CAOS in Mobile Bearing »Tibia Cut First« Total Knee Arthroplasty

J.B. Stiehl

Introduction

Mobile bearing total knee arthroplasty was initially introduced by Goodfellow with the concept of allowing greater mobility of the polyethylene insert while maintaining very high articular surface conformity with the idea of producing better wear characteristics. Buechel and Pappas developed the Low Contact Stress mobile bearing design in 1977 developing this concept into a system of devices that allowed for a variety of similar implants and surgical techniques. For many surgeons around the world, this concept has stood the test of time, offering favorable wear characteristics and more adaptable prosthetic knee kinematics. Stiehl et al. have performed a number of kinematic evaluations of mobile bearing total knees finding mobile bearing devices to be typical of all total knee arthroplasties, with a significant variation of condylar surface translations, condylar liftoff and screw-home rotation. Perhaps the most unique aspect of the mobile bearing device is the ability to allow for unrestricted femoral tibial rotation of the polyethylene insert. In addition, uncoupling the modular tibia allows the surgeon to have significant freedom from errors that may arise from mal-rotation of the tibial component, often leading to such problems as patellar subluxation, tibial post wear, and catastrophic posterior medial implant wear.

After total knee arthroplasty, fluoroscopic video kinematic studies have demonstrated that while some cases demonstrate the expected internal rotation with knee flexion, others will actually exhibit paradoxical external rotation with knee flexion. Computer assisted surgical navigation (CAOS) offers a unique opportunity to evaluate tibial rotation along with numerous other parameters such as mechanical alignment, joint flexion, ligamentous balance, and tibial axis alignment in flexion. This chapter describes an experience evaluating the data gathered from a large number of cases where tibial rotation was specifically documented before and after total knee arthroplasty in a group of patients where the »tibial cut first« method was utilized.

Methods

A group of 85 patients underwent primary total knee arthroplasty utilizing the »tibial cut first« technique. Implants utilized where either the LCS mobile bearing prosthesis or the Nexgen LPS Flex prosthesis. The Medtronic Universal imageless navigation system was used in all cases with dynamic reference base markers attached to either the medial proximal tibia or the distal medial femur over the medial epicondyle (Fig. 12.1). The medial femoral 3.2 mm pin placement is made by palpating the anatomical medial epicondyle and then directing the pin parallel to the transepicondylar axis. This placement avoids interference of the intra-medullary rod used in the standard »tibial cut first« method, and places the pin above the intercondylar notch such that implant may be placed without impingement on the pin. The second pin is placed 1.5 centimeters more proximal, medial to lateral anterior to the supra-condylar ridge in the dense cortical bone of the distal femur and

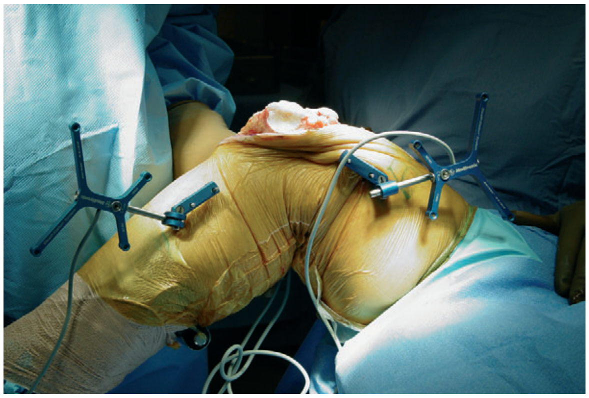

Fig. 12.1. Note medial placement of distal femoral and proximal tibial arrays (see text)

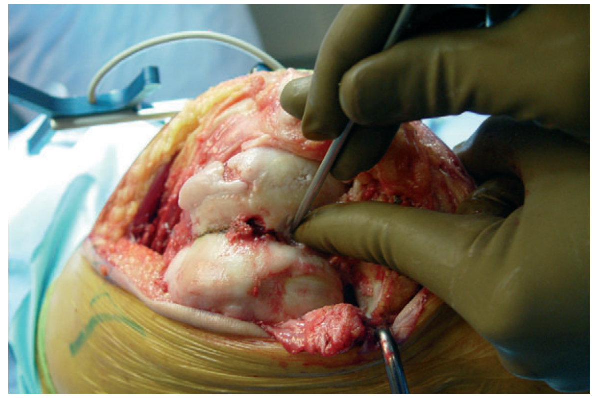

Fig. 12.2. Femoral center reference point selection which is located at the center of the intercondylar notch, and coincides with the AP axis of Whiteside and the transepicondylar axis

posterior to the intra-medullary canal. Prior anatomical studies have verified that this placement avoids neurovascular structures by a wide margin.

Navigation Referencing Protocol

The specifics of the navigation referencing are an important element of the technique and bear detailed description. Hip center determination is done using the kinematic method originally described by Saragaglia. Femoral referencing is done with the two most important points being the femoral center, and the cortical reference of the anterior femoral cortex. For the Medtronic Universal system, the computer definition of the femoral center is a point under the roof of the intercondylar notch that is in the middle of the intercondylar notch and lies in the anterior/posterior axis of Whiteside (Fig. 12.2). From dissections, this point also lies directly on the transepicondylar axis of the distal femur (Fig. 12.3). The surgical epicondyle depression is the reference for the medial epicondyle and the lateral epicondyle is the most prominent point of that landmark.

For the tibial reference, the tibial center is defined as the bisection of the transverse tibial axis. The transverse tibial axis is a line that connects the anterior/posterior midpoints of the medial and lateral condylar surfaces (Fig. 12.4). The tibial center approximates the lateral insertion of the anterior cruciate ligament. The anterior/posterior tibial axis is a perpendicular extension of the tibial center of the transverse tibial axis. This point typi-

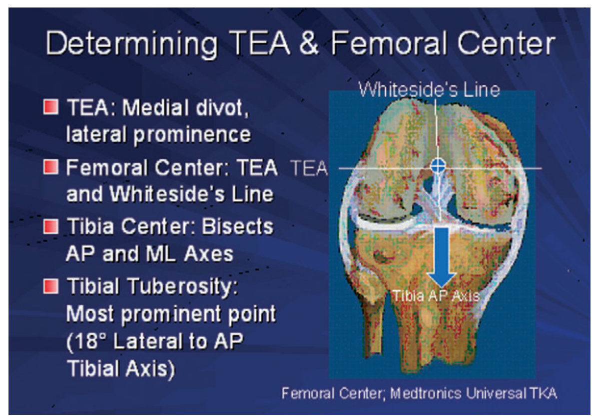

Fig. 12.3. Diagram demonstrates relationship of the AP axis of Whiteside, the transepicondylar axis, and the anterior/posterior tibial axis

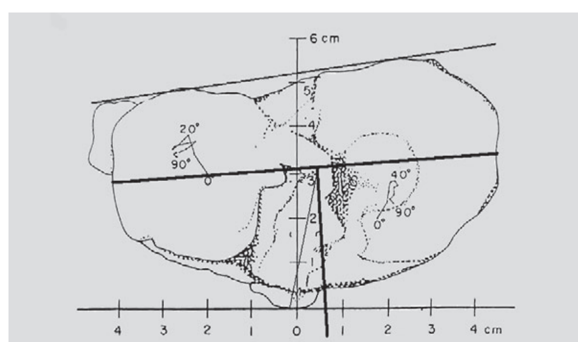

Fig. 12.4. Diagram demonstrates the transverse tibial axis, anterior/posterior axis of the tibia, and the vector from the tibial center to the tibial tuberosity (18°)

cally matches the extension of the femoral AP axis that may be extended onto the anterior surface of the tibia. Great care must be taken to determine the tibial center, as this will affect both coronal and sagital plane measurements. The posterior condylar axis of the tibia is 3–4° external to the transverse tibial axis. The center of the tibial tubercle is typically about 18° external to the AP axis of the tibia. Finally, the transverse tibial axis should nearly approximate the transepicondylar axis in regards to coupled rotation. The center of the distal tibia is determined by picking points that center over the medial and lateral malleoli, the transmalleolar axis. The computer algorithm then picks a point on the transmalleolar axis which is 40% from the most medial point.

Fig. 12.5. Operative example of the anterior cortical reference being established by using computer guidance

»Tibia Cut First« Surgical Technique

The »tibia cut first« method with mobile-bearing total knee arthroplasty follows the original technique of Insall where ligament balancing is done initially in extension before any bone cuts are made. The tibia cut is made perpendicular to the mechanical axis with a 7° posterior slope to the proximal tibia. The anterior distal femoral cut is made precisely at the distal anterior surface of the femur, and the flexion gap is cut with a block that removes the posterior condyles after ligament tensioning is done. Ligament tension is determined either with a gap spacer, or a custom tensioner that adjusts and measures the amount of tension to cut a specific gap (Fig. 12.5). With this technique, the flexion gap is determined by the ligament tension and not a specific anatomical reference such as the posterior condylar axis or the transepicondylar axis. The flexion gap is measured and a distal femoral resection then removes enough distal bone to create a similar gap in extension. For the Nexgen LPS Flex Mobile system, this gap is two millimeters less than the flexion space. Distal femoral chamfer and notch cuts complete femoral preparation.

Tibial component placement is centered on an initial mark on the proximal tibia that was a continuation from the femoral AP axis with the knee held in extension. This is also adjusted to make the spine cam relationship optimal and centered with motion. In general, the femoral AP axis mark matched the optimal position, and a new navigated instrument for tray positioning seeks to match this position which is determined at the beginning of the procedure. Because of the assumed inaccuracy of the transepicondylar axis referencing, all rotational measurements from the computer were considered to be relative. Axial rotation as a nominal measurement was determined at full extension and at 90° flexion and moved either external or internal to the femoral transepicondylar axis. The position of this rotation and the amount was then re-measured after the prosthetic implantation. Finally, the direction of rotation was determined after implantation to determine if this had altered. Following final preparation for femoral implantation, trials are inserted to assess the tension of the gaps that are created. These gaps typically will not have laxity over 3 mm, with a maximum allowed laxity in any plane of 6 mm.

Data Analysis

Alignment was determined by referencing the mechanical axis (MA) and the transepicondylar axis (TEA). Measurements included pre-release mechanical axis, 90° flexion alignment (tibial shaft axis) and tibial rotation. Post-implantation measurements included mechanical axis alignment compared to long-standing radiographs, femoral and tibial component rotation, and final 90° flexion alignment (tibial shaft axis) and rotation related to the TEA. The tibial rotation was defined mathematically by the relationship of the anterior posterior femoral axis which is perpendicular to the transepicondylar axis and measuring the vector to the midpoint prominence of the tibial tubercle (Fig. 12.6) More recently, the Medtronic image-

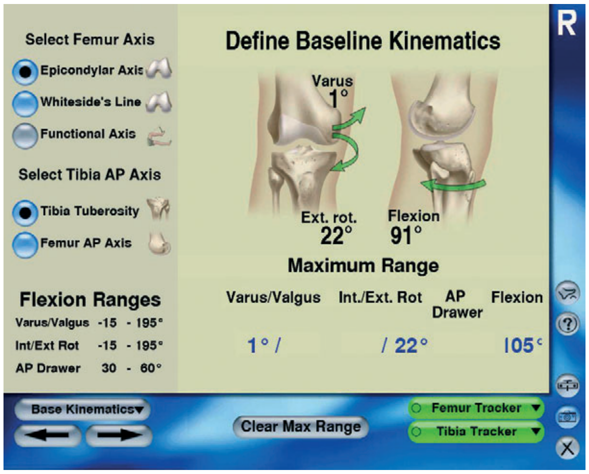

Fig. 12.6. Computer screen image of the 91° flexion measurement, demonstrating the tibial shaft axis to be varus 1° in relation to the transepicondylar axis, and tibial rotation of the tibial tuberosity at 22° external to the AP tibial axis

less reference added the femoral anterior posterior axis of Whiteside as an additional mark to determine femoral rotation eliminating the need for the transepicondylar axis. Standard descriptive statistical analysis was performed.

Results

Pre-release mechanical alignment(MA): 5° varus +/–7° (range: 14° valgus to 20° varus). CAOS post implant MA: 0.7° varus +/– 1.1° (range: 3° valgus to 2.5° Vvarus). Radiographic post MA: 0.3° varus +/– 1.3° (range 4° valgus to 4° varus). Pre-release (tibal shaft axis) 90° flexion: 2.6° varus +/– 5.5° (range: 13° valgus to 19° varus). Post implant (tibial shaft axis) at 90° flexion: 0.1° varus +/– 4.5° (range: 12° valgus to 10° varus). Tibial shaft axis at 90° did not change from baseline to post implant, and was outside the TEA: >5° – 25%; >2° – 50%. Baseline measurement of tibial rotation from 0° to 90° flexion: 4.1° +/– 8.9° of tibial internal rotation (range: 18° external rotation to 23° internal rotation). Post implant tibial rotation from 0° to 90° flexion: 3° +/– 7° of tibial internal rotation (range: 18.5° external rotation to 20° internal rotation). Of baseline group, 41% demonstrated tibial external rotation. After TKA, 37% had tibial external rotation with flexion. When comparing the nominal rotation at 0° before and after TKA, it was noted that the tibial rotation point at 0° moved more externally in 40% and more internally in the rest but the mean change for the overall group was 2.6° of internal rotation. In 23% of cases there was a change in the direction in tibial rotation from the baseline measurement to the final measurement after total knee arthroplasty. Finally, in 70% of cases, the final tibial rotation measured after TKA was +/– 5° from the starting baseline position.

Discussion

After TKA, alterations from the rotation of the normal knee may be related to anterior cruciate deficiency, prosthetic geometry, and differences in surgical technique in individual patients. Stiehl et al. have studied in-vivo weight-bearing kinematics of mobile-bearing TKA's using the tibial cut first method as used in this study and assessed the amount of screw-home rotation evident with gait [1]. Maximum internal rotation with flexion was 9.6° while the maximum external rotation with flexion was 6.2°. The average tibial rotation for 20 patients was internal rotation of 0.5° with knee flexion but 40% of TKA's demonstrated tibial external rotation with knee flexion.

Dennis et al. evaluated the LCS rotating platform mobile-bearing prosthesis finding that eighteen of 35 knees (51%) had a normal rotation pattern from heel-strike to toe-off, and 30 of 35 knees (86%) had a reverse rotation pattern during at least one analyzed increment (30°). The average amount of axial rotation from heel-strike to toe-off was 0°, and the average maximum amount of axial rotation at any increment during stance-phase was 3°. For gait, the average maximum amounts of normal and reverse rotation for the mobile-bearing PCL-sacrificing TKA study group were 7.3° and –10.1°, respectively. The overall maximum amounts of normal and reverse rotation of any individual TKA for gait, regardless of type, at any increment were 9.6° and –13.3°, respectively. Only 11 of 35 rotating platform total knees (31%) achieved at least 5° of normal rotation, no knees achieved more than 10°, and five of 35 knees (14%) achieved more than –5° of reverse rotation. Comparing the results of all different total knees, patients having a PCL-sacrificing mobile-bearing TKA had, on average, slightly less rotation during a deep knee bend than patients having either a PCL-retaining or posterior-stabilized mobile-bearing TKA, and less than patients with normal knees (p=0.0003). For deep knee bend, the average maximum amounts of normal and reverse rotation for the mobile-bearing PCL-sacrificing

TKA study group were 11.4° and −5.9°, respectively. The maximum amounts of normal and reverse rotation of the overall total knee group at any flexion increment were 21° and −8.4°, respectively. The authors conclude that although average axial rotation values after TKA were limited, review of individual TKA patients revealed a substantial number with high magnitudes (>20°) of both normal and reverse axial rotation that exceeds the rotation limits of most fixed-bearing TKA designs. This may be an advantage for mobile-bearing TKA designs with a rotating platform that can accommodate a wider range of axial rotation without generating excessive PE stresses.

The results of my study were similar to the fluoroscopic studies in that roughly 40% of TKA's demonstrated tibial external rotation with knee flexion. However, the range of rotation was much greater in the CAOS studied patients which could be as much as 20°. This would suggest that the lack of weight-bearing forces in the CAOS TKA's could explain much of this difference. The occurrence of tibial rotation after total knee arthroplasty would appear to be quite variable and there were no factors that predict which patients will externally rotate with flexion.

From the computed tomographic studies of Berger et al., the transtibial axis is defined as a line bisecting the sagittal plane centers of the tibial medial and lateral condyles. The anterior posterior line perpendicular to the transtibial axis is roughly 18° medial to the tibial tubercle center, and closely coincides with the femoral transepicondylar axis if it were translated distally in the coronal plane [2]. Thus, there is a strong reason to couple the femoral anterior-posterior axis with the anterior-posterior tibial axis, and to utilize these points as references in a CAOS system. Preliminary experience with an instrumented tibial tray trial would suggest that matching this placement with the initial computer referencing anterior posterior tibial axis provides a viable option for image guided tibial tray placement. This may have greater application in minimally invasive surgical approaches.

This study confirmed that the CAOS directed component position was within 2° of the optimum MA position in 97% of cases. However, in only a minority of cases did the final femoral component rotation and tibial shaft axis compare to the pre-operative normal transepicondylar axis reflecting a decoupling of flexion tensor spacing with extension space alignment. Tibial rotation findings parallel prior fluoroscopic kinematic analyses. This study suggests that there may be a fixed relationship between the initial baseline tibial rotation and the final tibial component implant position. Further study will be needed to prove if baseline tibial rotation may guide final implant positioning.

References

1. Stiehl JB, Dennis DA, Komistek RD, Crane HS (1999) In-vivo determination of condylar liftoff and screw home in a mobile bearing total knee arthroplasty. J Arthroplasty 14: 293–299
2. Berger RA, Crossett LS, Jacobs JJ, Rubash HE (1988) Rotation causing patellofemoral complications after total knee arthroplasty. Clin Orthop 356: 144–153
3. Berger RA, Crossett LS (1998) Determining the rotation of the femoral and tibial components in total knee arthroplasty: A computer tomography technique. Oper Tech Orthop 8: 128–133
4. Dennis DA, Komistek RD, Mahfouz MR, Walker SA, Tucker A (2004) A multicenter anaylsis of axial femorotibial rotation after total knee arthroplasty. Clin Orthop 428: 180–189
5. LaFortune MA, Cavanagh PR, Sommer III HJ, Kalenak A (1992) Three dimensional kinematics of the human knee during walking. J Biomech 25: 347–357
6. Boldt JG, Stiehl JB, Thuemler P (2002) Femoral rotation based on tibial axis. In: Hamelynck KJ, Stiehl JB (eds) LCS mobile bearing knee arthroplasty. Springer, Berlin Heidelberg New York Tokio, pp 175–182
7. Stiehl JB, Clifford D, Komistek RD (▮) Correlation of in-vivo kinematics with retrieval polyethylene insert wear patterns in failed total knee arthroplasty. Clin Orthop (Pending Publication)
8. Vertullo CJ, Easley ME, Scott WN, Insall JN (2001) Mobile bearings in total knee arthroplasty. J Am Acad Orthop Surg 9: 355–364