texas orthopaedic journal®

ORIGINAL RESEARCH

Tibial Resection and Coronal Alignment in Total Knee Arthroplasty

Joshua Choi, BS[1]; Carlos J. Meheux, MD[2]; Colin D. Canham, MD[2]; Shuyang Han, PhD[1]; Philip C. Noble, PhD[1]; Stephen J. Incavo MD[2]

[1]Institute of Orthopedic Research and Education; Houston, TX, USA
[2]Houston Methodist Orthopedics and Sports Medicine; Houston, TX, USA

ABSTRACT

Introduction: Restoration of coronal plane knee alignment is considered one of the mainstays of a successful total knee arthroplasty (TKA) to achieve a desired mechanical axis (MA) of the lower extremity. In this study, we aimed to determine the effect of tibial resection performed at different rotational positions on coronal plane alignment in TKA.
Methods: Three-dimensional digital models of 15 cadaveric lower limbs were reconstructed using high definition computed tomography. Neutral and 3° varus proximal tibial osteotomies were made with respect to MA of the tibia with varying degrees of slope and rotation of the virtual cutting guide. Osteotomies with 0°, 5°, and 10° of slope were made in 0°, 10°, and 20° of internal and external rotation with respect to the selected tibial rotational axis. The resulting coronal alignment was measured for each scenario.
Results: At 0° tibial slope, the coronal plane alignment was unaffected by rotation of the cutting guide resulting in a neutral MA for a neutral proximal tibial osteotomy; and a 3° varus MA for a 3° varus proximal tibial osteotomy. Internal and external rotation of the cutting guide in proximal tibial resection altered coronal plane alignment up to 3.4° with a 5° tibial slope and 6.9° with a 10° tibial slope.
Discussion: Tibial resection with slope that is not rotationally aligned with the desired tibial implant position will result in altered coronal plane alignment. The tibial cutting jig should be aligned in the desired rotational position of the tibial implant.
Level of Evidence: Experimental cadaver study.
Keywords: Tibial resection in TKA; Coronal plane alignment in TKA; Rotational position in TKA.

INTRODUCTION

Restoration of coronal plane knee alignment is considered one of the mainstays of a successful total knee arthroplasty (TKA) to achieve a desired mechanical axis (MA) of the lower extremity. While a 0° MA has been the traditional goal, some surgeons now favor a 3° varus alignment which is considered anatomic [1]. Several studies have evaluated the effect of mechanical axis alignment in TKA and reports show that a malaligned TKA may affect knee kinematics and lead to ligament imbalance, patellar maltracking,

Corresponding Author:
Stephen J. Incavo, MD
Houston Methodist Orthopedics & Sports Medicine
Outpatient Center, Suite 2500
6445 Main Street
Houston, TX 77030, USA
e-mail: sjincavo@houstonmethodist.org

pain, early failure and a high rate of dissatisfied patients [2-4].

Several factors can affect final coronal plane alignment after TKA including preoperative knee alignment, surgical technique, type of implant used and component positioning. It has been reported that the degree of preoperative coronal alignment may lead to an inferior postoperative results independent of the surgical technique [5,6]. Newer surgical techniques, such as navigation, robotics, and patient-specific implants have been championed to aid in proper alignment and function [7].

Errors in coronal, sagittal, and rotational alignment can affect implant positioning as well as soft tissue balancing and component sizing [8]. There is very little information on the effect of tibial slope and tibial component rotation on final coronal alignment.

The purpose of this study was to determine the effect of tibial resection performed at different rotational positions on coronal plane alignment in total knee arthroplasty. The authors hypothesized that rotational mismatch of the tibial component in the presence of tibial slope will affect final coronal alignment.

MATERIALS & METHODS

Computed tomography (CT) scans of 15 human cadaveric lower extremity specimens were obtained. The images were then incorporated into a custom simulation software (Rapidform, INUS Technology; Seoul, South Korea) to identify the mechanical axes and make virtual cuts on both the femur and tibia. The epicondylar axis of the distal femur was defined as delineated by Coughlin et al and was used to make the virtual distal femoral cut as it has been shown to remain nearly perpendicular to the tibial anatomic axis throughout flexion ranges from 0° - 90° (Figure 1) [9]. The tibial anatomic and mechanical axes were determined as a line perpendicular to the femoral epicondylar axis (Figure 2).

Neutral and 3° varus proximal tibial osteotomies were made with respect to the mechanical axis of the tibia with varying degrees of slope and rotation of the virtual cutting guide. Osteotomies with 0°, 5° and 10° of slope were made in 0°, 10°, and 20° of internal and external rotation with respect to the anteroposterior (AP) axis of the tibia. There were 18 distinct cutting conditions per tibia. The knees were placed in full extension as described by Oswald et al and the resulting coronal plane alignment of the knee was then measured for each specimen [10].

RESULTS

Neutral Proximal Tibial Resection

At 0° tibial slope, the coronal plane alignment was unaffected by rotation of the cutting guide resulting in a neutral coronal plane alignment (Table 1). Internal and external rotation of the cutting guide in proximal tibial resection altered the coronal plane alignment as much as 3.4° with a 5° tibial slope and 6.8° with a 10° tibial slope. Internal rotation of the tibial cutting guide resulted is more valgus coronal plane alignment while external rotation led to more varus alignment.

Anatomic 3° Varus Proximal Tibial Resection

At 0° tibial slope, the coronal plane alignment was unaffected by rotation of the cutting guide resulting in a 3° varus coronal plane alignment (Table 2). Internal and external rotation of the cutting guide in proximal

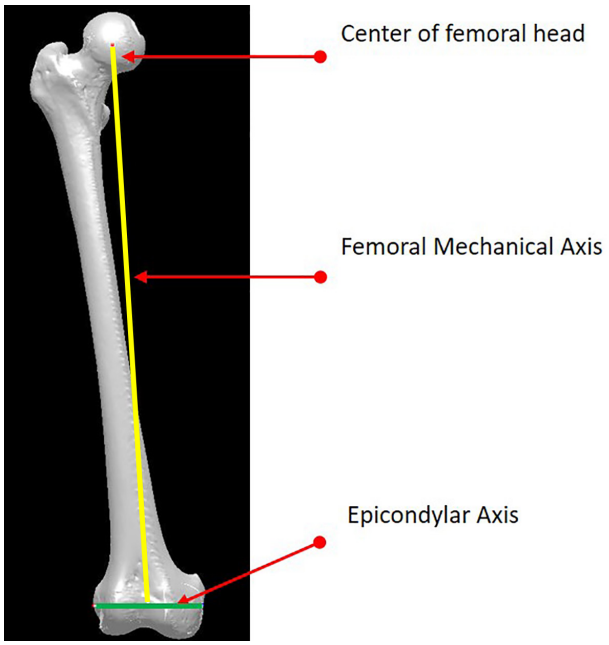

Figure 1. An image depicting the mechanical and epicondylar axes of the femur.

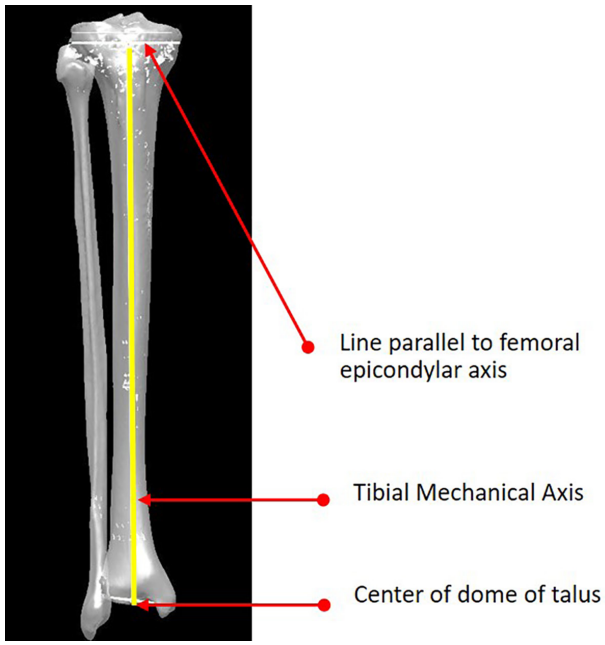

Figure 2. An image depicting the mechanical axis of the tibia.

tibial resection altered the coronal plane alignment as much as 3.4° with a 5° tibial slope and 6.9° with a 10° tibial slope. Internal and external rotation of the tibial cutting guide led to varus alignment with external rotation causing higher varus alignment.

DISCUSSION

We have demonstrated substantial coronal plane alignment alterations, up to 7°, with malrotation of the tibial cutting guide when a slope is introduced in the proximal tibia during total knee arthroplasty. Notably, internal rotation of the cutting jig produced more valgus alignment because more tibial bone will be resected posterolaterally that posteromedially. The less likely external rotation of the cutting jig resulted in more varus alignment. When a 3° varus tibial cut was performed the same degree of alignment change occurred, but was increased

Table 1. Mean Values of Coronal Plane Alignment with 0° Tibial Resection.

	0° slope (°)	5° slope (°)	10° slope (°)
20°(IR)	-0.02 ± 0.04	-1.9 ± 0.5	-3.7 ± 1.0
10° (IR)	-0.02 ± 0.04	-1.0 ± 0.5	-2.05 ± 1.0
0°	-0.02 ± 0.04	-0.17 ± 0.5	-0.35 ± 1.0
10° (ER)	-0.02 ± 0.04	0.7 ± 0.5	1.4 ± 1.0
20° (ER)	-0.02 ± 0.04	1.5 ± 0.5	3.1 ± 1.0

Coronal plane alignment results with varying tibial slopes and rotation of the tibial cutting guide when proximal tibial cut was done at 0° resection plane. IR, internal rotation; ER, external rotation. Negative values indicate valgus alignment.

Table 2. Mean Values of Coronal Plane Alignment with 3° Varus Tibial Resection.

	0° slope (°)	5° slope (°)	10° slope (°)
20° (IR)	2.96 ± 0.06	1.1 ± 0.49	-0.75 ± 1.0
10° (IR)	2.96 ± 0.06	2.0 ± 0.51	0.9 ± 1.0
0°	2.96 ± 0.06	2.9 ± 0.56	2.8 ± 1.1
10° (ER)	2.96 ± 0.06	3.7 ± 0.52	4.4 ± 1.0
20° (ER)	2.96 ± 0.06	4.5 ± 0.49	6.1 ± 1.0

Coronal plane alignment results with varying tibial slopes and rotation of the tibial cutting guide when proximal tibial cut was done at 3° varus resection plane. IR, internal rotation, ER, external rotation. Negative values indicate valgus alignment.

by 3° of varus. While the 10 and 20° rotational variation that we studied may seem large, it is in keeping with our clinical observations (Figure 3) [8].

There is a limited amount of information available on TKA alignment and tibial slope and/or cutting guide rotation. Tsukeoka et al studied tibial specimens and simulated external rotation error and found tibial cutting block malalignment of 20° of external rotation can produce varus malalignment of 2.4° and 3.5° with a 7° and a 10° sloped cutting jig, respectively [11]. In a related, but different study using long leg standing radiographs Schwartz et al evaluated the combined effect of image rotation and tibial slope on the perception of coronal alignment on a standing AP radiograph [12]. They found that each 10° interval of external rotation of a 7° sloped tibial cut (or relative internal rotation of the tibial component viewed in the AP plane) resulted in a perception of an additional 0.75° varus alignment.

As in all bench top studies, limitations were present. Most notably, the virtual cuts made to simulate those during actual surgery do not take into account the effect of the soft tissues on balancing and alignment.

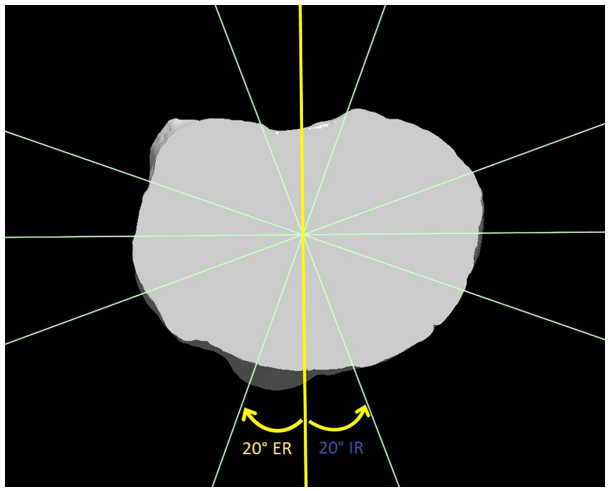

Figure 3. An image depicting the internal and external rotation mismatch of the tibial cutting guide.

However, any imbalance in the soft tissue balance would only increase the degree of malalignment reported here.

CONCLUSIONS

The results of the study demonstrate that tibial resection not rotationally aligned with the desired tibial implant position results in altered coronal plane alignment, and this malalignment is increased with increasing tibial slope. The tibial cutting jig should be aligned in the desired rotational position of the tibial implant.

REFERENCES

[1] Cherian JJ, Kapadia BH, Banerjee S, Jaurequi JJ, Issa K, Mont MA. Mechanical, Anatomical and Kinematic Axis in TKA: Concepts and Practical Applications. Curr Rev Musculoskelet Med. 2014;7(2):89-95 .

[2] Noble PC, Conditt MA, Cook KJ, Mathis KB. The John Insall Award: Patient expectations affect satisfaction with total knee arthroplasty. Clin Orthop Relat Res. 2006;452:35-43.

[3] Bourne RB, Chesworth BM, Davis AM, Mahomed NM, Charron KD. Patient satisfaction after total knee arthroplasty: who is satisfied and who is not? Clin Orthop Relat Res 2010;468(1):57-63.

[4] Slevin O, Schmid FA, Schiapparelli FF, Rasch H, Amsler F, Hirschmann MT. Coronal femoral TKA position significantly influences in vivo patella loading in unresurfaced patellae after primary total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc 2017;25(11):3605-10.

[5] Ritter MA, Davis KE, Davis P, Farris A, Malinzak RA, Berend ME, et al. Preoperative malalignment increases risk of failure after total knee arthroplasty. J Bone Joint Surg Am. 2013;16;95(2):126–31.

[6] Sorrells RB, Murphy JA, Sheridan KC, Wasielewski RC. The effect of varus and valgus deformity on results of cementless mobile bearing TKA. Knee. 2007;14:284–88.

[7] Rodrigues AST, Gutierres MAP. atient-specific instrumentation in total knee arthroplasty. Should we adopt it? Rev Bras Ortop. 2016;15;52(3):242-50.

[8] Incavo SJ, Wild JJ, Coughlin KM, Beynnon BD. Early revision of component malrotation in total knee arthroplasty. Clin Orthop Relat Res. 2007;458:131-36.

[9] Coughlin KM, Incavo SJ, Churchill DL, Beynnon BD. Tibial axis and patellar position relative to the femoral epicondylar axis during squatting. J Arthroplasty 2003;18(8):1045-55.

[10] Oswald MH, Jakob RP, Schneider E, Hoogewoud HM. Radiological analysis of normal axial alignment of femur and tibia in view of total knee arthroplasty. J Arthroplasty 1993;8(4):419-26.

[11] Tsukeoka T, Tsuneizumi Y, Lee TH. The effect of the posterior slope of the tibial plateau osteotomy with a rotational error on tibial component malalignment in total knee replacement. Bone Joint J. 2013;95-B(9):1201-03.

[12] Schwartz AJ, Ravi B, Kransdorf MJ, Clarke HD. Does tibial slope affect perception of coronal alignment on a standing anteroposterior radiograph? J Arthroplasty 2017;32(7):2285-88.