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HOW FREQUENTLY DO FIVE TOTAL KNEE ARTHROPLASTY METHODS CHANGE THE ALIGNMENT OF THE JOINT LINES AND LIMB FROM NORMAL?

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INTRODUCTION

One strategy for aligning the limb and positioning components in total knee arthroplasty (TKA) in the coronal plane is mechanical alignment, which has the goal of positioning the center of the hip, knee, and ankle on a straight-line by establishing a femoral and tibial joint line at the knee that is perpendicular to the mechanical axis of the femur and tibia respectively. Another strategy is gap balancing, which has the goal of creating equal gaps between the medial and lateral compartments at 0° of extension and 90° of flexion.

There is evidence that these strategies can change knee and limb alignment from normal [1]. Radiographs have shown that the joint line at the knee is not always perpendicular to the mechanical axes of the femur and tibia. Further most normal limbs do not form a straight-line [1].

Changing the angles of the distal and posterior femoral joint lines, the tibial joint line, and the limb alignment from normal has important clinical applications in TKA. The axes describing femoral-tibial and patella-femoral kinematics are either parallel or perpendicular to these joint lines [1]. Hence changing the angle of any of these joint lines from normal will alter knee kinematics as well as soft-tissue balance about the knee. Altering soft-tissue balance may result in knee instability [1].

One objective of this study was to determine, after mechanical alignment of TKA with three methods based on anatomic landmarks for aligning the femoral component in internal-external (I-E) rotation, the frequency and magnitude of 1) changes in the varus-valgus (V-V) angle of the distal femoral joint line, the I-E angle of the posterior joint line, and the V-V angle of the tibial joint line from normal, and 2) changes in limb alignment from normal, and 3) ligament instability between 0° of extension and 90° of flexion. The second objective was to determine, after two gap-balancing methods, the frequency and

magnitude of 1) changes in the angles of the joint lines from normal, and 2) changes in limb alignment from normal.

METHODS

Fifty, three-dimensional long-bone models of normal limbs were created from computed tomography scans. The limb was rotated into a standard coronal projection perpendicular to the flexion-extension plane of the knee that was tangent to the posterior femoral condyles and the posterior greater trochanter.

On each limb model, mechanically aligned TKA was simulated by cutting the distal femur and proximal tibia perpendicular to the mechanical axes of the femur and tibia respectively. The posterior femoral cut was made 1) perpendicular to the Whiteside's line (anterior-posterior axis) in Method 1, 2) parallel to the transepicondylar axis (TEA) in Method 2, and 3) 3° externally rotated to the posterior joint line in Method 3. The angular change from normal of each joint line and the limb (hip-knee-ankle angle) was computed. Positive values indicate valgus/external rotation change and negative values indicate varus/internal rotation change in the angle of the distal femoral joint lines, tibial joint lines, and posterior femoral joint lines, respectively. The total bone resection thickness in each compartment quantified the gap. The difference in the gap between the medial and lateral compartments at 0° of extension and at 90° of flexion was computed. When the difference between the medial and lateral gaps at a particular flexion angle exceeded 1 mm, it was considered asymmetric. When the difference of the difference between medial and lateral gaps at 0° of extension and at 90° of flexion exceeded 1 mm, it was considered unequal and represented collateral ligament instability.

On each limb model, two gap balancing methods for TKA were simulated. In Method 4, the distal femoral cut and the tibial cut were made perpendicular to the femoral and tibial mechanical axes

respectively. With the knee in 0° of extension, the tibia was distracted on the narrower side until the gaps in the medial and lateral compartments were equal, the knee was flexed to 90°, and the posterior femoral cut was made parallel to the tibial cut. In Method 5, the tibial cut was made perpendicular to the tibial mechanical axis, and the distal and posterior femoral cuts were made parallel to the tibial cut. The angular change from normal of each joint line and the limb was computed.

RESULTS

In the mechanically aligned TKA, the range of change in the V-V angle of the distal femoral joint line was 0 to 8° (mean 3.3°) (Table 1). The range of change in I-E angle of the posterior joint line was -7 to 11° (mean 4.0°) for Method 1, was -11 to 10° (mean 4.2°) for Method 2, and was 3 to 3° (mean 3.0°) for Method 3. The range of change in the V-V angle of the tibial joint line was -8 to 8° (mean 3.4°). The percentage of mechanically aligned TKAs with unequal flexion and extension gaps was 72% for Method 1 (Figure 1), 72% for Method 2 (not shown), and 48% for Method 3 (not shown).

TABLE 1. SUMMARY OF THE CHANGES OF JOINT LINES AND LIMB ALIGNMENT WITH USE OF THREE MECHANICAL ALIGNMENT METHODS.

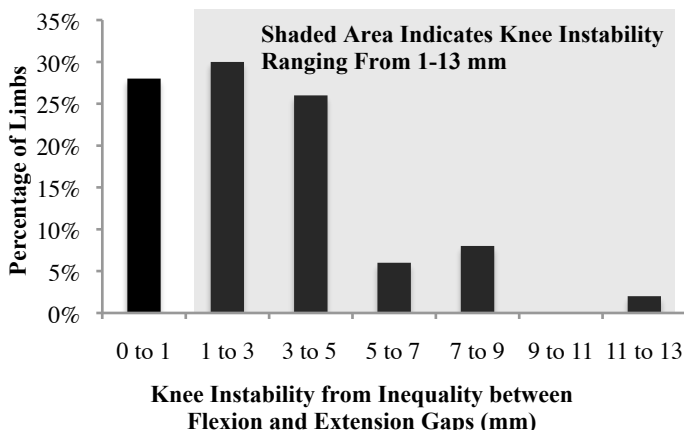| Change in Angular Measurement From Normal	Method 1	Method 2	Method 3
Distal Femoral Joint line $\geq 1^0$		84%	
Distal Femoral Joint line $\geq 3^0$		50%	
Posterior Femoral Joint line $\geq 1^0$	94%	88%	100%
Posterior Femoral Joint line $\geq 3^0$	74%	66%	100%
Tibial Joint line $\geq 1^0$		82%	
Tibial Joint line $\geq 3^0$		60%	
Limb Alignment $\geq 1^0$		68%	
Limb Alignment $\geq 3^0$		22%	

FIGURE 1. HISTOGRAM OF KNEE INSTABILITY FROM INEQUALITY BETWEEN THE FLEXION AND EXTENSION GAPS WITH USE METHOD 1 (WHITESIDE'S LINE).

With gap balancing the change in V-V angle of the distal femoral joint line was -8 to 8° (mean 3.1°) and -8 to 8° (mean 3.4°) for Method 4 and 5 respectively (Table 2). The range of change in V-V angle of the tibial joint line was -8 to 8° (mean 3.4°) in both methods. The range of change in I-E angle of the posterior joint line was -10 to 7° (mean 4.0°) and -10 to 7° (mean 3.7°) for Method 4 and 5 respectively. The range of change in limb alignment was -7 to 5° (mean 2.0°) in Method 4 and was 0° in Method 5.

TABLE 2. CHANGES OF JOINT LINES AND LIMB ALIGNMENT WITH USE OF GAP BALANCING METHODS.

Change in Angular Measurement From Normal	Method 4	Method 5
Distal Femoral Joint line $\geq 1^0$	82%	82%
Distal Femoral Joint line $\geq 3^0$	46%	60%
Posterior Femoral Joint line $\geq 1^0$	88%	86%
Posterior Femoral Joint line $\geq 3^0$	62%	66%
Tibial Joint line $\geq 1^0$	82%	
Tibial Joint line $\geq 3^0$	60%	
Limb Alignment $\geq 1^0$	68%	0%
Limb Alignment $\geq 3^0$	22%	0%

DISCUSSION AND CONCLUSION

In arthroplasty of joints other than the knee, the primary alignment goal is to position components to restore the kinematics to normal. In TKA however, the primary goal of mechanical alignment is to establish joint lines perpendicular to the mechanical axes of the femur and tibia and change the alignment of the limb to a straight-line. The present study showed that mechanical alignment with three rotational methods frequently change the angles of the distal femoral joint line, the posterior femoral joint line, the tibial joint line, and the limb alignment from normal. Furthermore, these angular changes are sufficient in magnitude to cause unequal flexion and extension gaps which will result in collateral ligament instability. Changing the joint line from normal disrupts the kinematics of the knee.

Because all alignment methods studied yielded substantial changes in joint line angles which affect knee alignment, limb alignment, and/or flexion and extension gaps, each method has pitfalls. The results of this study indicate that gap balancing Method 5 is better than the other methods because it restores the limb alignment and creates equal flexion and extension gaps. However, it changes the joint lines more than 3° in a majority of limbs (>60%). Three-degree posterior condylar axis appears to be a better option to be combined with mechanical alignment than either Whiteside's Line or the transepicondyler axis because it yields less change in the posterior joint line on average.

In conclusion, all five alignment methods changed the knee and limb alignments in a substantial number of limbs and mechanical alignment resulted in ligament instability. Not restoring the pre-operative distal and posterior femoral joint lines causes abnormal tibio-femoral kinematics and patellofemoral complications in some patients and compromises clinical outcome [2]. Unequal flexion and extension gaps may require extensive, often complicated soft tissues releases and might explain why flexion instability occurs and is difficult to treat.

REFERENCES
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