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Long term effects of laterally wedged insoles on knee frontal plane biomechanics in patients with medial knee osteoarthritis

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Research Article

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Purpose: The aim of this study was to examine the effects of laterally wedged insoles to treat knee osteoarthritis on frontal plane mechanics and knee varus moment after one year. **Methods:** Fourteen individuals diagnosed as having medial knee osteoarthritis (OA) and 13 healthy controls were included in this study. Patients wore bilateral full length laterally wedged insoles with medial longitudinal arch, made of high density ethyl vinyl acetate, with 5° tilt angle in their shoes on a regular basis for at least one year. Three dimensional kinematics and kinetics were recorded as the knee OA patients walked in the laboratory after nearly one year both barefoot and with their insoles. **Results:** Knee angles and total range of motion in the frontal plane were not significantly different between walking conditions when compared to control group ($p>0.05$). Walking speed and step width were similar when patients walked barefoot and with laterally wedged insoles ($p>0.05$). Knee varus moment was prominently high when walking barefoot, and significantly decreased with laterally wedged insoles ($p<0.05$). **Conclusion:** Our data suggests that use of 5° laterally wedged insole have significant effects on knee varus moment in knee OA.

Key words: Knee joint, Osteoarthritis; knee, Gait, Insole; laterally wedged.

Medial diz osteartritli hastalarda lateral kamalı tabanlığın dizin frontal düzlem biyomekaniği üzerine uzun süreli etkisi

Amaç: Bu çalışmanın amacı diz osteoartrit tedavisinde lateral kama kullanılmasından yaklaşık bir yıl sonra yürüme sırasında frontal düzlemde mekanik diz varus moment üzerindeki etkisini incelemekti. **Yöntem:** Bu çalışma medial diz osteoatrit (OA) teşhisi konmuş 14 kişi ve 13 sağlıklı kişi içermekteydi. Hastalar tabanlıkları bilateral kullandıkları ayakkabı içerisine giydiler. Yüksek yoğunluklu etil vinil asetattan yapılan tabanlık boyunca uzanan 5° tilt açılı lateral kama ile medial longitudinal ark takviyeli tabanlığı düzenli olarak en az bir yıl kullandılar. Yaklaşık bir yıl sonra medial diz osteoartritli hastalar laboratuvarda tabanlıkla ve çıplak ayak yürütülerek yapılan üç boyutlu kinetik ve kinematik analiz kaydedildi. **Sonuçlar:** Frontal plan diz açıları ve hareket açıklığı her iki yürüme değerleri arasında ve kontrol grubu değerleri ile karşılaştırıldığında farklılık bulunmadı ($p>0.05$). Hastaların çıplak ayak ve lateral kamalı tabanlık ile yürümelerinde yürüme hızı ve adım genişliği arasında fark saptanmadı ($p>0.05$). Ayakkabısız oldukça yüksek olan diz varus moment değeri lateral kama ile yürüme sırasında azaldı ($p<0.05$). **Tartışma:** Çalışmamızdan elde ettiğimiz sonuçlar, diz osteoartritinde 5° lateral kama kullanımının diz varus momenti üzerinde etkili olduğunu gösterdi.

Anahtar kelimeler: Diz eklemi, Osteoartrit; diz, Yürüme, Tabanlık; lateral kamalı.

Knee osteoarthritis (OA) is a leading cause of chronic pain and disability in the adult and elderly population. The medial tibiofemoral compartment is involved nearly 10 times more frequently than the lateral compartment,[1] probably because of the greater load applied to this compartment during walking and other weight bearing activities. Therefore, progressive loss of cartilage and joint space typically results in varus malalignment, increasing the load across the medial compartment.[2-4]

Management of knee OA aims to reduce pain and optimize physical function while minimizing adverse side effects of therapy. Hence, conservative, and especially non-pharmacologic, treatments are desirable. The laterally wedged insoles have been recommended as an efficacious method in this regard.[5,6] Several studies have shown that it effectively reduced the load at the medial compartment of the knee joint.[7-10] Thereby, optimizing the gait pattern of the patients, these insoles are considered to decrease pain and restore function. Van Raaij et al. suggested that a laterally wedged insole may be an alternative to knee orthosis for noninvasively treating symptoms of knee OA.[11] Laterally wedged soles may represent a substantial potential in the treatment of symptomatic knee OA because they are safe and generate fewer cost than knee orthosis.[12] In persons with knee OA, lateral wedges have been shown to reduce the peak knee adduction, an indirect biomechanical surrogate for medial compartment knee load, by approximately 4-12% on average.[9,13-18]

Biomechanical studies showed that lateral wedges reduce the adduction moment during walking compared with barefoot or shoes alone in medial knee osteoarthritis.[13-18] Similar results have been reported by more recent studies,[14,16-24] with Kerringan et al. demonstrating that a 5° laterally wedged insoles significantly reduces the knee adduction moment by 6% in medial knee OA.[9] Research also suggests that lateral wedges may laterally shift the center of pressure of ground reaction force, reducing its adduction lever arm at the knee; however, findings across studies are generally limited by small sample size and evaluated of short duration.[15,25,26] In fact, no study to date has assessed whether biomechanical effects of lateral wedges decline over one year.

The aim of this study was to evaluate effects of wearing lateral wedged insoles on the knee frontal plane biomechanics in medial knee OA after a 12-month period. It was hypothesized that after a 12-month application of laterally wedged insoles in patients with knee OA wearing would be effective at reducing knee varus moment when compared with walking barefoot.

METHODS

Subjects:

Fourteen patients who were under the follow-up in Hacettepe University Department of Physical Medicine and Rehabilitation due to bilateral osteoarthritis in medial compartment of the knee and treated with wedged insoles were invited to participate in the study. Patients wore bilateral full length laterally wedged insoles with medial longitudinal arch, made of high density ethyl vinyl acetate, with 5° tilt angle in their shoes on a regular basis for at least one year (12 or 14 months). All lateral wedged insoles were manufactured in Ankara University Department of Prosthetics and Orthotics. A 5° wedge was selected because greater wedging is associated with discomfort.[9] Participants started wearing the insoles for 1 hour, thereafter increasing use by 1 hour per day until wearing them between 5 and 10 hours each day. The device was checked every 2 months and proper use of insole was confirmed by the wear. In this study, patients wore their insole inserted in 1.5 inch heel height into regular shoes. Subjects were reevaluated using gait analysis after 12 months.

Patients were excluded if they had a history of inflammatory or infectious arthritis, major trauma of the knee, peripheral or central nervous system disorders, previous lower extremity surgery or were unable to walk without walking aids. After informed consent was obtained, 14 female patients aged between 48-61 (mean 52.6±4.6) years underwent assessment for pain, physical examination, and standing antero-posterior

radiological evaluation of the knee. Duration of daily use of the laterally wedged insoles was noted. Patient's global assessments of effectiveness of laterally wedged insoles were assessed using a 5-point Likert's scale and frequency of analgesic/NSADs usage was inquired.[27]

Thirteen healthy volunteers among the hospital personnel with similar body weight and height were also included in the study as controls. None of these subjects had pain and history of trauma or arthritis in the lower extremities.

Gait analysis:

Three-dimensional gait analyses were done in Motion Analysis Laboratory via Vicon motion analyses system (Vicon 612 System, Oxford Metrics, Oxford, UK) with six infrared JAI cameras at 50 Hz. The standard Plug-in Gait marker set (15 markers; one on sacrum and each anterior superior iliac spine, mid-lateral thigh, lateral knee joint, lateral shank, lateral malleolus, on the shoe over the second metatarsal head, and over posterior calcaneus) was used. Ground reaction forces were measured using two Bertec force plates (Bertec Co, Columbus, OH, USA) which were placed on the middle of a 10-meter walkway. Before data collection, each camera and force plate were calibrated. Patients and control subjects were asked to walk at their natural comfortable speed. Data was collected after several practice trials, both on barefoot and while wearing own daily shoes with wedged insoles in random order. Only barefoot walking was recorded for control subjects. The average of five trials for each walking condition was calculated. The knee adduction moments were normalized for body weight and height. All data collection was carried out by the same experienced physiotherapist.

Statistical analysis:

Statistical analyses were performed by using SPSS Software Program, version 16.0. Mann-Whithey U test was done for comparison of data of patients and control group. Wilcoxon's signed-ranks test was used to compare data between barefoot and walking with insole conditions in knee osteoarthritis patients. The statistical significance level was set at $p<0.05$.

RESULTS

All of the patients reported that laterally wedged insoles were effective on pain reduction and functional improvement on daily living activities. They also stated that their analgesic usage decreased during the last year. All of the patients had mild to moderate knee pain with no limitations in daily living activities. None of the patients had pain during passive motion, effusion or fixed contractures or deformity of the knee. Twenty eight knees of the 14 patients had grade 2 (10 knees) or 3 (4 knees) osteoarthritis according to Kellgren Lawrence radiologic scale.[28] Body weight, height, and body mass index were not different between the patients and controls except for the age ($p>0.05$) (Table 1).

Walking speed, step width, and cadence were not statistically different between patients' and controls' barefoot walking ($p>0.05$). Regarding knee varus moments; peak 1, peak 2, and average knee varus moments throughout stance phase were higher in patients' barefoot walking than the control group, but the differences were not statistically significant ($p>0.05$) (Table 2).

Walking speed and step width were similar when patients walked barefoot and with laterally wedged insoles($p>0.05$). Cadence was slightly higher during barefoot walking. Knee angles and total range of motion in frontal plane were not different in both walking conditions and control group ($p>0.05$) (Figure 1). Medial knee loading was prominently high when walking barefoot, and significantly decreased with laterally wedged insoles ($p<0.05$) (Figure 2). Spatiotemporal, kinematic and kinetic data of the patients are summarized in Table 3.

DISCUSSION

The results of this study showed that laterally wedged insoles significantly reduced knee varus moment walking when compared with barefoot condition after 12-month implementation. Up to date, no study has evaluated the biomechanical effects of laterally wedges over time. Our findings were similar to other studies which have shown

Table 1. Characteristics of the patients and the control group.

	Knee OA Patients (N=14) Mean±SD	Control Group (N=13) Mean±SD	p
Age (years)	52.6±4.6	42.9±0.6	<0.001
Body weight (kg)	78.2±10.9	79.9±10.5	0.430
Height (cm)	157.3±4.6	158.7±4.0	0.302
Body mass index (kg/m^2)	31.6±3.8	31.7±3.8	0.793

Table 2. Comparison of spatiotemporal, kinematic, and kinetic parameters between patients and controls (barefoot walking).

	Knee OA Patients Mean±SD	Healthy Subjects Mean±SD	p
Cadence (steps/min)	108.9±5.1	111.1±7.8	0.685
Step width (cm)	19.4±0.2	18.7±0.2	0.430
Walking Speed (m/s)	1.0±0.1	1.1±0.1	0.685
Knee varus-valgus ROM throughout gait cycle (°)	10.6±2.4	10.9±2.1	0.793
KVM peak 1 (Nm/BWxHT %)	4.6±1.0	4.2±1.5	0.325
KVM peak 2 (Nm/BWxHT %)	3.7±0.7	3.3±0.7	0.116
Average KVM throughout stance phase (Nm/BWxHT %)	3.0±0.7	2.6±0.6	0.185

ROM: Range of motion. KVM: Knee varus moment.

Table 3. Spatiotemporal, kinematic, and kinetic parameters of the patients with knee OA walking barefoot and with laterally wedged insoles (N=14).

	Barefoot Mean±SD	With insole Mean±SD	p
Cadence (steps/min)	108.9±5.1	105.8±6.2	0.041*
Step width (cm)	19.4±0.2	19.7±0.2	0.626
Walking Speed (m/s)	1.0±0.1	1.0±0.1	0.284
Knee varus-valgus ROM throughout gait cycle (°)	10.6±2.4	10.1±2.7	0.900
KVM peak 1 (Nm/BWxHT %)	4.6±1.0	3.3±1.0	<0.001
KVM peak 2 (Nm/BWxHT %)	3.7±0.7	2.8±0.9	<0.001
Average KVM throughout stance phase (Nm/BWxHT %)	3.0±0.7	1.9±0.8	<0.001

*p<0.05. ROM: Range of motion. KVM: Knee varus moment.

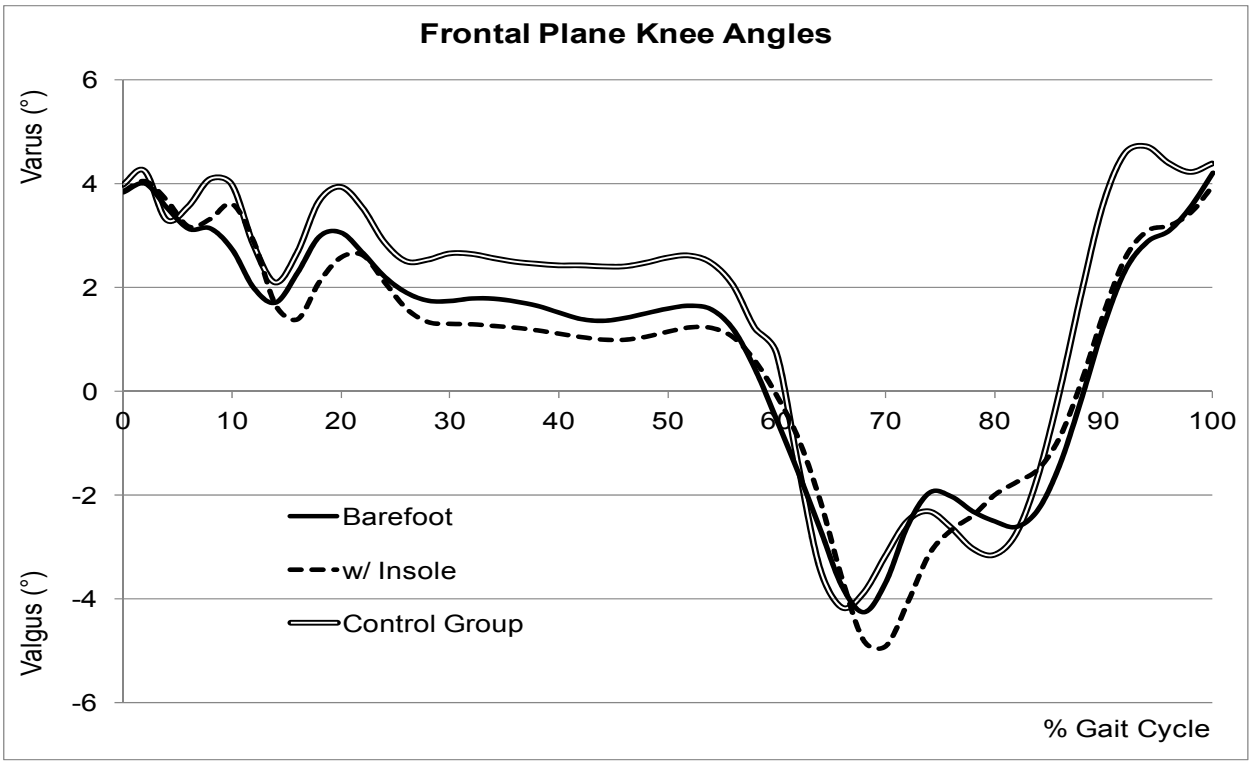

Figure 1. Frontal plane knee angles.

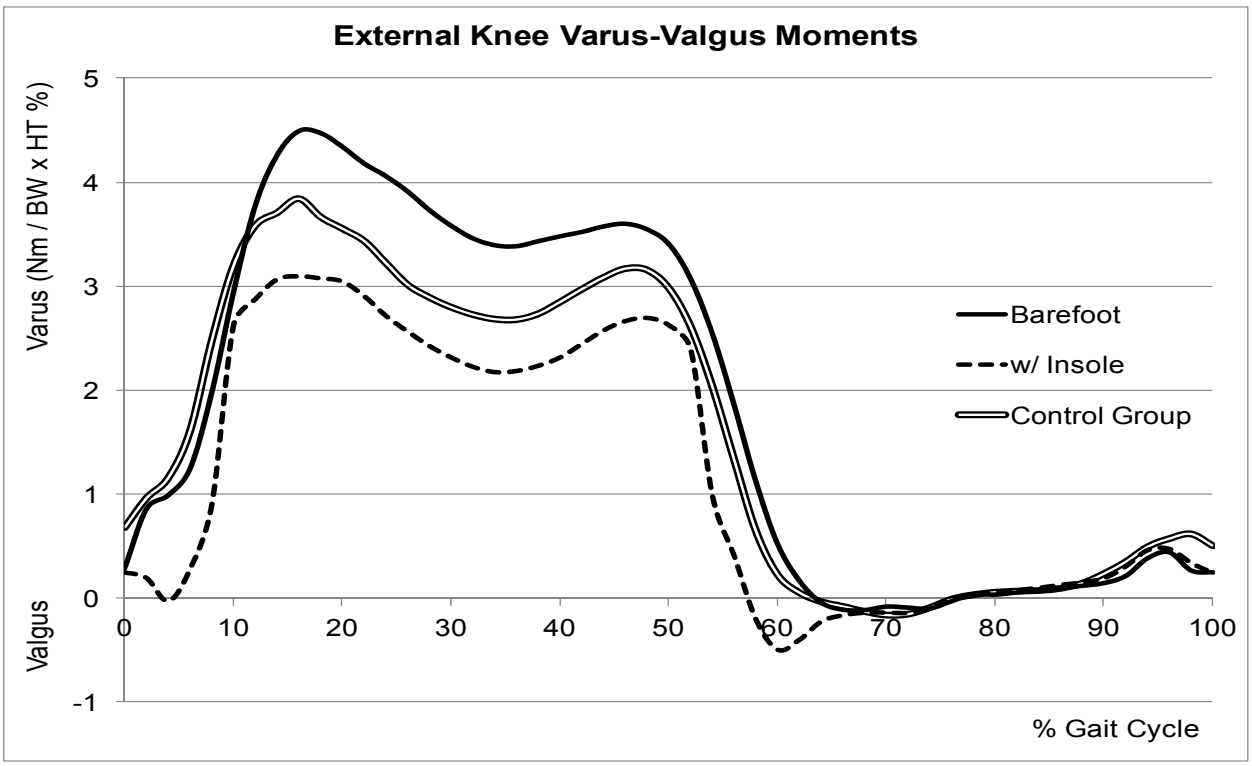

Figure 2. External knee varus moments normalized for body weight and height.

that lateral wedge insoles significantly reduce the peak knee adduction moment in knee OA.[9,13-18,24] Hinman et al. evaluated the immediate effects of lateral wedge insoles on lower limb frontal plane biomechanics in a large cohort with medial knee OA and demonstrated significant reduction in peak adduction moment and knee adduction angular impulse with lateral wedges.[24] Many studies have only evaluated the clinical evidence effect of lateral wedges in knee OA, providing no information as to whether the biomechanical analysis of insoles decline over time. The only long- term study in the effect of laterally wedged insole on disease progression failed to demonstrate any structural effect.[23] On the other hand, that study tested an insole that wedged rear foot only, and did not include any biomechanical gait analysis. Erhart et al. showed that wearing variable-stiffness shoes lowered adduction moment, reduced pain and improved functionality in subjects with medial compartment knee OA after 6 months of wear.[29]

Biomechanical studies have evaluated the effects of laterally wedged insoles on knee alignment and medial compartment loading. Lateral wedged insoles are supported for management of medial tibiofemoral knee OA, and biomechanical data have showed that such an intervention can immediately decrease the knee adduction moment by 5-10% on average.[9,15,19] This study supports that the same reduction in the knee joint varus moment obtained with laterally wedged insole in OA patients. In 15 patients with knee OA, Kerrigan et al. demonstrated that lateral wedges reduced the first peak by 5.3% and the second peak by 6.5%. In another small group (N=13), Kakihana et al. demonstrated that lateral wedges attached to the bare feet reduced stance phase adduction moment.[15] Our findings showed that lateral wedges reduced the first and the second peak knee varus moment when compared with barefoot walking in OA patients and the control group. It seems that wedges increase valgus moment arm at the subtalar joint, causing a lateral shift in the center of pressure location. In contrast, Maly et al. failed to show any significant effects of 5° lateral heel wedge on adduction moment in nine subjects with medial OA.[26] It may be that wedging the entire length of the foot with medial longitudinal arch, and not just the heel, is an insole feature necessary for the knee adduction moment to be reduced. Nakajima et al. reported that the addition of arch support to laterally wedged insole reduced knee adduction moment more efficiently possibly through the elimination of potential negative effects of the laterally wedged insole.[31] Mailleferd et al. in 156 patients with medial knee OA reported non significant effect of laterally wedged insoles on symptoms over 2 years.[22]

Crenshaw et al. and Kerrigan et al. reported that wearing a laterally wedged insole reduced knee joint varus moment, suggesting an effective mechanism for knee pain reduction in patients with OA. Using a mathematical model of tibiofemoral joint, Crenshaw et al. calculated a 4% reduction in medial contact force when healthy subjects wore a 5° lateral-wedge insole.[9,19] Shelburne et al. showed that a three-dimensional model of the lower limb was used to calculate muscle, ligament, and joint loading at the knee with 5 mm lateral shoe wedge during the gait. A lateral shoe wedge that shifts the center of pressure of ground force by 1 mm in the lateral direction will decrease the peak medial compartment load by 12 N.[30] Yasuda and Sasaki[8] speculated that the beneficial effects of insole were due to the reduction in the medial knee joint surface loading with a concurrent reduction in lateral tensile forces even though the device failed to correct the femorotibial angle in patients with medial compartment OA knee. Keating et al. suggested that the knee joint varus moment during gait with a laterally wedged insole was associated with the subtalar joint valgus angle.[10] We proposed that mechanism of reduction of knee varus moment with the usage of insoles is a lateral shift in the center of pressure on the foot, thereby reducing the moment arm of the adduction moment.[26] We found that wearing a 5° laterally wedged insole significantly reduced knee varus moment when compared with barefoot walking in OA patients. Shimada et al. reported that kinematic and kinetic effects of wearing lateral

wedged insoles were significant in Kellgren-Lawrence grade I and II knee OA, and the results support the recommendation of use of lateral wedged insoles for patients with early and mild knee OA.[17] Marks and Penton indicated that wedged foot orthotics are effective in patients with mild medial compartment knee OA.[32] All of our patients had mild medial compartment knee OA of grade 2 and 3.

A limitation of this study was the quantity of sample size, which was 14 participants. Further studies on larger samples are needed to validate the current findings. Prospective studies should assess different insole materials or different level orthoses. In addition, future research should address how changes in wedging at the foot affect ankle and hip mechanics during a prolonged period of time. In the present study, we did not attempt to examine the relation between the radiographic severity of knee OA and the biomechanical effects of lateral wedge insoles.

In conclusion, our data suggest that the use of laterally wedged insoles have significant effects on frontal plane knee varus moment in knee OA after a use of over a period of one year. Findings demonstrated a significant reduction in peak knee varus moment when compared with barefoot walking. Our results supported the proposal made by several groups that using of lateral wedged insoles is recommended for mild knee OA.

REFERENCES

1. Ahlback S. Osteoarthritis of the knee: a radiographic investigation. Acta Radiol. 1968;277(Suppl.):70-72.
2. Duncan RC, Hay EM, Saklatvala J, et al. Prevalence of radiografic osteoarthritis: it all depends on your point of view. Rheumatology (Oxford). 2006;45:757-760.
3. Schipplein OD, Andriacchi TP. Interaction between active and passive knee stabilizers during level walking. J Orthop Res. 1991;9:113-119.
4. Andriacchi TP, Mundermann A. The role of ambulatory mechanics in the initiation and progression of knee osteoarthritis. Curr Opin Rheumatol. 2006;18:514-518.
5. Jordan KM, Arden NK, Doherty M, et al, and the Standing Committee for International Clinical Studies Including Therapeutic Trials (ESCISIT). EULAR recommendations 2003: an evidence based approach to the management of knee osteoarthritis: report of task force of the Standing Committee for International Clinical Studies Including Therapeutic Trials (ESCISIT). Ann Rheum Dis. 2003;62:1145-1155.
6. American College of Rheumatology Subcommittee on Osteoarthritis Guidelines. Recommendations for the medical management of osteoarthritis of the hip and knee: 2000 update. Arthritis Rheum. 2000;43:1905-1915.
7. Sharma L, Song J, Felson DT, et al. The role of knee alignment in disease progression and functional decline in knee osteoarthritis. JAMA. 2001;286:188-195.
8. Yasuda K, Sasaki T. The mechanics of treatment of the osteoarthritic knee with wedged insole. Clin Orthop Relat Res. 1987;215:162-172.
9. Kerrigan DC, Lelas JL, Goggins J, et al. Effectiveness of a lateral-wedged insole on knee varus torque in patients with knee osteoarthritis. Arch Phys Med Rehabil. 2002;83:889-893.
10. Keating EM, Faris PM, Ritter MA, et al. Use of lateral heel and sole wedges in the treatment of medial osteoarthritis of the knee. Orthop Rev. 1993;22:921-926.
11. Van Raaij TM, Reijman M, Bierma-Zeinstra SM, et al. Medial knee osteoarthritis treated by insoles or braces. Clin Orthop Relat Res. 2010;468:1926-1932.
12. Baker K, Goggins J, Xie H, et al. A randomized crossover trial of a wedged insole for treatment of knee osteoarthritis. Arthritis Rheum. 2007;56:1198-1203.
13. Butler RJ, Marchesi S, Royer T, et al. The effect of a subject-specific amount of lateral wedge on knee mechanics in patients with medial knee osteoarthritis. J Orthop Res. 2007;25:1121-1127.
14. Hinman RS, Bowles K, Payne C, et al. Effect of length on laterally wedged insoles in knee osteoarthritis. Arthritis Rheum. 2008;59:144-147.
15. Kakihana W, Akai M, Nakazawa K, et al. Effects of laterally wedged insoles on knee and subtalar joint moments. Arch Phys Med Rehabil. 2005;86:s1465-1471.
16. Kuroyanagi Y, Nagura T, Matsumoto H, et al. The lateral wedged insole with subtalar strapping significantly reduces dynamic knee load in the medial compartment-gait-analysis on patients with medial knee osteoarthritis. Osteoarthritis Cartilage. 2007;15:932-936.
17. Shimada S, Kobayashi S, Wada M, et al. Effects of disease severity on response to lateral wedged shoe insole for medial compartment knee osteoarthritis. Arch Phys Med Rehabil. 2006;87:1436-1441.

18. Hinman RS, Payne C, Metcalf BR, et al. Lateral wedges in knee osteoarthritis: what are their immediate clinical and biomechanical effects and can these predict a three-month clinical outcome? Arthritis Care Res. 2008;59:408-415.
19. Crenshaw SJ, Pollo FE, Calton EF. Effects on lateral wedged insole on kinetics at the knee. Clin Orthop Relat Res. 2000;375:185-192.
20. Barrio JA, Crenshaw JR, Royer TD, et al. Walking shoes and laterally wedged orthosis in the clinical management of medial tibiofemoral osteoarthritis: a one-year prospective controlled trial. Knee. 2009; 16:136-142.
21. Bennell KL, Bowles K, Payne C, et al. Lateral wedge insoles for medial knee osteoarthritis: 12 month randomized controlled trial. BMJ. 2011;342:d2912. Doi:10.1136/bmj.d2912.
22. Maillefert JF, Hudry C, Baron G, et al. Laterally elevated wedged insoles in the treatment of medial knee osteoarthritis: a prospective randomized controlled study. Osteoarthritis Cartilage. 2001;9:738-745.
23. Pham T, Maillefert JF, Hundry C, et al. Laterally elevated wedged insoles in the treatment of medial knee osteoarthritis. A two year prospective randomized controlled study. Osteoarthritis Cartilage. 2003;12:46-55.
24. Hinman RS, Bowles K, Metcalf BB, et al. Lateral wedge insoles for medial knee osteoarthritis: effects on lower limb frontal plane biomechanics. Clin Biomech (Bristol Avon). 2011;27:27-33.
25. Kakihana W, Akai M, Nakazawa K, et al. Inconsistent knee varus moment reduction caused by lateral wedge in knee osteoarthritis. Am J Phys Med Rehabil. 2007;86:446-454.
26. Maly MR, Culham EG, Costigan PA. Static and dynamic biomechanics of foot orthoses in people with medial compartment knee osteoarthritis. Clin Biomech (Bristol Avon). 2002;17:603-610.
27. Bolognese JA, Stat M, Schnitner TJ, et al. Response relationship of VAS and Likert scales in osteoarthritis. Osteoarthritis Cartilage. 2003;11:499-507.
28. Kellgren JH, Lawrence JS. Radiological assessment of osteoarthritis. Ann Rheum Dis. 1957;16:494-501.
29. Erhart JC, Mündermann L, Elspas B, et al. Changes in knee adduction moment, pain and functionality with a variable-stiffness walking shoe after 6 months. J Orthop Res. 2010;28:873-879.
30. Shelburne KB, Torry MR, Steadman JR, et al. Effects of foot orthoses and valgus bracing on the knee adduction moment and medial joint load during gait. Clin Biomech (Bristol Avon). 2008;23:814- 821.
31. Nakajima K, Kakihana W, Nakagawa T, et al. Addition of an arch support improves the biomechanical effect of a laterally wedged insole. Gait Posture. 2009;29:208-213.
32. Marks R, Penton L. Are foot orthotics efficacious for treating painful medial compartment knee osteoarthritis? A review of the literature. Int J Clin Pract. 2004;58:49-57.