.5% showed medial thrust. This may be a predictor of the pattern of later OA. In Japan medial compartment OA, associated with the commoner lateral thrust pattern, is far more frequent than lateral compartment OA.

The study demonstrates that wedged insoles significantly alter the lateral and medial thrusts of both normal and osteoarthritic knees during walking. The varus insole, which decreased the medial thrust, was more effective both dynamically and clinically. These findings would appear to support previous suggestions that it is easier to

Table 2. Effects of clinically effective and ineffective insoles on the first peak of lateral acceleration of the knees with medial compartment OA

Wedge-insoles	Without insole	With insole	Reduction rate
Effective ($n = 27$)	7.1 ± 1.8 (m/s ²)#	4.9 ± 1.9	32.6 ± 17.2 (%)
Ineffective ($n = 23$)	5.4 ± 2.3	4.6 ± 2.0	13.4 ± 15.8
<i>P</i> -value	< 0.01	N. S.	< 0.01

mean $\pm$ SD

compensate for valgus rather than varus deformity [2].

In our study, early OA was more amenable to pain relief with insoles than late OA. This correlates well with findings that patients with early osteoarthritic changes have more instability in varus and valgus than those with late OA. It was hypothesised that osteophytes and a reduced speed of walking due to pain were the cause of reduced instability in late OA [1]. Reductions in the thrust were significantly associated with a reduction in pain due to OA knee.

None of the wedges used altered the accelerographic pattern from medial thrust to lateral thrust or vica versa. All the changes produced involved reduction in the FP of acceleration, the direction was unchanged. Other authors have found high tibial osteotomy to alter the thrust pattern from lateral to medial in medial compartment OA of the knee [7].

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