CLINICAL ORTHOPAEDICS AND RELATED RESEARCH
Number 408, pp. 209–217

Use of a Lateral Offset Short-Leg Walking Cast Before High Tibial Osteotomy

Brian J. Cole, MD, MBA,**; Kevin B. Freedman, MD, MSCE*,**; Sudeep Taksali, BS*,**; Brooke Hingtgen, BS**,†; Michelle DiMasi, MS*,**; Bernard R. Bach, Jr., MD*,**; and Debra E. Hurwitz, PhD***

The clinical results after high tibial osteotomy for the treatment of symptomatic varus gonarthrosis are unpredictable. Although preoperative gait analysis has been shown to be useful in predicting successful outcome after high tibial osteotomy, there are no readily available preoperative clinical tests for predicting success. The authors did a study to determine the effects of an offset short-leg walking cast as a potential predictor of clinical success after high tibial osteotomy. Specifically, the authors evaluated the effect of an offset short-leg walking cast on pain relief and changes in the peak external adduction moments in patients with symptomatic varus gonarthrosis indicated for high tibial osteotomy. Nineteen consecutive patients indicated for high tibial osteotomy were enrolled and completed the study. All patients had precast gait analysis to determine baseline parameters. Immediately after gait analysis, a short-leg lateral offset walking cast was applied and worn for 3 days to allow time for adaptation. Gait analysis then was repeated. Western Ontario and McMaster Universities Osteoarthritis Index pain scores were obtained before and after the cast was applied. The cast resulted in a mean reduction in pain of 53%, and a mean reduction in the peak external adduction moment of 36% in the 17 of 19 patients who tolerated the cast. The reduction in pain was correlated with the reduction in the peak adduction moment (r = 0.63). The authors conclude that an offset short-leg walking cast results in pain reduction that correlates with changes in external adduction moments about the knee. Therefore, an offset short-leg walking cast may prove to be an effective tool for predicting patients who ultimately will benefit from valgus high tibial osteotomy.

From the *Division of Sports Medicine and the **Department of Orthopaedic Surgery, Rush Medical College, Rush-Presbyterian-St. Luke's Medical Center, Chicago, IL; and the †Department of Biomedical Engineering, University of Iowa, Iowa City, IA.

Funding for this study was received from the National Institutes of Health Special Center of Research in Osteoarthritis grant AR39329.

Reprint requests to Brian J. Cole, MD, MBA, Department of Orthopaedic Surgery, Rush-Presbyterian-St. Luke's Medical Center, 1725 W. Harrison St., Suite 1063, Chicago IL, 60612. Phone: 312–243-4244; Fax: 312–942-1517; E-mail: bcole@ortho4.pro.rpslmc.edu.

Received: November 15, 2001.
Revised: April 25, 2002.
Accepted: June 21, 2002.
DOI: 10.1097/01.blo.0000049087.70448.16

Osteoarthritis is the most common condition affecting synovial joints, and the knee is the most commonly affected weightbearing joint.[47] High tibial osteotomy has long been recognized as beneficial for the treatment of medial compartment osteoarthritis and varus deformity of the knee.[10,11] Many reports show a satisfactory result in approximately 80% of patients at 5 years, and 60% of patients at 10 years after high tibial osteotomy. However, the clinical success rates of high tibial osteotomy at 5 years or greater have ranged from 43% to 88%.[9–13,21,22,31,34,37,39] Given the unpredictable clinical results, attempts have been made to identify patients most likely to have a successful outcome from realignment osteotomy.

Varus angulation at the knee has been associated with increased loading of the medial compartment and the progression of degenerative joint disease.[25,30,43] The rationale for high tibial osteotomy is that realignment of the joint and correction of the varus deformity can decrease the stress in the medial compartment of the knee.[30,33] The amount of static varus deformity in the symptomatic knee, however, does not necessarily correlate with force distribution in the joint.[18,23] Gait analysis allows dynamic assessment of knee loading, and the adduction moment of the knee is considered to be the most influential factor for determining the load distribution between the medial and lateral compartments.[2,17,36,46] Higher adduction moments are indicative of higher loads on the medial compartment relative to the lateral compartment. Furthermore, the distribution of bone between the medial and lateral compartments of the knee has been correlated with the peak external adduction moment in healthy subjects and patients with knee osteoarthritis.[20,45] Previous studies using gait analysis have shown that the magnitude of the external adduction moment at the knee during walking in the symptomatic varus knee is related to postoperative clinical results after high tibial osteotomy.[36] Specifically, patients with low adduction moments preoperatively had superior long-term clinical results when compared with patients with high adduction moments measured preoperatively.[36,46] However, gait analysis is an expensive test that is not readily available in all medical settings. With these factors in mind, the need for a more readily available, inexpensive, and predictable prognostic tool for outcome after high tibial osteotomy is indicated.

Krackow and Galloway[28] proposed a potential preoperative technique for predicting success after valgus osteotomy with the use of an offset short-leg walking cast. In the patient with varus gonarthrosis, a cast with a laterally-placed wedge serves to immobilize the subtalar joint and ankle and alter the heel contact point in such a manner to model the effect of a high tibial osteotomy (Fig 1). Theoretically,

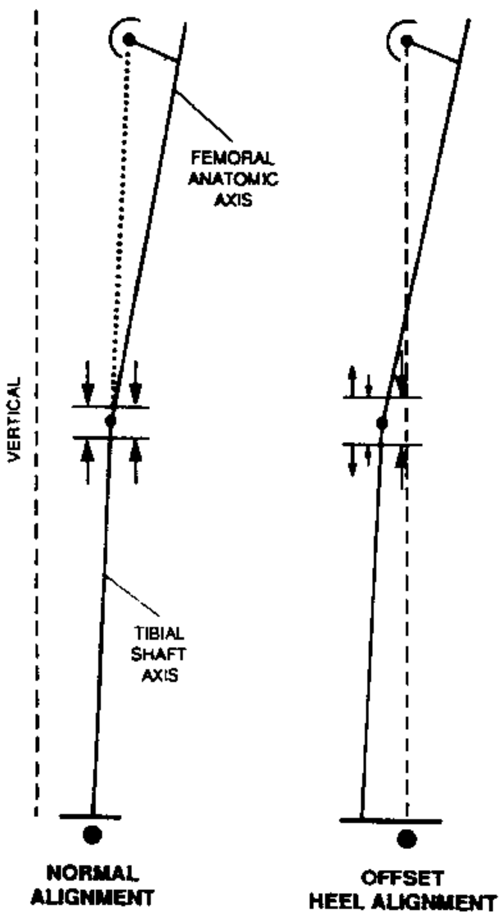

Fig 1. A schematic of a short-leg lateral offset cast shows the relative change in contact position with the lateral offset cast, and the associated change in alignment. The lateral point of contact at the heel shifts the weight from the medial to lateral compartment. Reprinted with permission from Krackow RD, Galloway E: A pre-operative technique for predicting success after varus or valgus osteotomy of the knee. Am J Knee Surg 2:164–170, 1989.

the cast could be used as a preoperative tool to predict postoperative success after a high tibial osteotomy. Five of the eight patients in the study of Krackow and Galloway considered to be candidates for high tibial osteotomy reported that the pain in their knees was gone or significantly decreased after application of the cast.[28] The other three patients did not experience a significant reduction in pain, and therefore high tibial osteotomy was not recommended in that study. The study by Krackow and Galloway did not evaluate whether the cast resulted in similar alterations to the dynamic knee loads (reduction in external adduction moment) as seen after high tibial osteotomy or, more importantly, whether the change in the adduction moment was predictive of pain relief.

The purpose of the current prospective study was to explore the potential use of the offset short-leg walking cast as a preoperative tool to predict postoperative high tibial osteotomy success. This study tested: (1) if significant reductions in pain scores occur with the use of the offset short-leg walking cast; (2) if significant reductions in adduction moment are achieved with the use of the offset short-leg walking cast; and (3) if the reduction in pain correlates with the reduction in adduction moment in individuals who wear a cast. This basic science study then could serve as the basis of a clinical study using an offset short-leg walking cast to predict postoperative success with high tibial osteotomy.

MATERIALS AND METHODS

Nineteen patients indicated for high tibial osteotomy because of symptomatic varus gonarthritis of the knee were enrolled in the study from January 1998 to August 2000. These patients were recruited from an outpatient orthopaedic clinic of the senior author (BJC). Patient inclusion criteria consisted of patients with symptomatic osteoarthritis limited to the medial compartment as determined principally by long-cassette anteroposterior (AP) mechanical axis and posteroanterior flexion weightbearing radiographs taken with the patient standing.[38] Additional criteria were the presence of appropriate indications for high tibial osteotomy including: a symptomatic varus deformity ($< 15°$); relative youth or active lifestyle; unicompartmental medial arthrosis; absence of joint line subluxation; and preserved range of motion (ROM) ($< 15°$ flexion contracture; $> 90°$ flexion). Exclusion criteria included lateral compartment arthrosis and morbid obesity (defined by body mass index > 25).

Testing Protocol

The testing protocol was approved by the institutional review board at the author's institution. After completing the appropriate clinical and radiographic evaluations and being indicated for high tibial osteotomy, informed consent was obtained before patient enrollment.

For each patient enrolled, the study was done over 4 days. On Day 1, patients completed the Western Ontario and McMaster Universities Osteoarthritis Index questionnaire, completed gait analysis, and were fitted with the offset short-leg walking cast. Patients were instructed to ambulate as tolerated on the cast for 3 days and return on Day 4. At the Day 4 visit, the Western Ontario and McMaster Universities Osteoarthritis Index pain questionnaire was completed and gait analysis was done with the cast on the affected leg. The cast then was removed. The 4-day interval was selected to optimize patient adaptation to the cast while minimizing potential discomfort from extended cast wear.

Radiographic Analysis

Posteroanterior flexion weightbearing, 45° flexion lateral and axial patella radiographs taken with the patient standing were obtained for each subject to determine the extent and location of joint space narrowing and arthrosis. Long-leg radiographs determined the anatomic and mechanical axis of the lower extremity, including the hip, knee, and ankle. The femoral mechanical axis was measured from the center of the hip to the center of the ankle; the tibial mechanical axis was measured from the knee's center to the ankle's center. Angular alignment was defined as the angle of the intersection of the femoral mechanical axis and the tibial mechanical axis (neutral, 0° varus, $> 0°$; valgus, $< 0°$).

Offset Short-Leg Walking Cast

The short-leg cast was applied using a standard casting technique. Materials included one 3-inch stockinet placed from the toes to just distal to the popliteal fossa, four rolls of 4-inch webroll (Johnson & Johnson, New Brunswick, NJ), three rolls of

5-inch and one roll of 3-inch fiberglass casting tape (Johnson & Johnson), and two strips of Reston (3M Health Care, St Paul, MN). With the patient in the seated position at the edge of an examination table, the foot was maintained in a neutral position. The stockinet was placed and incised over the ankle to eliminate wrinkles in the material. The webroll was applied from distal to proximal overlapping each wrap by approximately 50%. A strip of Reston was placed on the plantar aspect of the foot incorporating the proximal heel and another placed longitudinally on the dorsal aspect of the foot and ankle for additional padding. The three rolls of 5-inch fiberglass were placed from the distal end of the metatarsal heads to the tibial tuberosity proximally leaving approximately 1 inch of webroll and 2 inches of stockinet exposed at each end.

The offset wedge was applied using a block of wood that measured 4 cm in width, 9 cm in length, and 2 cm in thickness. The wedge was applied to the lateral aspect of the cast extending from the midfoot to the heel. The wedge was fixed to the cast using the 3-inch fiberglass roll with care taken to keep the wedge flush with the plantar aspect of the cast. Moleskin adhesive tape was applied to the plantar aspect of the cast to provide traction as patients ambulated directly on the cast (Fig 2). For comfort and hygiene, a toe cover and shower bag was provided to the patient. Patients were instructed to perform activities of daily living and to ambulate as tolerated without the use of ambulatory assistance devices. Generally, patients adapted to the presence of the cast without a significant limp within 2 hours of cast placement.

Fig 2. A short-leg lateral offset cast is shown.

This technique differed from the original technique described by Krackow and Galloway.[28] They only used fiberglass to construct the offset wedge with unspecified dimensions. The use of a standard piece of wood and 3-inch fiberglass roll offered the advantages of ease of application, standardization between patients, and easy reproducibility. On the day of gait testing, a hole was cut into the cast at the lateral malleolus and fifth metatarsal for application of reflective markers required for gait analysis.

Gait Analysis

The patients were tested immediately before the application of the cast, and after 3 days of cast wear to allow for adaptation during gait. Gait analysis was done at the author's institution using protocols and methods previously described in detail.[36,46] Gait data were collected at midstride on a 10-m walkway. Four trials at each of three self-selected speeds of slow, normal, and fast (12 stride-cycles per patient) were obtained. For the analysis, a representative trial at approximately 1 m/second was chosen for each patient during testing without and with the cast (1.07 $\pm$ 0.13 m/second and 1.06 $\pm$ 0.16 m/second, respectively).

The instrumentation included an optoelectronic system with a passive retroreflective marker system (Computerized Functional Testing Corporation, Chicago, IL) and a multicomponent force plate (Bertec, Columbus, OH). Markers were placed at five locations on the lower extremity including: the lateral aspect of the superior most iliac crest, center of greater trochanter, lateral joint line of the knee, lateral malleolus of the ankle, and the head of the fifth metatarsal. The external moments about the joint centers then were calculated using inverse dynamics and a link model.[3] The lower extremity was modeled as three rigid links with no axial rotation about the long axis of the segment. The inertia properties were lumped at the mass center of each segment. Moments were expressed as a percentage of the patient's body weight and height (% body weight $\times$ height). The external knee moments were resolved about a local coordinate system that was aligned with the shank.

The primary gait parameter of interest for the current study was the peak external adduction moment at the knee during the gait cycle. The peak adduction moment was measured by gait analysis before and with cast wear after at least 72 hours of cast adaptation.

Measurement of Pain

Self-reports of pain were recorded using the pain section of the Western Ontario and McMaster Universities Osteoarthritis Index.[4–7,32] The Western Ontario and McMaster Universities Osteoarthritis Index is a multidimensional self-administered health status assessment that uses a visual analog scale for assessment of hip and knee pain resulting from osteoarthritis. It has been validated in randomized clinical trials of nonsteroidal antiinflammatory drugs and has been shown to be the most responsive tool in trials for operations for osteoarthritis of the knee and hip.[4–7,32] The Western Ontario and McMaster Universities Osteoarthritis Index tests across three domains; pain, stiffness, and physical function. The score can be reported as a score for an individual domain or as an aggregate for all three domains. In the current study, the authors chose to focus on the pain domain because it was thought to be the most responsive to cast wear and the most clinically useful for prognostic value. The pain domain assesses pain at night and pain associated with walking, climbing stairs, standing, and sitting. The 4-day course was not thought to be a sufficient interval to assess a change in physical function and stiffness.

Data Analysis

Each question in the Western Ontario and McMaster Universities Osteoarthritis Index pain domain was represented by a 100-mm visual analog scale, ranging from 0 (no pain) to 100 (the most severe pain). For the pain domain (five questions), the maximum score was 500. Western Ontario and McMaster Universities Osteoarthritis Index scores were tabulated and descriptive statistics were calculated (means and standard deviations) for patients immediately before the cast was applied and after 3 days of cast wear. Total change and percentage of change in pain were calculated. A paired, two-tailed, Student's t test was used to test for a significant change in pain after cast wear.

Total change and percentage of change in the peak adduction moment were calculated. A paired, two-tailed, Student's t test was used to test for a significant change in adduction moment after cast wear. Pearson correlation analysis also was done to test for a significant relationship between percentage change in pain with the percentage change in adduction moment after cast wear. Statistical significance was defined at a level of alpha < 0.05.

RESULTS

Seventeen men and two women with a mean age of 50 ± 7 years (range, 34–61 years) were enrolled in the study. Patients had mean preoperative varus angulation of 9° (standard deviation +/− 3°) by mechanical axis measurements. Clinically, patients had a mean ROM in extension of 1° (range, 0°–8°) and in flexion 132° (range, 120°–140°). On average, patients were symptomatic for 53 months (range, 7–132 months) before being indicated for high tibial osteotomy.

Two of the patients withdrew from the study before the pain and gait evaluations were completed after cast application because they were unable to tolerate the cast. All subsequent data analyses therefore were done on the remaining 17 patients.

Effect of Casting on Pain

For the 17 patients completing the entire protocol, the average Western Ontario and McMaster Universities Osteoarthritis Index pain score before wearing the cast was 219 (standard deviation +/− 84). When the cast was worn, the average pain score was 96 (standard deviation +/− 78) (Fig 3). When the cast was worn, the pain was reduced significantly by a mean of 53% ± 36% (range, 35%–100%) ($p < 0.001$). After wearing the cast for 3 days, all but three patients who completed the protocol had a clinically significant improvement in pain, as evidenced by at least a 20% reduction in pain, a criteria established by the Osteoarthritis Research Society International's Response Criteria Initiative.[15]

Effect of Casting on Adduction Moment

The peak external adduction moment was reduced significantly while wearing the cast by 36% ± 25% ($p < 0.001$) (Fig 3). Moreover, the change in pain was correlated significantly with the change in the peak adduction moment ($r = 0.63$; $p = 0.007$) (Fig 4). The patients

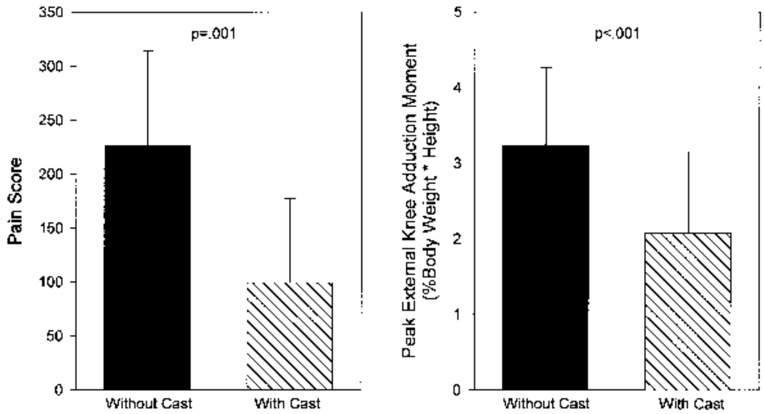

Fig 3. The change in pain score and peak adduction moment with the use of a short-leg offset walking cast is shown.

with the greatest reductions in pain were the patients with the greatest reductions in the adduction moment. Although the change in the adduction moment was a significant predictor of the change in pain, the adduction moment before the cast was applied was not predictive of the subsequent clinical response to the cast ($p = 0.596$), nor was the pain score before the cast was applied ($p = 0.357$).

DISCUSSION

The current study showed that a lateral offset short-leg walking cast leads to a reduction in

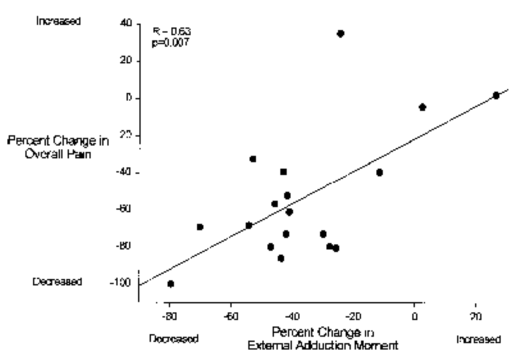

Fig 4. The correlation of percent change in pain with the percent change in peak adduction moment using a short-leg lateral offset cast is shown.

adduction moment, which correlates with a reduction in pain in patients with varus gonarthrosis. The knee adduction moment is a major determinant of the load distribution between the medial and lateral tibial plateau.[2,41] In addition, knee adduction moment has been shown to correlate with the severity of medial compartment osteoarthritis.[19,42] Therefore, mechanically-induced reductions in the peak adduction moment, which are associated with reduced loads on the medial compartment of the knee, are associated with reductions in pain in varus gonarthrosis.

High tibial osteotomy has been shown to be successful for the treatment of varus gonarthrosis at 5 and 10 years postoperatively.[9–13,21,22,31,34,37,39] However, the clinical results of high tibial osteotomy have not been consistent, and attempts have been made to identify patients who are less likely to have long-term relief from the procedure. Several preoperative risk factors have been associated with poorer results, including varus deformity greater than 10°, ligament instability, lateral tibial thrust, preoperative flexion arc, and relative body weight.[1,8,31,48] In addition, gait analysis has been done to examine the dynamic contribution of knee loading to postoperative outcome. Gait analysis has been shown to be indicative of the results of high tibial osteotomy. Patients with high adduction moments preoperatively have been shown to have worse clinical results after high tibial osteotomy than patients with low adduction moments.[36,46] However, the ability to do preoperative gait analysis on patients before high tibial osteotomy is limited. In addition, the prognostic value of gait analysis may be variable, because patients may have similar clinical results regardless of their adduction moments if sufficient valgus overcorrection is obtained.[44] Therefore, an easier, more available technique would be beneficial for predicting the postoperative success after high tibial osteotomy. A lateral offset short-leg walking cast may prove to be predictive of postoperative success after high tibial osteotomy. The current study provides the basic science background behind the use of preoperative use of a lateral offset short-leg walking cast, by showing that the cast can provide a reduction in pain in patients with varus gonarthrosis, and this reduction in pain is correlated with a reduction in the adduction moment. In addition, the cast was applied easily and consistently in the office, and was well-tolerated by approximately 90% of the patients.

The current study showed that a lateral offset short-leg walking cast creates an objective change in the dynamic loading of the knee. The cast serves to change the contact position of the foot, which without additional compensations during walking results in the ground reaction force vector being closer to the knee center in the frontal plane. The significant reduction in the peak adduction moment measured by gait analysis in this study serves as evidence that the cast is creating the anticipated result. Therefore the short-leg cast lowered the adduction moment, just as a high tibial osteotomy results in a lower adduction moment. Changes in other gait parameters from the cast were not examined, as in all likelihood changes in these parameters are unlikely to occur after a high tibial osteotomy. The additional changes may result from the fact that the ankle motion is restricted in the cast.

It is anticipated that the pain relief from the reduction in the adduction moment attributable to the cast will correlate with the pain relief from realignment osteotomy. Therefore, a lateral offset short-leg walking cast may predict patients who can expect significant pain relief from a high tibial osteotomy. The final clinical result of realignment osteotomy depends on various factors, including careful patient selection and surgical technique.

The concept from this study that reduced knee pain results from a mechanically induced reduction in the adduction moment is consistent with the mechanisms of other conservative treatments for knee osteoarthritis. These conservative treatments for medial compartment osteoarthritis include the use of valgus bracing and a lateral heel wedge. The purpose of both of these devices is to unload the degenerative medial compartment by reducing the external knee adduction moment during gait. Several studies have shown that the use of a valgus unloading brace or lateral heel wedges can lead to improvements in pain in patients with osteoarthritis of the knee.[16,24,26,27,29,35,40,49] Gait studies have supported that knee loading can be altered by a brace, which acts to unload the medial compartment by decreasing the adduction moment.[29] In a similar manner it has been shown that a lateral heel wedge also reduces the adduction moment during gait.[14] Given the similarity, in theory, between a lateral heel wedge and a lateral offset short-leg walking cast, the current study also provides an additional rationale for future studies examining the effect of lateral heel wedges on adduction moment and pain relief and disease progression in patients with medial compartment knee osteoarthritis.

The ultimate ability of a lateral offset short-leg walking cast to be used as a clinical predictor of success after high tibial osteotomy only can be determined by a clinical study. A properly-designed study would require the use of the cast on patients already indicated for high tibial osteotomy. Regardless of the benefit of the cast, all patients in the study then would have a high tibial osteotomy. The pain relief achieved with lateral offset casting then could be correlated to ultimate pain relief and long-term survival from the realignment procedure.

The current study provides the basic science behind a well-designed clinical study, by showing that lateral offset short-leg casting results in a reduction in pain that correlates to a reduction in adduction moment in patients with varus gonarthrosis indicated for high tibial osteotomy.

Acknowledgments

The authors thank Novisa Petrusich for contributions to the modification of the short-leg walking cast, Thomas Andriacchi, PhD, for initial input on the study, and Rohita Shah and Jennifer West for collecting, processing, and organizing the data for the current study.

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