Techniques in Knee Surgery 7(3):172–177, 2008

A Simplified Technique for High Tibial Osteotomy With Early Radiographic Follow-up Results

MAJ Michael S. Todd, MD
Orthopaedic Surgery Service
William Beaumont Army Medical Center
Fort Hood, Texas, U.S.A.

MAJ Steve J. Lalliss, MD
Orthopaedic Surgery Service
Carl L. Darnall Army Medical Center
Fort Hood, Texas, U.S.A.

COL Thomas M. DeBerardino, MD
John A. Feagin, Jr, Sports Medicine Fellowship
Keller Army Hospital
West Point, New York, U.S.A.

ABSTRACT

A technique for measuring the desired angular correction and plate selection for an opening-wedge high tibial osteotomy has been developed by the lead author using a modification of a technique described in the literature by Miniaci et al. Using the preoperatively measured desired angular correction to accurately determine the appropriate plate selection is unique to our system and is necessary to avoid correction especially in the face of a patient whose tibia plateau width is greater than 60 mm. This technique also limits radiation exposure by eliminating intraoperative measurement that is highly inaccurate. Although described for a high tibial osteotomy in conjunction with a medial meniscus transplant or osteochondral transfer, the technique can be effectively used for terminal procedures.
Keywords: high tibial osteotomy, tibial slope, angular correction, alignment, osteotomy

High tibial osteotomy (HTO) is a common procedure for treatment of symptomatic medial compartment arthrosis associated with varus malalignment.[1–7] An HTO is also indicated in varus angulated knees when performing meniscal transplantation or cartilage restoration procedures (osteochondral transplants, autologous chondrocyte implantation) either concomitantly or staged.[6,8–10] Various authors, such as Noyes, Dugdale, Fugisawa, and Coventry, have established corrective goals for patients with medial compartment arthrosis that shifts the weight-bearing line (WBL) through the lateral compartment.[1–7] However, the amount of correction for a patient undergoing HTO for medial meniscus transplantation or cartilage restoration has not been definitively established.[6,8,9] It has been recommended that the WBL be placed within the tibial spines and approach neutral mechanical alignment.[6]

The primary goal of this paper is to present the HTO preoperative templating and operative technique that are used at our institution for the treatment of varus malalignment when associated with medial meniscus allograft transplantation (MMAT) or osteochondral transplantation. The operative technique focuses on preoperative templating for angular correction and its relationship to accurate plate selection. No intraoperative, fluoroscopically guided mechanical axis with an alignment rod or Bovie cord is felt to be necessary. The goal of correction was to have the WBL pass through the center of knee but not greater than through the lateral tibial eminence unless a terminal procedure is deemed necessary after arthroscopy. It was not the intention of this study to report the subjective and functional outcomes of the patients.

Address correspondence and reprint requests to COL Thomas M. DeBerardino, MC, USA, Keller Army Community Hospital, 900 Washington Rd, West Point, NY 10996. E-mail: thomas.deberardino@na.amedd.army.mil.

None of the authors have commercial associations that may pose a conflict of interest for this unsolicited paper.

MATERIALS AND METHODS

This study was approved by our Institutional Review Board.

Subjects

All HTOs performed by one of the authors (T.M.D.) were identified through the use of a surgical log. The inclusion criteria included either staged or concomitant MMAT and/or osteochondral transfer (fresh osteochondral allograft or autologous) and preoperative and postoperative full-length radiographs. A total of 10 candidates met the inclusion criteria.

The mean age of the patients was 28.6 years (range, 23–42 years). Seven patients had staged procedures, 1 of which was still waiting for a MMAT at the time of this report. Six patients had a MMAT and 4 had an osteochondral transplant procedure to the medial femoral condyle. One patient had an autologous case, and the remainders were fresh osteochondral allografts. One patient underwent a revision anterior cruciate ligament reconstruction at the time of his medial meniscus transplantation.

Radiographs

All patients in this study had standardized preoperative radiographs including the following: 1) 4-view weight bearing—anteroposterior (AP), lateral, notch, and sunrise; 2) bilateral weight bearing Rosenberg (45-degree AP); 3) bilateral weight bearing full-length hip-to-ankle radiographs.

The technique used to determine the angle of correction needed for the HTO is a modification of the

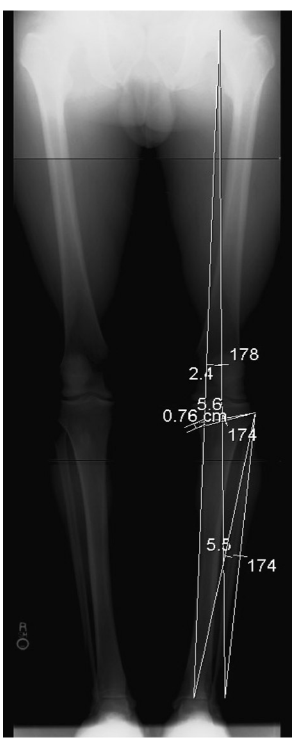

FIGURE 1. A detailed radiograph using the modified technique of Miniaci et al[5] for angular correction including plate determination.

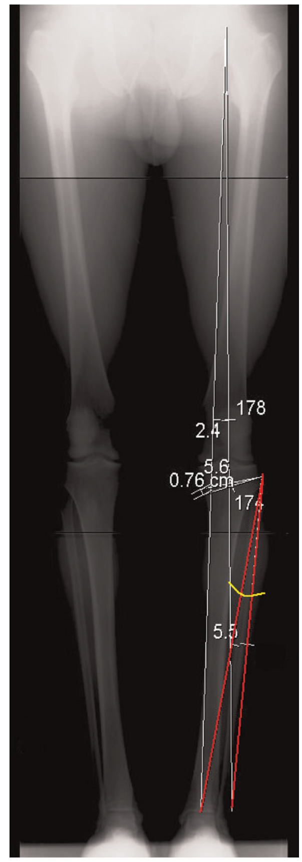

FIGURE 2. The desired angular correction, 5.5 degrees in this case, using the technique of Miniaci et al is highlighted in red and centered at the rotation axis of our osteotomy.

technique described by Miniaci et al.[5] The technique was originally described for closing-wedge osteotomies but is easily transferable to an opening-wedge technique.[11] All radiographs were evaluated using the Impax system (AGFA, Ridgefield Park, NJ) and the computers digital software measurement package. Using a digital bilateral weight bearing hip-to-ankle radiograph, the mechanical axis is determined by taking a line from the center of the femoral head to the center of the talar dome (Fig. 1). The desired weight-bearing axis is then constructed by passing a line from the center of the femoral head through the desired central weight-bearing area of the knee to the ankle (Fig. 1). In the case of a varus deformity, the desired weight-bearing axis line will pass lateral to the ankle joint. Two line segments are then generated from the pivot point on the lateral tibial cortex (just proximal to the proximal tibiofibular joint) at the desired apex of the osteotomy to both the preoperative mechanical axis and the desired postoperative axis (Figs. 1 and 2). The angle formed by these 2 segments, as measured digitally, equates to the desired angular correction to achieve the new weight-bearing axis. Using the angle creation tool provided

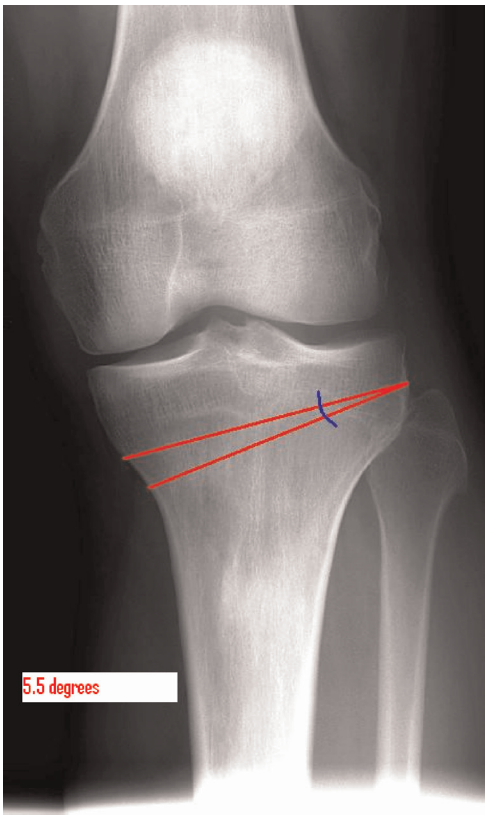

FIGURE 3. Desired angular correction is reproduced from the osteotomy rotational axis point and extended to the medial tibial cortex, that is, osteotomy start site.

within our system's software package, the angle is then reproduced from the osteotomy rotational axis point and extended to the osteotomy starting point on the medial tibial cortex staying above the tibial tubercle shadow (Fig. 3). Most importantly, the distance measured between the segments of the angular correction at the medial tibial cortex is equal to the size of the plate to be used intraoperatively to achieve the desired weight-bearing axis (Fig. 4). At our institution, measured radiographic magnification is approximately 4%. Owing to the small amount of change this magnification equates to, no adjustment is necessary for our calculations. However, each institution should evaluate its own system's capabilities.

Operative Technique

The patient is placed supine on the operating table. An examination under anesthesia is performed and documented. A thigh tourniquet is applied but not routinely used for any portion of the procedure. The operating table is flexed to 90 degrees. The operative leg is then allowed to hang free with a small bump under the distal end of the bed to elevate the thigh to approximately 15 degrees.

A 5-cm incision is made midway between the tibial tubercle and the posteriomedial cortex. Dissection is carried laterally to the tibial tubercle allowing for visualization of medial edge of the patellar tendon. The sartorial fascia is then incised horizontally, and hamstrings are retracted distally. The superficial medial collateral ligament is then incised and gently elevated distally and posteriomedially. A radiolucent soft tissue protector is then gently placed posteriorly, staying on bone, to protect the neurovascular bundle. The radiolucent guide (Arthrex Inc, Naples, Fla) also acts as a positioning guide for the osteotomy. The guide is angled so that the osteotomy will be approximately 1 to 2 cm distal to the lateral tibial plateau, just superior to the proximal tibiofibular joint. A soft retractor is placed under the patellar tendon as well. A portable fluoroscan is positioned to achieve a true AP of the posterior slope of the tibial plateau. The true lateral of the saw blade is aligned with the AP tibial slope, and a single-cut osteotomy is performed approximately 9/10 of the distance to the lateral cortex. Completion of the osteotomy is confirmed with C-arm visualization.

The osteotomy site is then gently opened using calibrated wedges from the Arthrex Opening Wedge Osteotomy System (Arthrex Inc) until the templated correction size had been achieved. This is done over several minutes to allow stress relaxation and prevent fracture migration to the lateral cortex or superiorly into the lateral tibial plateau. A trapezoidal wedge locking Puddu plate (Arthrex Inc) is then fixed with 4-mm locking cortical screws distally and 6.5-mm locking cancellous

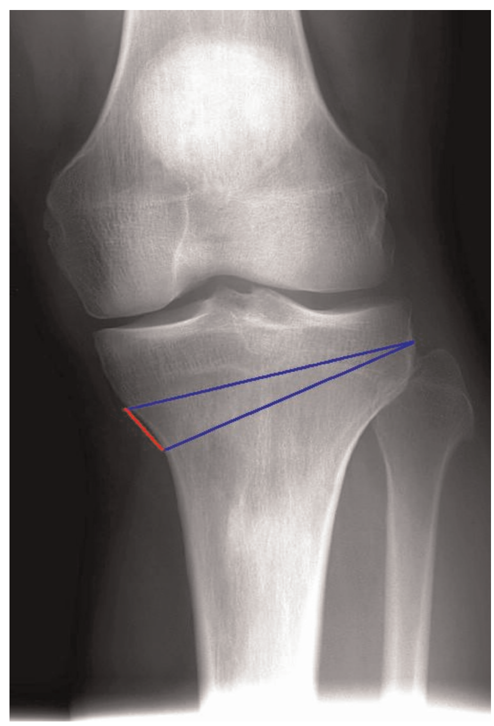

FIGURE 4. The distance between the angular line segments is measured. Critical—this distance is equivalent to the size of the fixation plate to achieve the desired correction and the new weight-bearing axis.

TABLE 1. *Preoperative and Postoperative Radiographic Measurements*

Patient No.	Goal, degrees	Final, degrees	Plate size, mm	Goal WBA, mm	Corrected WBA, mm	Plateau width, %	Preslope	Postslope
1	6.3	5.4	9	49	45.6	51	17.1	15
2	9	8.6	9	42	44	55	9.1	6.2
3*	4.8	10.3	7.5	41	70	NR	10.5	9.5
4	5.5	5.5	7.5	44	43	48	6.8	5.2
5†	10.6	8.6	10	46	42	50	7.9	8.2
6‡	4.1	7.6	7.5	42.5	52.5	70	8.6	11.4
7†	10.9	7.2	12.5	43	40	46	10.1	10
8	8.2	8.2	10	52	53	58	8.9	6
9	4.8	4.8	9	51	49	56	13.7	12
10	5.7	5.7	7.5	41	41	55	6.8	7.5

*Patient had flexion contracture during weight bearing long views.
†Patients 5 and 7 had plates downsized owing to the availability and concerns of shear stress.
‡Patient 6 converted to terminal procedure upon diagnostic arthroscopy.
NR indicates not recorded.

screws proximally. The plate position is placed centrally in the sagittal plane unless it is determined that the tibial slope needs to be modified because it relates to associated ligamentous injury or deficiencies (eg, posterior cruciate ligament) as described by Noyes et al.[6,7] In cases of meniscal allograft transplantation, the hemiplateau that accompanies the meniscus is used to form matched wedges for the osteotomy void both anteriorly and posteriorly. Cancellous chips are combined with DBX paste (Synthes USA, Westchester, Pa) and placed to fill any remaining defect. C-arm is used to confirm placement of our bone wedges. No mechanical axis or WBL is evaluated intraoperatively in any fashion (radiolucent rod, Bovie cord, etc) because correction is based solely on preoperative templating plate selection.

Discretion can be used if a plate is felt to provide too large of a correction. This is evident in a few of our procedures owing to concerns by the treating surgeon (T.M.D.) that the correction was too large and risked increased shear forces across the osteotomy site. The plate was downsized in 2 patients (patients 5 and 7) from 15-mm plates to 12.5-mm plates. Patient 5 required further downsizing owing to plate availability. Patient 6 was corrected to a WBL passing through the center of the knee (50%), and patient 8 was corrected to a WBL lateral to the medial tibial eminence but short of neutral alignment (Table 1).

RESULTS

Degree of Correction

The goal of our operative technique was to place the WBL through the lateral tibial eminence. We will accept neutral alignment or 50% of the tibial plateau width[3,6,7] (Table 1).

The mean angle of correction needed for our population was 6.9 degrees (SD, 2.5; range, 4.1–10.9 degrees) based on the modified technique of Miniaci et al. The mean plate size needed was 9.7 mm (SD, 3.6; range, 6.5–15.7 mm). Note that these are the radiographic plate sizes, not the actual plate used. The calculated plate was rounded to the closet actual plate available in the system (Table 1). The mean angle of postoperative correction was 7.03 degrees (SD, 2.02; range, 3.8–10.3 degrees).

Five of 10 patients achieved the preoperatively templated weight bearing axis (WBA). Patient 1 was only 1 degree short of the new WBA and fell well within tibial spines for a neutral mechanical axis. Patient 3 sustained a flexion contracture postoperatively, and we feel this skewed the postoperative weight bearing radiographs. Patient 6 was converted to a terminal procedure after diagnostic arthroscopy with the new WBA being at the base of the lateral tibial eminence.

The plate was downsized in 2 patients (patients 5 and 7) from 15-mm plates to 12.5-mm plates. Patient 5 required further downsizing owing to plate availability. Patient 5 was corrected to a WBL passing through the center of the knee (50%). Patient 8 was corrected to a WBL lateral to the medial tibial eminence but short of neutral alignment (Table 1) owing to previously mentioned concerns by the treating surgeon (T.M.D.) of increased shear across the osteotomy site with a 15-mm plate.

Tibial Slope

The preoperative and postoperative tibial slopes were measured using the radiographic technique described by Dejour and Bonnin.[12] The mean preoperative tibial slope was 9.95 degrees (SD, 3.2; range, 6.8–17.1 degrees). The mean postoperative tibial slope was 9.1 degrees (SD, 3.1; range, 5.2–15 degrees). The preoperative and postoperative tibial slopes are presented in Table 1.

Reproducibility

The correlation between surgeons was 0.98 for preoperative templating for angular correction using the modified Miniaci technique. The correlation between surgeons for radiographic plate determination was 0.97. The postoperative correlation for angular correction between 2 of the authors (M.S.T. and S.L.) was 0.94. These results indicate a high degree of reproducibility among users allowing for consistency for the technique.

DISCUSSION

The primary goal of this paper was to present the HTO preoperative templating and operative technique that are used at our institution for the treatment of varus malalignment when associated with MMAT or osteochondral autograft transfer system (OATS). Our operative technique relies on preoperative templating for angular correction measurement and its critical association with appropriate plate selection to achieve the new weight-bearing axis. Six of 10 patients from this small cohort achieved or nearly achieved the new weight-bearing axis using our technique. Two patients, one of which was patient 5, were intentionally undersized by 2 plate sizes, and we still achieved an acceptable neutral mechanical axis postoperatively. The idea that for every 1 degree of correction needed equates to 1 mm of plate selection does not ring true. Each patient must be individualized, otherwise undercorrection will occur. We are aware of no other study in which the preoperative angular measurement of correction is used to determine the appropriate plate size that is essential to an accurate postoperative weight-bearing axis. The technique is relatively simple, transferable between surgeons, and reproducible. The limited use of fluoroscopy is also advantageous and eliminates the need for protective lead when a large fluoroscopy unit is used. By establishing the plate selection preoperatively, the surgeon is able to limit the operative time, identify instrumentation availability, and eliminate obvious variability associated with intraoperative attempts at alignment measurement. Although it is our feeling that neither a large fluoroscopy unit nor an intraoperative mechanical axis determination is needed, it is the treating surgeon's preference should they decide to use them.

We are aware of the concern about changing the tibial slope and its effects on ligamentous stability and contact pressures.[6–8,12–14] Dejour and Bonnin[12] reported that the anterior cruciate ligament load increased when the posterior tibial slope was greater than 10 degrees. We attempt to place the plate in a central position consistent with the recommendations of Noyes et al[6,7] to maintain our preoperative posterior tibial slope, unless otherwise indicated. Our technique of placing the saw blade parallel to the tibial plateau before osteotomy achieved posterior tibial slope results similarly to those described by Noyes et al.[6]

The determination of where to place the WBL is still rather arbitrary and a relative weakness of this report. The purpose of an osteotomy is to offload an area of early arthrosis thereby decreasing contact pressures on the cartilage. van Arkel and de Boer[15] attributed 3 of their graft failures to an uncorrected weight-bearing axis.[16] Cameron and Saha[17] compared the results of meniscal transplant with and without osteotomy. They had equivalent results between the groups.

Verdonk et al[18] reported on 39 medial meniscus allografts in which 13 were combined with an osteotomy and found that those patients who underwent both procedures had less graft failures and longer survival time. The study notes, however, that there is no clear indication to perform an osteotomy in patients with normal weight-bearing axis but an osteotomy should be performed for patients with varus malalignment.[18]

The degree of correction is obviously different for a patient with medial compartment arthrosis versus a patient with an osteochondral defect or absent medial meniscus. Generally speaking, most candidates for meniscal transplantation or osteochondral transfer have a relatively normal compartment that is at risk if intervention is not undertaken. The correction needed for this patient population is generally small, but as seen in 2 of our patients (patients 5 and 7), even achieving a neutral mechanical

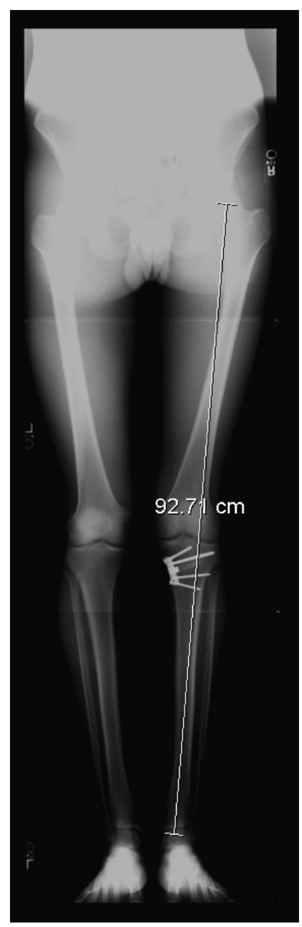

FIGURE 5. Postoperative full-length weight bearing views with desired correction.

axis can require a large correction. The objective was to protect the new transplant by establishing at least a more normal mechanical axis or weight-bearing axis. Overcorrection should be minimized to avoid injury to the contralateral side.[8,13] Our goal, as previously stated, was to move the weight-bearing axis through the lateral tibial eminence (Fig. 5). We do accept a correction that passes through the midportion of the eminences or the 50% mark of the tibial width.[3,6] Our results suggest that by using our technique for plate selection, satisfying results can be achieved. Although our technique is described for use in meniscal transplants and osteochondral allografting, we do feel it is applicable to patients requiring terminal procedures. The desired WBA is simply shifted to the base of the lateral tibial eminence, as is our preference, and the angular correction measured and the plate size determined using our described technique.

The use of digital radiographs and computer-assisted angle measurement software is supported in the literature for improved reliability and precision of measurement and its elimination of intrinsic error associated with manual techniques.[10,19,20]

CONCLUSIONS

This study presents the radiographic outcome for a simplified technique for medial opening-wedge HTO. The technique presents a unique technique for preoperative templating and its critical determination of plate selection that to our knowledge has not been described. Our results show reproducibility among surgeons and consistent performance for achieving our templating correction goal. Continued investigation will be undertaken to determine functional outcomes of these and future cases in which this technique is applied. Further research is warranted to determine if a reliable association between tibial width and angular correction can be determined for subsequent plate selection.

REFERENCES

1. Coventry MB. Upper tibial osteotomy for osteoarthritis. *J Bone Joint Surg Am*. 1985;67:1136–1140.
2. Hernigou P, Medevielle D, Debeyre J, et al. Proximal tibial osteotomy for osteoarthritis with varus deformity: a ten year to thirteen year follow-up study. *J Bone Joint Surg Am*. 1987;69:332–354.
3. Dugdale TW, Noyes FR, Styer D. Preoperative planning for high tibial osteotomy: the effect of lateral tibiofemoral separation and tibiofemoral length. *Clin Orthop Relat Res*. 1992;274:248–264.
4. Fugisawa Y, Masuhara K, Shiomi S. The effect of high tibial osteotomy on osteoarthritis of the knee: an arthroscopic study of 54 knee joints. *Orthop Clin North Am*. 1979;10:585–602.
5. Miniaci A, Ballmer FT, Ballmer PM, et al. Proximal tibial osteotomy: a new fixation device. *Clin Orthop Relat Res*. 1989;246:250–259.
6. Noyes FR, Mayfield W, Barber-Westin SD, et al. Opening wedge high tibial osteotomy: an operative technique and rehabilitation program to decrease complications and promote early union and function. *Am J Sports Med*. 2006;34:1262–1273.
7. Noyes FR, Goebel SX, West J. Opening wedge tibial osteotomy: the 3-triangle method to correct axial alignment and tibial slope. *Am J Sports Med*. 2005;33:378–387.
8. Amendola A. Knee osteotomy and meniscal transplantation: indications, technical considerations and results. *Sports Med Arthrosc*. 2007;15:32–38.
9. Cole BJ, Carter TR, Rodeo SA. Allograft meniscal transplantation: background, techniques, and results. *Instr Course Lect*. 2003;52:383–396.
10. Grainger AJ, Duryea J, Elliott JM, et al. The evaluation of a new digital semi-automated system for the radiological assessment of distal radius fractures. *Skeletal Radiol*. 2002;31:457–463.
11. Brown GA, Amendola A. Radiographic evaluation and preoperative planning for high tibial osteotomies. *Oper Tech Sports Med*. 2000;1:2–14.
12. Dejour H, Bonnin M. Tibial translation after anterior cruciate ligament rupture: two radiologic test compared. *J Bone Joint Surg Br*. 1994;76:745–749.
13. Giffin JR, Shannon FJ. The role of the high tibial osteotomy in the unstable knee. *Sports Med Arthrosc*. 2007;15:23–31.
14. Marti CB, Gautier E, Wachtl SW, et al. Accuracy of frontal and sagittal plane correction in open-wedge high tibial osteotomy. *Arthroscopy*. 2004;20:366–372.
15. van Arkel ER, de Boer HH. Human meniscal transplantation: preliminary results at 2 to 5 year follow-up. *J Bone Joint Surg Br*. 1995;77:589–595.
16. de Boer HH, Koudstaal J. Failed meniscus transplantation: a report of three cases. *Clin Orthop Relat Res*. 1994;306: 155–162.
17. Cameron JC, Saha S. Meniscal allograft transplantation for unicompartmental arthritis of the knee. *Clin Orthop Relat Res*. 1997;337:164–171.
18. Verdonk PC, Demurie A, Almqvist KF, et al. Transplantation of viable meniscal allograft: survivorship analysis and clinical outcome of one hundred cases. *J Bone Joint Surg Am*. 2005;87:715–724.
19. Shea KG, Stevens PM, Nelson M, et al. A comparison of manual versus computer-assisted radiographic measurement: intraobserver measurement variability for Cobb angles. *Spine*. 1998;23:551–555.
20. Farber DC, DeOrio JK, Steel MW. Goniometric versus computerized angle measurement in assessing hallux valgus. *Foot Ankle Int*. 2005;26:234–238.