

# Valgus Bracing for Degenerative Knee Osteoarthritis

## Relieving Pain, Improving Gait, and Increasing Activity

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**In Brief:** Pain from osteoarthritis, the leading cause of disability in older patients, affects gait mechanics. Wearing an unloading brace may improve gait symmetry, decrease symptomatic pain, and increase activity for patients who have osteoarthritis of the knee or other varus knee deformities. Brace use may contribute to improved knee proprioception, gait parameters, and pain scores. Clinicians can recommend a trial of brace wear for patients who have knee pain as a conservative measure or to provide temporary pain relief before joint replacement surgery.

**A**pproximately one in four Americans has arthritis, the leading cause of disability in middle-aged and older patients.<sup>1</sup> Osteoarthritis (OA) occurs most frequently in individuals who are obese or inactive. In addition, abnormal gait changes that result from dysfunctional mechanical forces acting on the knee have been associated with worsened OA symptoms.

Disability related to knee OA reduces activity levels, thereby increasing inactivity and weight gain and worsening arthritis. If the dysfunctional mechanical forces are not corrected, then progressive joint surface fissuring, followed by erosion, can occur (figure 1).<sup>2</sup> Moderate levels of activity have been shown to reduce the pain associated with arthritis. Likewise, valgus knee bracing for OA may reduce pain and thereby promote activity.

Figure 1: Courtesy of Jon G. Divine, MD



**FIGURE 1.** A coronal MRI of the left knee of a 40-year-old man demonstrates typical findings of osteoarthritis: medial joint-space narrowing (arrow), absence of the medial meniscus, and osteophyte formation (arrowheads). Presence of bone anchor sites (open arrows) from a failed ACL reconstruction are postoperative changes common in patients who had posttraumatic ACL reconstruction more than 15 to 20 years ago.

## Gait Changes With Osteoarthritis

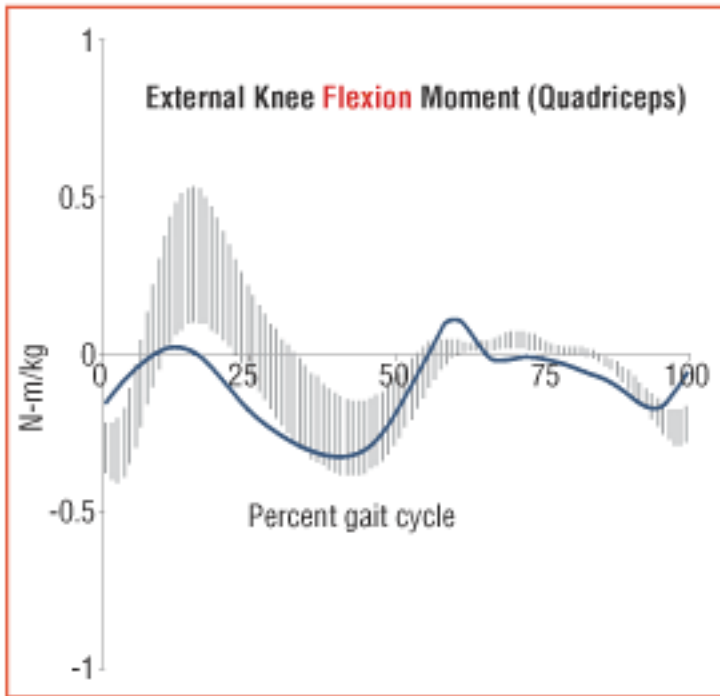
OA typically involves hyaline cartilage destruction and repetitive mechanical friction in one or more of the three knee compartments. The medial compartment is the most frequently affected, followed by the patellofemoral compartment. Increased loading of the medial compartment is easily recognized clinically by the bow-legged or varus knee deformity. As dysfunctional mechanical forces combine to narrow the medial compartment, additional shear forces affect the load-bearing articular surface, and further hyaline destruction occurs.

Pain from OA likely affects gait mechanics. In one of the earliest gait studies in patients who had symptomatic OA of the knee, Messier et al<sup>3</sup> observed poor leg flexibility in both the affected and unaffected legs. Patients showed significantly less angular velocity at the knee and, to a lesser extent, decreased knee range of motion during gait. They observed an

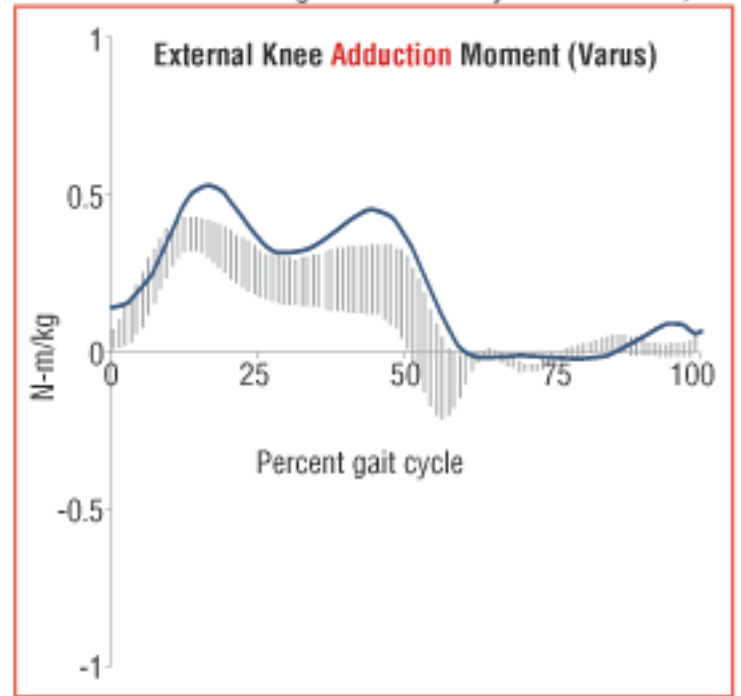
increased loading rate in the unaffected leg after heel strike, less peak vertical force during push-off, and less muscle strength in both legs. The authors attributed these alterations in gait to pain from OA.

Compensatory gait changes (table 1) may lead to a reduction in the internal knee extensor (external flexor) or quadriceps moment in patients who have OA (figure 2).<sup>4</sup> Load-reducing mechanisms, such as a decreased midstance knee flexion angle (identified by others in subjects who had end-stage knee OA) or reduced external flexion or extension moments, were not present in a group of subjects who received conservative treatment for knee OA. The finding of a significantly greater-than-normal external knee adduction (varus) moment in the knee OA group versus the control group supports the hypothesis that an increased knee adduction moment during gait is associated with knee OA (figure 3).<sup>4</sup>

Figures 2-4: Courtesy of Kevin R. Ford, MS



**FIGURE 2.** Graph of the flexion and extension (external) moments at the knee during walking. The knee is flexed when the value is above zero and extended when the value is below zero. The solid line represents the subject, and the vertical lines represent the mean plus one standard deviation from the normal population. The subject has a lower-than-normal flexion moment, which is common in those who have medial osteoarthritis.



**FIGURE 3.** Graph of the adduction (external) moment at the knee. The vertical lines represent the mean plus one standard deviation from the normal population. The subject (solid line) has a higher-than-normal moment, which is common in those who have medial osteoarthritis. Patients tend to swing the affected leg to the side and then inward during walking to compensate for a stiff knee.

**TABLE 1. Definitions of Terms Commonly Used in Gait Analysis****Biomechanical Terms**

**Adduction (external) moment:** Ground-generated torque that forces the distal tibia toward the midline of the body, which forces the knee away from the midline, into a varus or "bow-legged" position

**Angular velocity:** Rate of change in the angle of a leg joint during walking; usually expressed in degrees per second

**External joint (knee) moment:** Load (torque) applied to the knee by ground reaction forces, gravity, and external forces; calculated from motion analysis cameras and force plates

**External knee flexion moment:** External torque that tends to flex the knee and is balanced by internal forces (quadriceps activity) (see figure 2)

**External knee adduction moment:** External torque that tends to adduct (varus thrust) the knee (see figure 3)

**Varus knee deformity:** A fixed (static) malalignment of the knee away from the midline of the body (see figure 4A); also called "bow-legged" abnormality

**Gait Parameters**

**Cadence:** A stepping rate; usually expressed as steps per minute

**Double support time:** Gait stance when both feet are in contact with the ground

**Kinematic parameters:** Motion (angle) measures

**Kinetic parameters:** Force and moment (torque) measures

**Heel strike:** Point at which the heel hits the ground during gait

**Loading response:** Point at which the knee begins to bend and the quadriceps begins to eccentrically load during gait

**Mechanical axis:** The angle of the leg as defined by the intersection of a line drawn from the center of the ankle mortise to the center of the knee and a line from the center of the knee to the center of the hip (the head of the acetabulum)

**Midstance knee flexion angle:** The angle of the joint when the weight of the body is balanced over one foot and the external moments drop near zero

**Stride length:** Distance between the sequential points of contact by the same foot

**Stride time:** Time between the sequential points of contact by the same foot

**Toe-out angle:** The foot progression angle or the angle of the great toe relative to the heel as the subject moves his or her body forward over the foot during single-leg stance

**Valgus knee position:** A "knock-kneed" knee position

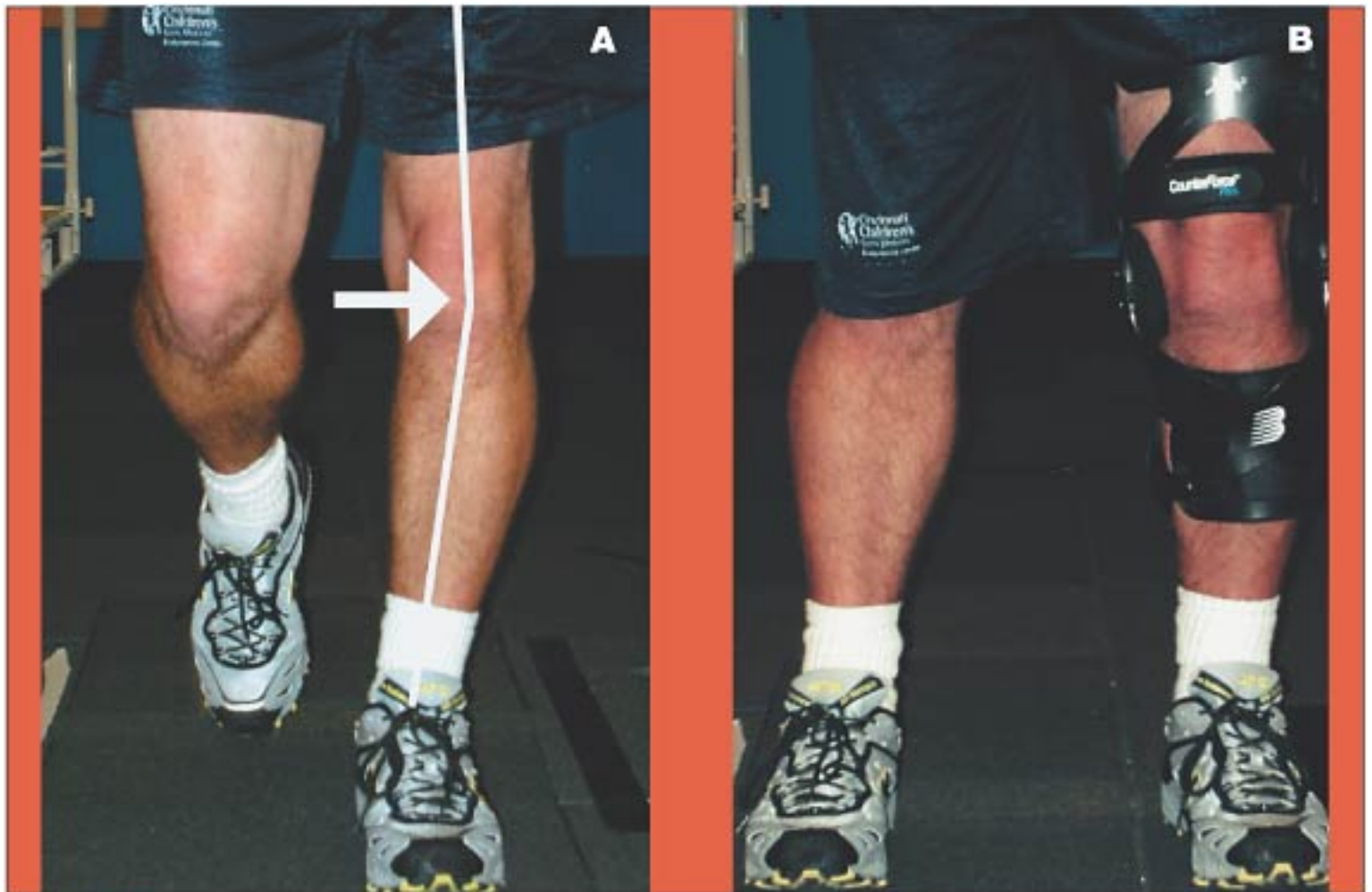
**Varus knee position:** A "bow-legged" knee position

**Walking velocity:** Speed of walking; usually expressed in meters or feet per second

The changes induced by the pain response likely lead to gait biomechanics that may cause further deleterious effects on the joint. Gok et al<sup>5</sup> examined the kinetic and kinematic gait characteristics in 13 patients who had early medial knee arthrosis and 13 normal controls. Compounding the pathology within the medial compartment, knee varus in the stance phase and valgus in the swing phase were increased. From this study, it appears that changes in gait biomechanics contribute to worsening disease.<sup>6</sup>

Understanding what clinical measures of OA are most closely associated with dynamic knee loads may ultimately result in a better understanding of the disease process and the development of therapeutic interventions. Patients with increased OA knee pain have a significant inversely related decrease in the peak external adduction (varus) and flexion (quadriceps) moments, whereas patients who have less or no knee pain have relatively normal peak external adduction, flexion, and extension moments.<sup>7</sup>

In a follow-up study by Hurwitz et al,<sup>8</sup> subjects who had OA walked with a greater-than-normal peak adduction moment during early stance. The mechanical axis (figure 4) was the best single predictor of the peak adduction moment during walking in both early and late stance. The radiographic measures of OA severity in the medial compartment were also predictive of early and late peak adduction moments. Once mechanical axis was taken into account, other factors increased the ability to predict the peak knee adduction moments by only 10% to 18%. The mechanical axis was indicative of the peak adduction moments, but it accounted for only about 50% of the variation, thus emphasizing the need for a dynamic evaluation of knee loading.<sup>8</sup>



**FIGURE 4.** Varus or "bow-legged" knee position (A) in a 40-year-old man. The approximate mechanical axis of the leg (arrow) is measured by drawing lines from the ankle mortise to the center of the knee and from the center of the knee to the acetabulum. The same patient (B) after being fitted with a three-point, pressure-transfer-system, valgus-producing brace to correct the knee varus.

## Valgus Bracing for Osteoarthritis

Developed in the mid 1990s as an off-shoot of functional braces, unloading braces are becoming more frequently used and accepted by people with knee OA. The science behind this technology is not definitive, because the few published studies lack the design strength of randomized controlled trials; however, ongoing research provides solid evidence that the three-point pressure design of these braces can normalize joint mechanics.

Barnes et al<sup>9</sup> evaluated the CounterForce brace (Breg, Inc, Vista, California) for symptomatic relief in 30 patients who had unicompartmental OA. The study subjects had undergone at least 6 months of conservative treatment without resolution of symptoms. After 8 weeks of brace use, the patients reported substantially reduced pain, reduced use of oral pain medication, and an increased ability to work and to engage in activities of daily living. At long-term follow-up (mean, 2.7 years), 41% of 29 patients were still using the brace, 35% had stopped using the brace (for a variety of reasons), and 24% had undergone arthroplasty.<sup>9</sup>

Finger and Paulos<sup>10</sup> evaluated the OAdjuster load-shifting brace (dj Orthopedics, Inc, Vista, California) in 28 patients who had symptomatic OA. At 3 months, average resting pain decreased from 4.2 to 2.1 on a 10-point Likert scale. Night pain decreased from 3.9 to 2.6, and pain with activity decreased considerably, from 7.2 to 3.9. The results of both studies<sup>9,10</sup> showed that load-shifting braces effectively reduce pain and shift the center axis of pressure.

## Brace Use, Pain, and Activity Level

Hewett et al<sup>11</sup> conducted one of the first studies to evaluate the effectiveness on OA symptoms and functional gait patterns of a brace designed to decrease loads on the medial tibiofemoral compartment. Nine OA patients who had chronic pain and arthrosis underwent a dynamic gait analysis to determine if the brace decreased pain symptoms, improved function, and altered dynamic gait characteristics. The 9 subjects were compared with 11 controls matched for age and walking speed. The brace was worn an average of 7 hours a day, 5 days a week. Following 9 weeks of brace wear, statistically significant improvements were found for all pain parameters, and these improvements continued at the 1-year evaluation.

Before brace wear, 78% had pain with activities of daily living, but after the first evaluation, only 39% continued to have similar pain, and at the second evaluation, only 31% were affected. Before brace wear, patients had a walking tolerance of 51 minutes before pain onset. At the first evaluation, patients could walk 138 minutes without pain, and after 1 year they could walk 107 minutes without pain. Before brace wear, 78% rated their overall knee condition as fair or poor, whereas at the first evaluation, only 33% continued to provide this rating. No differences were found in the dynamic gait parameters measured with and without the brace.<sup>11</sup>

Another study<sup>12</sup> examined the potential changes in adduction moment in OA patients who wore an unloading brace with a different three-point pressure-strap design. Adduction moment forces the knee into a more painful varus-thrust (lateral) position (see figures 3 and 4A). Scores from an analog pain scale decreased 48% with brace wear, and function with activities of daily living increased 79%. Mean adduction moment was 10% greater without the brace ( $4.0 \pm 0.8\%$  body weight times height versus  $3.6 \pm 0.8\%$  body weight times height) than with the brace. The mean adduction moment for control subjects was  $3.5 \pm 0.6\%$  body weight times

height. Thus, the mean adduction moment decreased from approximately one standard deviation from the normal mean to a value that was similar to the control value. Nine of 11 patients had a decrease in the adduction moment with the brace, 5 of 11 patients had a decrease greater than 10%, and some were as great as 32%. The study concluded that pain, function, and biomechanical knee loading can be altered by a brace designed to unload the medial compartment of the knee.

In a study<sup>13</sup> examining actual condylar separation while wearing the unloading brace, 12 of 15 subjects (80%) reported relief of pain and demonstrated condylar separation of the degenerative compartment. The remaining 3 patients were obese, which made accurate brace fitting difficult. The average change in condylar separation and condylar separation angle was 1.2 mm (range, 0.0 to 4.5 mm) and 2.2° (range, 0° to 7.8°), enough to provide symptomatic relief. This study demonstrated that off-loading braces can achieve condylar separation and subjective pain relief in patients who have degenerative knee problems.

**Quality of life and function.** In a prospective, parallel-group, randomized clinical trial,<sup>14</sup> patients who had OA with a varus deformity were evaluated for their ability to improve the disease-specific quality of life and for their functional status. The patients were stratified according to age (<50 yrs or >50 yrs), deformity (<5° varus or >5° varus), and the status of the anterior cruciate ligament (torn or intact). The patients were randomly assigned to one of three treatment groups: medical treatment only (control group), medical treatment and use of a neoprene sleeve, or medical treatment and use of a valgus unloading brace. The disease-specific quality of life was measured using the Western Ontario and McMaster University Osteoarthritis Index (WOMAC) and the McMaster-Toronto Arthritis Patient Preference Disability Questionnaire (MACTAR).

At the 6-month follow-up evaluation, the disease-specific quality of life and function in both the neoprene-sleeve group and the unloading-brace group were substantially improved compared with the control group. The unloading-brace group and the neoprene-sleeve group had a significant difference in pain after both a 6-minute walking test and the 30-second stair-climbing test. A strong trend was observed toward a significant difference between the unloading brace group and the neoprene sleeve group with regard to the change in the WOMAC aggregate ( $P = 0.062$ ) and WOMAC physical function scores ( $P = 0.081$ ).<sup>14</sup>

**Gait symmetry.** Improving gait symmetry in those who have OA is thought to help provide symptomatic relief. In a 3-month study,<sup>15</sup> OA patients who wore a valgus brace showed consistent and immediate improvement in symmetry indices at 0 and 3 months: 3.9% and 3.4% in the stance phase, and 11.8% and 9.6% in the swing phase of gait, respectively. All patients reported immediate symptomatic improvement, with less pain on walking. This finding was confirmed by a significant improvement at 3 months in the mean Hospital for Special Surgery knee rating score; it rose from 69.9 to 82.0.

A change in gait symmetry is likely associated with a reduced varus moment (see figure 4). Five subjects diagnosed as having medial compartment OA were fitted with a custom Monarch valgus unloading knee brace (Smith & Nephew DonJoy Inc, Carlsbad, California). A three-dimensional video-based motion analysis system and force plate information were used to calculate forces and moments at the knee during various percentages of stance. Wearing the Monarch brace significantly reduced the varus moment at 20% and 25% of stance.<sup>16</sup>

In another similar gait study by Pollo et al,<sup>17</sup> valgus bracing reduced the net varus moment at the knee by an average of 13% (7.1 N-m) and the medial compartment load at the knee by an average of 11% (114 N) in the calibrated 4° valgus brace setting.

## Proprioception

Part of the improvement in pain scores and gait parameters when wearing a valgus-producing brace may be caused by improved proprioception at the knee. In a study by Birmingham et al,<sup>18</sup> proprioception was assessed by the patients' ability to replicate target knee angles. Postural stability was also compared on solid and foam surfaces. All tests were performed with and without a custom-fit valgus brace on patients who had varus alignment and OA of the medial knee compartment. Proprioception was significantly improved following application of the brace (mean ability to replicate = 0.7°, 95% confidence interval = 0.2° to 1.1°). Postural control was not significantly affected by the use of the brace during the stable-surface test or the foam-surface test.<sup>18</sup>

## Potential Drawbacks to Bracing

The valgus-producing brace seems to work better in patients who have a lower body mass index (BMI).<sup>3</sup> Patients who have higher BMIs seem to have more difficulty with the brace, because it is harder for the clinician to adjust the brace to fit properly. Komistek et al<sup>13</sup> reported that 3 of 15 subjects had inadequate condylar separation as a result of inappropriate fitting related to patients' obesity.

Long-term compliance is another drawback to brace use. In one study,<sup>11</sup> half the patients no longer wore the brace after 1 year. Brace migration down the leg is often a complaint of patients, especially during exertion or after the patient sweats.

A three-point pressure-transfer system, whether it uses a crossover strap, struts, or a balloon, is required for an effective brace. However, the transfer of pressure to the distal tibia may create discomfort. With a brace that employs a three-point pressure system, the force from the knee is transferred to the thigh and tibia. The thigh is not a major problem, because it is well-cushioned, but the arm of the brace rests on the bony distal tibia and can push in and cause indentations or even abrasions on the skin that can cause discomfort.

## Bracing for the Future

Arthritis and obesity are likely to become more prevalent as our population ages; therefore, clinicians will see more patients who have varus deformities and knee pain. Nonsurgical management should be optimized prior to joint replacement surgery. Usually initiated by the primary care physician, current nonsurgical options include glucosamine, hyaluronic acid injections, exercise, weight loss if appropriate, and wearing of an unloading brace. These options may be used either individually or in some combination. The effectiveness of each intervention and various combinations are under investigation. The application of an unloading brace is the only knee OA management strategy that can redistribute dysfunctional mechanical forces immediately and potentially provide pain relief when fitted properly and used

consistently.

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