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Comparison of three knee braces in the treatment of medial knee osteoarthritis

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ABSTRACT

Background: Conservative orthotic treatments rely on different mechanisms, such as three-point bending systems or hinges forcing external rotation of the leg and knee stabilization, to alter the biomechanics of the lower limbs and thus reduce knee loading on the affected compartment in patients with knee osteoarthritis (KOA). No previous study had compared the effects of these mechanisms on external loading and leg kinematics in patients with KOA.

Methods: Twenty-four patients with medial KOA (Kellgren–Lawrence grade II or III) wore three custom knee braces: a valgus brace with a three-point bending system (V3P-brace), an unloader brace with valgus and external rotation functions (VER-brace) and a functional knee brace used in ligament injuries (ACL-brace). Pain relief, comfort, lower extremity kinematics and kinetics during walking were compared with and without each knee brace.

Results: Knee pain was alleviated with all three braces ($p < 0.01$). The VER- and ACL-braces allowed a significant reduction in peak knee adduction moment (KAM) during terminal stance from 0.313 to 0.280 Nm/Bw∗Ht ($p < 0.001$) and 0.293 to 0.268 ($p < 0.05$), respectively, while no significant reduction was observed with the V3P-brace ($p = 0.52$). Reduced knee adduction and lower ankle and knee external rotation were observed with the V3P-brace but not with the VER-brace. The ACL-brace did not modify lower limb kinematics.

Conclusions: No difference between the knee braces was found for pain reduction, discomfort or KAM. The VER-brace was slightly more comfortable, which could ensure better compliance with treatment over the long term.

1. Introduction

The knee joint is specifically affected by osteoarthritis, and 12.1% of the population aged 60 years and older is affected by symptomatic radiographic knee osteoarthritis (KOA) [1]. The knee joint plays an important stabilizer and shock absorber role during gait [2], so KOA is a major cause of disability and leads to significant declines in activity among people over 50 years old [3]. The compartments of the knee are not all affected in the same way, and people are at 10 times more risk of having medial than lateral KOA [1,4]. Some authors have suggested that this differential effect on knee compartments could be due to the difference in weight distribution on the knee during gait. Indeed, during walking, the medial compartment supports 2.2 times as much loading as the lateral compartment [5,6].

Because no cure exists for osteoarthritis, non-pharmacological and pharmacological treatments are used to reduce pain and improve function and quality of life before surgery is resorted to [3,7]. However, to relieve pain in malaligned knees, it may be necessary to reduce the load on the affected compartment, which is why several conservative treatments aim to alter the biomechanics of the lower limbs [8,9].

A valgus knee brace is one of the non-pharmacological treatments recommended to manage medial KOA [7]. It uses a three-point bending system and a predetermined angulation of the brace hinge components [9] and generally relieves pain by 10% or more [10,11]. Furthermore, its use also reduces the medial/lateral knee loading ratio by nine to 30 percentage points [12] and the knee adduction moment (KAM) by 8% or more [13,14] during weight bearing on the affected leg.

One compensatory strategy often used to unload the medial compartment of the knee (i.e., reduce the second peak of KAM) is an increase in the toe-out angle of the weight-bearing foot during the stance phase [15]. By externally rotating the leg, toe-out gait alters the length of the ground reaction force lever arms acting on the knee joint

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in the frontal plane. Recently, an unloader brace with a mechanism that induces outward (valgus) displacement and external rotation of the leg when fully extended was found to reduce the second peak of KAM by 22% in patients with KOA [16]. One limitation on that study was the lack of a control group to assess the real benefits of the unloader brace.

It has been suggested that perception of pain relief and improved function among KOA patients could also be due to joint stability [10]. A functional knee brace used in ligament injuries, such as tears of the anterior cruciate ligament (ACL), could generate benefits by stabilizing the knee during walking, but to date no study has verified this hypothesis.

The purpose of this study was to compare the immediate effects on pain, comfort and medial knee loading during gait of three knee braces: a valgus knee brace with a three-point bending system (V3P brace), an unloader brace with valgus and external rotation functions (VER brace), and a functional knee brace used to stabilize the knee after ligament injuries (ACL brace), in patients suffering from medial compartment KOA. We hypothesized that both valgus braces (V3P and VER) would provide the same alleviation of pain and reduction in knee loading, but the ACL brace would not. Comfort would be better with the VER brace than with the V3P brace because of its smaller size and because the VER brace's mechanism of action does not push on the knee joint in loading conditions.

2. Material and methods

2.1. Participants

Fourteen males and ten females with medial compartment KOA participated in this study. None of the participants had used knee braces before. The mean (SD) age, height, body mass and body mass index of participants were 57.2 (8.6) years, 1.68 (0.09) m, 89.3 (18.7) kg and 31.6 (5.2) $kg \cdot m^{-2}$, respectively.

Inclusion criteria were symptomatic medial KOA (Kellgren–Lawrence grade II or III) according to the American College of Rheumatology's clinical and radiological criteria [2,17], knee pain > 31/100 (WOMAC), moderately active lifestyle, and varus knee alignment equal or superior to 2° (the mechanical tibiofemoral angle was measured on radiographs). The exclusion criteria were mild or severe KOA (Kellgren–Lawrence grade I or IV), rheumatoid arthritis or other inflammatory arthritis, avascular necrosis, history of periarticular fracture or septic arthritis, bone metabolic disease, pigmented villonodular synovitis, cartilaginous disease, neuropathic arthropathy, synovial osteochondromatosis, total or partial knee arthroplasty, flexion contracture of ipsi- or contralateral knee greater than 15°, hip or ankle joint damage with mobility limitation, obesity (BMI ≥ 40), intra-articular corticosteroid injection in the affected knee during the previous two months, and reduced mobility (Charnley class C).

Patients were recruited through a campus mailing list. Patients diagnosed with KOA by their family physicians were asked to call a research nurse, who screened for their level of disability and knee pain using the WOMAC score. Then a radiological assessment, evaluated by an orthopedic surgeon, was necessary to verify the inclusion and exclusion criteria. Once patients consented to take part in the study, they were referred to an orthotist to be fitted with custom braces and then, two weeks later, to the gait laboratory for testing (Fig. 1). Ethical approval was obtained from the institutional ethics committee, and written informed consent was obtained from all participants.

2.2. Apparatus

Kinematic data were acquired by an optoelectronic motion analysis system composed of 13 cameras (FLEX:V100R2, *NaturalPoint Inc., Corvallis, OR, USA*), capture software (Capture 2D™, *C-Motion Inc., Germantown, MD, USA*) and 42 reflective markers: 26 were attached to anatomical landmarks (iliac crest, anterior superior iliac spine, posterior superior iliac spine, greater trochanter, medial and lateral femoral epicondyle, fibula apex of lateral and medial malleolus, heel and medial and lateral forefoot of the shoe) and four rigid marker clusters made up of four markers apiece were affixed to the thigh and shank of both legs according to the CAST protocol [18,19]. When knee braces were worn, femoral epicondyle markers were attached directly on the knee brace, and then virtual landmarks were created to relocate the knee markers. Moreover, two force plates (Model BP400600NC, AMTI, *Advanced Mechanical Technology Inc., Watertown, MA, USA*) were used to acquire kinetic data. Kinematic data were sampled at 100 Hz while kinetic data were sampled at 1000 Hz. Finally, a 3.5-meter instrumented walkway measured natural gait velocity and cadence (GAITRite, *CIR System, Sparta, NJ, USA*).

Three customized knee braces were made for each participant (Fig. 2; *Orthoconcept Inc., Laval, QC, Canada*): a functional knee brace to stabilize the knee (ACL brace), a valgus brace designed to work with a three-point bending force mechanism (V3P brace), and an unloader brace with valgus and external rotation functions (VER brace).

For the V3P brace, the three forces are generated by the tension of the straps and forces applied to the thigh, knee joint and leg [9]. Participants were instructed to tighten the diagonal strap so as to put pressure on their knee, but in such a way that they could wear it comfortably for several hours. The VER brace was a new-generation brace with a different mechanism of action, which is described in detail elsewhere [16]. Briefly, this unloader knee brace is composed of a semi-rigid anterior femoral band and a rigid anterior tibial band (Fig. 2D). This new brace is designed to work by creating a valgus (i.e., distraction between femur and tibia) and applying a slight external rotation to the leg during knee extension. These actions are performed by a medial trammel hinge, which stretches out the medial components during knee extension, and a lateral trammel hinge, which moves the brace's center of rotation backward. Comfort is ensured by copolymer anti-slip protection on the anterior tibial band, a breathable lining on the femoral band, and silicone padding on each strap. The ACL and VER braces were approximately 5% and 25%, respectively, smaller and narrower than the V3P brace. For instance, for a person 1.71 m tall, the customized V3P brace was 17.8 cm wide and 37.5 cm long, and the customized VER brace was 15.2 cm wide and 28.1 cm long.

2.3. Experimental procedure

A crossover study was done to evaluate the effects of wearing the three types of knee braces over a three-month period; each period of wear was followed by a two-week washout period without a brace. Knee brace order was randomized and each patient underwent a biomechanical assessment in the gait laboratory. The mechanisms and functions of each brace were not explained to the participants. The present study focuses on the immediate effects of the knee braces (first visit for each brace) and examines and describes the mechanisms explaining KAM reduction during the stance phase of gait among medial KOA patients.

At the first assessment, participants were instructed to perform six gait trials without the knee brace on the instrumented walkway at a self-selected regular gait speed, starting to walk 3 m before they stepped onto the walkway in order to reach a steady-state walk when their steps were recorded. These trials were processed immediately and determined the individual natural gait cadence for the duration of the study. Then, in all sessions, static model and gait analysis with and without the knee brace were done. Each patient walked on an 8-m walkway with the force plates located 2.75 m and 3.40 m from the start. Participants were instructed to walk following the beat of a metronome, which was adjusted to their self-selected cadence, as measured at the first assessment on the instrumented walkway. Before official data gathering began, several trials were carried out to determine the exact distance of the start so participants' heel-strikes would hit each force plate without modifying their gait pace. Ten trials were carried out in