Knee Bracing for Unicompartmental Osteoarthritis

Fabian E. Pollo, PhD
Robert W. Jackson, MD

Abstract

Unicompartmental osteoarthritis of the knee affects millions of individuals. Most nonsurgical management of this progressive disease is primarily directed at reducing inflammation and pain with medication. Evidence supports the clinical efficacy of bracing for managing osteoarthritis of the knee. In some patients, bracing significantly reduces pain, increases function, and reduces excessive loading to the damaged compartment. A variety of health and functional status instruments, as well as radiologic techniques and biomechanical investigations, has been used to evaluate the unloading capabilities of these braces. Although changes in angulation are relatively minimal, the braces have been shown to load share and thus reduce the stresses in the degenerated medial compartment of the knee.

Dr. Pollo is Director, Orthopaedic Research, and Assistant Administrator for Orthopaedics, Department of Orthopaedic Surgery, Baylor University Medical Center, Dallas, TX. Dr. Jackson is Chief, Emeritus, Department of Orthopaedic Surgery, Baylor University Medical Center.

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Reprint requests: Dr. Pollo, Baylor University Medical Center, Sixth Floor, South Hoblitzelle Building, 3500 Gaston Avenue, Dallas, TX 75246-9990.

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Pain from knee osteoarthritis (OA) affects daily life for millions of people; in the United States alone, 6% of adults aged 30 years and older (approximately 10 million) have symptomatic OA of the knee.[1] These figures are expected to double over the next 20 years as the age and activity level of the general population increase as a result of better overall health.

OA of the knee is usually a slowly progressive disease process. When appropriately treated nonsurgically in the early stages, major surgical intervention may be delayed. Nonsurgical intervention may include viscosupplementation, nutritional supplementation, and/or knee bracing. According to Sharma et al,[2] "knee OA is widely believed to be the result of local mechanical factors acting within the context of systemic susceptibility." In primary OA of the knee, it has been shown that varus or valgus malalignment increases the risk of medial or lateral progression of the disease, respectively, and that the disease can progress to a higher Kellgren-Lawrence level[3] in as little as 18 months. In the absence of a cure, most current therapeutic modalities are primarily aimed at reducing pain and improving joint function with nonspecific symptomatic agents. Much attention has been focused on treatment modalities that can provide both the needed pain modification and functional improvement while simultaneously affecting some of the mechanisms underlying the disease.

Preliminary evidence suggests that knee bracing for OA can provide that disease-modifying effect.[2,4] Knee bracing for OA gained attention in the late 1980s. Acceptance of such bracing has increased over the past 15 years, as evidenced by the large number of knee brace designs on the market and their increased use.[5] An estimated 125,000 braces for knee OA were sold in the United States in 2002.[5] Currently, 12 major companies produce more than 30 commercially available off-the-shelf and custom-made knee braces specifically indicated for knee OA.[5] Retail prices for off-the-shelf braces range from $700 to $1,000; those for custom-made braces, from $900 to $1,300.[5] A custom-made brace may be necessary for the obese patient whose leg is difficult to fit with a standard off-the-shelf design. Several studies demonstrate the efficacy of knee braces and their mechanisms of function.

Clinical Studies

Braces for managing unicompartmental OA of the knee are designed to reduce excessive loading on the damaged compartment, with the desired outcome of lessened pain and increased function. In one early study, Horlick and Loomer[6] evaluated 39 patients with medial compartment OA who were treated with a medial compartment–unloading, valgus-producing brace. The study involved a crossover design, with each patient evaluated for 6 weeks under three conditions: no brace, the brace in neutral alignment, and the brace in valgus alignment. Assessment of pain using a visual analog scale during activities of daily living demonstrated a reduction in pain only during the interval with the brace in valgus alignment ($P < 0.0001$). In a subsequent retrospective study of 233 patients with medial compartment OA who wore a brace for a mean of 25.6 months, the majority (>70%) showed overall pain reduction in the evening, as well as during exercise.[7]

In another randomized prospective trial of patients with medial compartment OA, each received either standard medical treatment (control group), a neoprene sleeve, or a valgus-alignment knee brace.[8] Two disease-specific, health-related, quality of life instruments—the Western Ontario and McMaster Universities (WOMAC) OA index and the McMaster-Toronto Arthritis (MACTAR) patient preference disability questionnaire—and two functional scores were used to evaluate 119 patients at baseline, 6 weeks, 3 months, and 6 months. Normal and overweight patients with a body mass index <35 kg/m^2 were included in the study. At 6 months, significant improvement was noted with both the WOMAC ($P = 0.001$) and MACTAR ($P \leq 0.001$) outcome measures in both the neoprene-sleeve and valgus-brace groups compared with the control group. However, the disease-specific WOMAC pain scores demonstrated that the valgus-brace group significantly reduced their pain compared with both the neoprene-sleeve group ($P = 0.045$) and the control group ($P < 0.001$) (Figure 1).

Draper et al[9] correlated subjective and objective outcome measures by using the Hospital for Special Surgery knee score and instrumented gait symmetry in their study of 30 patients treated with a valgus knee brace for medial compartment OA. At 3 months, patients showed significant improvement in Hospital for Special Surgery scores ($P < 0.001$) and in gait symmetry, as assessed in the swing phase ($P = 0.005$) and stance phase ($P = 0.0235$).

Two additional studies, both using a visual analog scale to assess pain and the Cincinnati knee score to assess function, demonstrated significant improvement when patients wore valgus braces to treat OA of the knee.[10,11] Hewett et al[10] reported significant improvement in pain and function compared with baseline at 9 weeks ($P = 0.0001$ and $P = 0.001$, respectively) and at 1 year ($P = 0.0001$ and $P = 0.0008$, respectively) in patients wearing a different type of valgus-producing brace. In 11 patients with medial compartment arthrosis, Lindenfeld et al[11] reported a 48% decrease in pain ($P = 0.01$) and a 69% increase in function ($P = 0.004$) with valgus bracing.

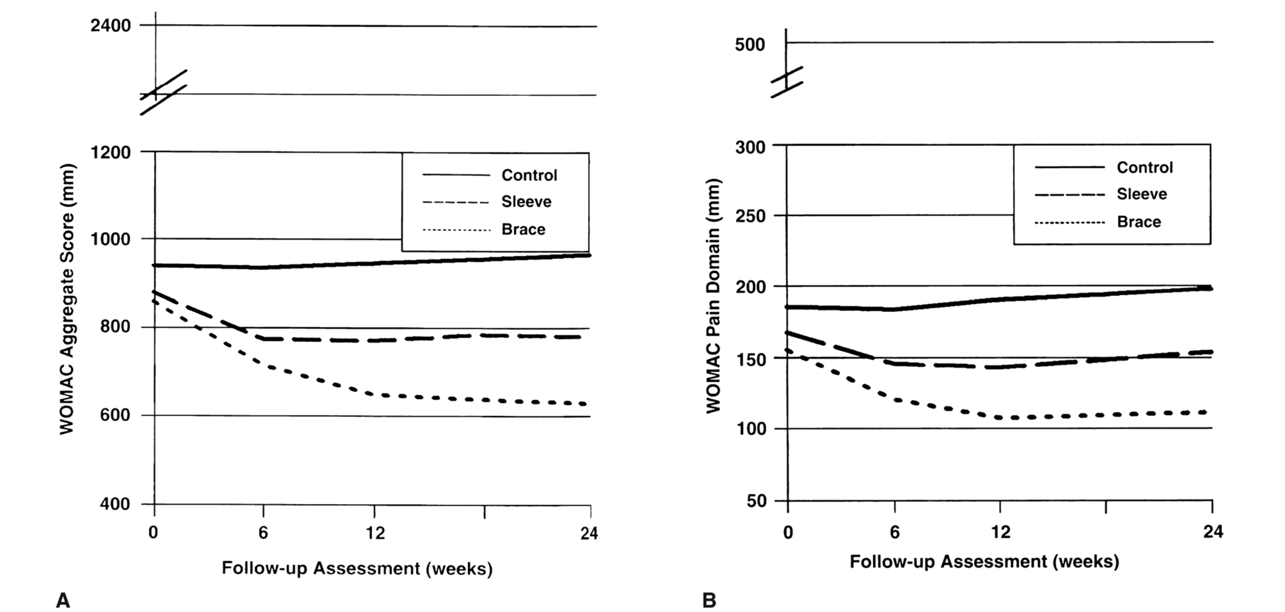
Twenty-eight patients who used a valgus brace for medial compartment OA reported improvement in resting pain, night pain, and pain with activity.[12] The patients had an average body mass index of 27.2 (range, 15 to 38) and moderate to severe arthritis (2 patients with Outerbridge grade I, 13 with grade II, and 8 with grade III arthritis).[13] Five patients were lost to follow-up.

Gait Analysis Studies

Early gait analysis studies focused on the alterations produced by knee braces on gait mechanics in an attempt to explain the results. Initially, it was thought that the pain reduction and functional improvement in OA patients was caused by the changing biomechanics of the gait pattern, leading to lower forces in the affected compartment. The studies focused on the effects of knee bracing for OA on gait mechanics, which varied from simple temporospatial measurements to full three-dimensional gait analysis. In a series of 119 patients undergoing functional gait analysis at 6-month follow-up, the valgus knee brace significantly improved functional performance during a 6-minute walk ($P = 0.021$) and 30-second stair climb ($P = 0.016$), compared with a neoprene sleeve and anti-inflammatory drugs.[8] Other studies also reported improvement in temporospatial parameters (eg, walking velocity, stride length) with the valgus knee brace.[4,8-11]

Alterations in lower limb joint kinematics also have been observed with knee bracing for OA; the coronal knee angle was the primary parameter that improved. This result is not surprising in view of the realignment mechanism of these braces.

Figure 1



Western Ontario and McMaster Universities (WOMAC) OA index aggregate **(A)** and pain **(B)** scores of the three patient groups with medial compartment arthritis that were treated with medication (control), a neoprene sleeve, or a valgus brace. The worst score possible in panel A is 2,400 mm, and in panel B, 500 mm. (Reproduced with permission from Kirkley A, Webster-Bogaert S, Litchfield R, et al: The effect of bracing on varus gonarthrosis. *J Bone Joint Surg Am* 1999;81:539-548.)

Most studies reported only a few degrees of varus angle reduction during gait, mostly during the lower force areas of the stance phase.[14,15] Even though the angular changes were small, it seems logical that reducing the varus angle of the knee during walking would reduce the loads transmitted to the medial compartment.

The external coronal moment (ie, torque) is an important mechanism involved with loading the knee joint during gait. This moment is generated when the foot contacts the ground during stance phase and the ground reaction vector falls either medial (varus moment) or lateral (valgus moment) to the knee joint in the coronal plane. The coronal moment, which typically is varus, places more load on the medial compartment than on the lateral compartment during gait.[16-18] This may explain why OA is more prevalent in the medial than the lateral compartment.

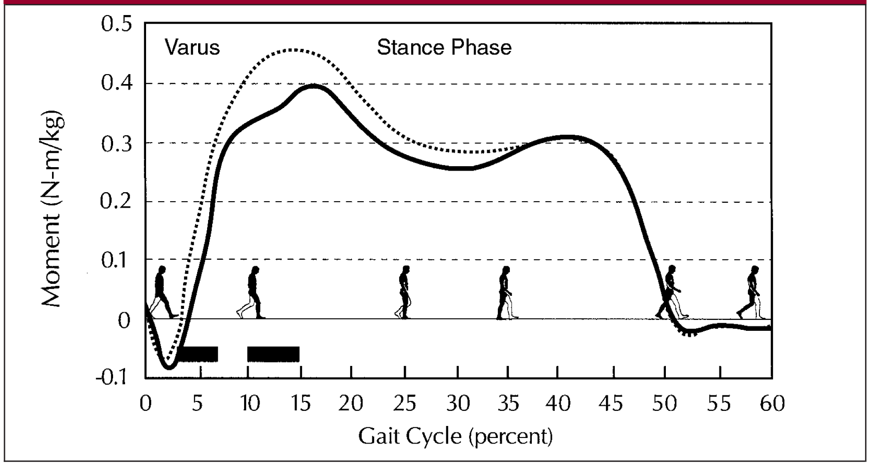
Concurrent presence of both an increased external knee varus moment and varus malalignment in patients with OA has been reported in several studies.[16,18] Because knee braces for OA apply counteracting forces to the knee (ie, a valgus moment in the presence of medial involvement), the expectation would be that the external moments are reduced. Bowton et al[19] first investigated this phenomenon. Using three-dimensional gait analysis, they studied eight OA patients with and without a valgus-producing knee brace. Five of the eight patients demonstrated a reduction in the total varus moment during gait with the brace. In 1994, Pollo et al,[20] using three-dimensional gait analysis, studied nine patients with knee OA and reported similar findings. During the highest loading portion of stance, the valgus brace significantly ($P < 0.05$) reduced the varus moment at the knee (Figure 2).

It was also postulated that, in addition to reducing the external varus moment during gait, valgus braces assisted the knee joint in absorbing those external forces.[20] In other words, in an unbraced condition, the knee would need to counteract the entire external varus moment, which would fall predominantly on the medial compartment. In the valgus braced condition, however, the knee would receive help from the brace, which would absorb some of that external load.

Radiologic Studies

Several radiologic studies have been performed to investigate the effect of knee bracing for OA on the weight-bearing coronal tibiofemoral angle. In 1993, Horlick and Loomer[6] examined 39 OA patients using a posteroanterior radiographic view with the knee in 30° of flexion. No changes were noted in the tibiofemoral an-

Figure 2



Mean external varus moment about the knee in nine OA patients with and without a valgus knee brace. The solid line represents the braced condition, and the dashed line, the unbraced condition. The solid bars represent the areas during the gait cycle that are significantly different.[20]

gle with the addition of a valgus brace. However, two subsequent studies reported small changes in the tibiofemoral angle with valgus bracing; the largest change was approximately 4°.[14,21] This small change could be within the range of measurement error; taking measurements from radiographic film is not extremely precise. Also, one difference between the later studies and the earlier Horlick and Loomer study[6] was the positioning of the limb during radiography. In the later studies, the patient's knees were in full extension.

Komistek et al[14] used fluoroscopy to examine the dynamic effect of a knee brace on the coronal knee angle and joint space separation in OA patients. In 15 patients with unicompartmental OA of the knee who were wearing a valgus knee brace, the authors reported an average of 1.2 mm condylar separation on the medial side and a tibiofemoral coronal angle change of approximately 2.2° just after heel strike (Figure 3). In theory, a visible condylar separation implies that the compartment is at least partially unloaded. However, this condylar separation occurred just after heel strike, when there is typically a small external valgus moment about the knee that assists in unloading the medial compartment.

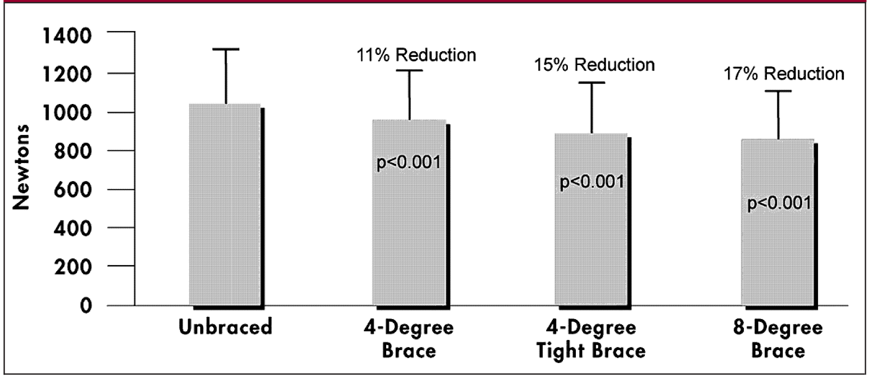
In 1999, Katsuragawa et al[22] used dual-energy x-ray bone densitometry to investigate the effect of valgus knee bracing on the bone mineral

Figure 3

A B

Fluoroscopic images of an OA patient at heel strike without **(A)** and with **(B)** a knee brace. A significant increase in the joint space in the medial compartment is visible in panel B. **Insets,** Frontal views of the experimental setup with the patient on the treadmill without (inset A) and with (inset B) knee bracing. (Reproduced with permission from Komistek RD, Dennis DA, Northcut EJ, Wood A, Parker AW, Traina SM: An in vivo analysis of the effectiveness of the osteoarthritic knee brace during heel-strike of gait. *J Arthroplasty* 1999;14:738-742.)

Figure 4



The average medial compartment load for a group of OA patients in four conditions: unbraced, bracing with 4° of valgus correction, bracing with 4° of valgus correction and a tight Dynamic Force Strap (Össur, Reykjavik, Iceland), and bracing with 8° of valgus correction.[15]

density of the proximal tibia in 14 patients with OA. The patients were tested before bracing and at 3 months. The authors theorized that if a valgus-producing brace shifted load from the medial to the lateral compartment, there should be some evidence of increased bone mineral density on the lateral side as a consequence of the increased load. The authors reported a 7% increase in bone mineral density on the lateral compartment of the braced knee ($P = 0.011$) over the 3-month period; the unbraced knee had only a 4% increase ($P = 0.09$), thus proving that OA bracing can alter load distribution in the knee joint.

Compartmental Load Studies

Pollo et al[15] evaluated load sharing and knee compartmental load reduction during gait in 11 patients with isolated medial compartment OA who were treated with valgus bracing. The braces were instrumented with strain gauges, which recorded the unloading moment (ie, torque) placed on the leg during walking. This information provided the load-sharing capabilities of the brace and enabled determination of the net external varus moment on the knee. Previous three-dimensional gait analysis studies were capable of measuring only the total external varus moment, which included the portion absorbed by the knee and the portion absorbed by the brace. The net external knee moment was reduced by as much as 20% in the Pollo study. The authors developed an analytical model to estimate medial and lateral knee compartment forces. Their data demonstrated that with a valgus brace, the load on the medial compartment could be reduced by as much as 17%. The load reduction was dependent on the amount of valgus correction adjusted into the brace (Figure 4). The results also demonstrate that, as more correction is placed into a valgus brace, more load sharing can be accomplished. Otis et al[23] reported similar load-sharing results with a different OA knee brace design.

In 2001, Anderson et al[24] took load-sharing investigations one step further by using a method to directly measure compartment unloading. They temporarily implanted pressure sensors in the medial compartment of five OA patients during prescheduled arthroscopic procedures. After sensor implantation, each patient stood while medial compartment forces were directly recorded during single- and double-leg standing trials. The patients performed these tests unbraced and with four commercially available OA knee braces. The authors reported an average medial compartment load reduction of 68% during double-leg stance and 61% during single-leg stance in braced knees, compared with unbraced knees.[24]

Clinical Indications and Use

The primary indication for knee bracing is pain and swelling caused by mild to severe arthrosis in a patient who is willing to use and can tolerate an external brace. Patients who need to delay realignment osteotomy or knee replacement also may benefit. Currently, there is no firm guideline regarding how much coronal angulation is too much, but manufacturers recommend varus or valgus angulation ≤10°. The coronal deformity need not be passively correctable. These braces seem to work more by sharing the load with the affected compartment than by altering the coronal angle.

The duration of brace use during the day may vary from patient to patient. Patients with milder degrees of arthritic change may need to wear the brace only during high-impact activities, such as sports, walking long distances, or standing for long periods. However, patients with more advanced stages of OA may need to wear the brace all day. With bracing, the patient determines when to wear the brace based on his or her symptoms. Most current brace designs contain features that allow the patient to adjust the degree of unloading.

Contraindications

Contraindications to knee bracing include marked bicompartmental arthritic changes in the tibiofemoral joint and notable knee instability.

Patients with medial compartment arthritis who have injury or chronic stretch of the medial collateral ligament or other medial or anteromedial structures of the knee should avoid using a valgus-unloading brace. Patients with lateral compartment arthritis who have injury or chronic stretch of the lateral collateral ligament or other lateral or posterolateral connective structures of the knee should avoid using a varus-unloading brace. Because these braces are designed to unload the compartments through coronal plane torque, patients with problems in the medial or lateral structures of the knee may be susceptible to further damage of those structures with the continued stress applied by the braces. In addition, patients with a flexion contracture >10° probably should avoid this form of therapy.

Patellofemoral involvement should not be a contraindication for bracing, although skin or peripheral vascular disease may prevent its use. Obesity is not a contraindication, but a custom-made brace may be required. Several studies have shown that even obese patients may attain pain relief with bracing when they are properly fitted with a custom-made design or a brace that incorporates a knee-ankle-foot orthosis to increase the lever arm.

Summary

Knee bracing for OA may effectively relieve pain and improve function in the arthritic population. Bracing is beneficial for many different types of patients, regardless of age, sex, or weight. In several studies, patients with a body mass index >35 (ie, morbidly obese) were successfully treated. Patient compliance may be a problem with bracing because the patients may easily remove the device. Although no published studies have specifically investigated patient compliance with bracing, our experience indicates that most patients (>75%) will continue to use braces for many years when the braces are properly fitted and the patients educated on their use. The potential for side effects, such as skin breakdown, cellulitis, and allergic reactions, is relatively small.

Although published studies have evaluated several brace designs, (eg, single-hinge, double-hinge, with dynamic force straps, with condylar pads), in no study have these different braces been compared with each other. Therefore, deciding which brace to prescribe is based only on the available clinical and biomechanical research. Biomechanical data for a few brace designs have confirmed that claims of unloading are valid. Other factors, such as proprioception and knee joint stability, also may contribute to brace function. Because patients with a varus alignment have increased risk for medial OA progression, it has been suggested that modalities that reduce the load on the involved compartment may modify the disease course. However, this supposition is unproved. It may be helpful to combine knee bracing with other forms of nonsurgical management, such as nonsteroidal anti-inflammatory drugs, viscosupplementation, and nutritional supplementation.

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