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How Well Does Kinematically Aligned Total Knee Arthroplasty Prevent Clinically Important Changes in Laxities and Shifts in the Neutral Positions of the Tibiofemoral Joint?

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INTRODUCTION

The goal of kinematically aligned total knee arthroplasty (KA TKA) is to align the femoral and tibial components to restore both the native joint lines and native alignments of the limb and knee and hence native knee function. However, two unavoidable changes that might prevent posterior cruciate-retaining KA TKA from restoring native knee function are (1) the replacement of the articular surfaces with implants of discrete sizes and average shapes and (2) resection of the anterior cruciate ligament (ACL). To determine whether either or both of these unavoidable changes inhibit KA TKA from restoring to native two important metrics of knee function, the objectives were to determine how well KA TKA prevents clinically important (1) changes in the laxities and (2) shifts in the neutral positions (Table 1) in varus-valgus (V-V) rotation, internal-external (I-E) rotation, anterior-posterior (A-P) translation, and compression-distraction (C-D) relative to those of the native knee and the ACL-deficient (ACL-d) knee.

METHODS

The eight laxities and four neutral positions were measured in thirteen native human cadaveric knees in three knee conditions (i.e. native, ACL-d, and KA TKA) using a six degree-of-freedom (DOF) load application system (Figure 1) from 0° to 120° of flexion in 30° increments (Table 2). Throughout testing, muscle loads were applied to the tendons of the quadriceps (80 N), biceps femoris (15 N), and the semimembranosus/semitendinosus (26 N) to maintain the inherent stability of the knee.

Table 1. Clinically important changes in laxities and shifts in neutral positions for each of the four DOFs

DOF	Laxity	Neutral Position
V-V	1.4°[1]	1.5°[2]
I-E	3.6°[3]	5.0°[4]
A-P	1.8 mm[3]	1.1 mm[5]
C-D	1.0 mm[6]	1.0 mm[6]

Table 2. Applied loads used to deterimine the laxities in each of the four DOFs

DOF	Load
V-V	±5 Nm[7]
I-E	±3 Nm[8]
A-P	±45 N[9]
C-D	±100 N[10]

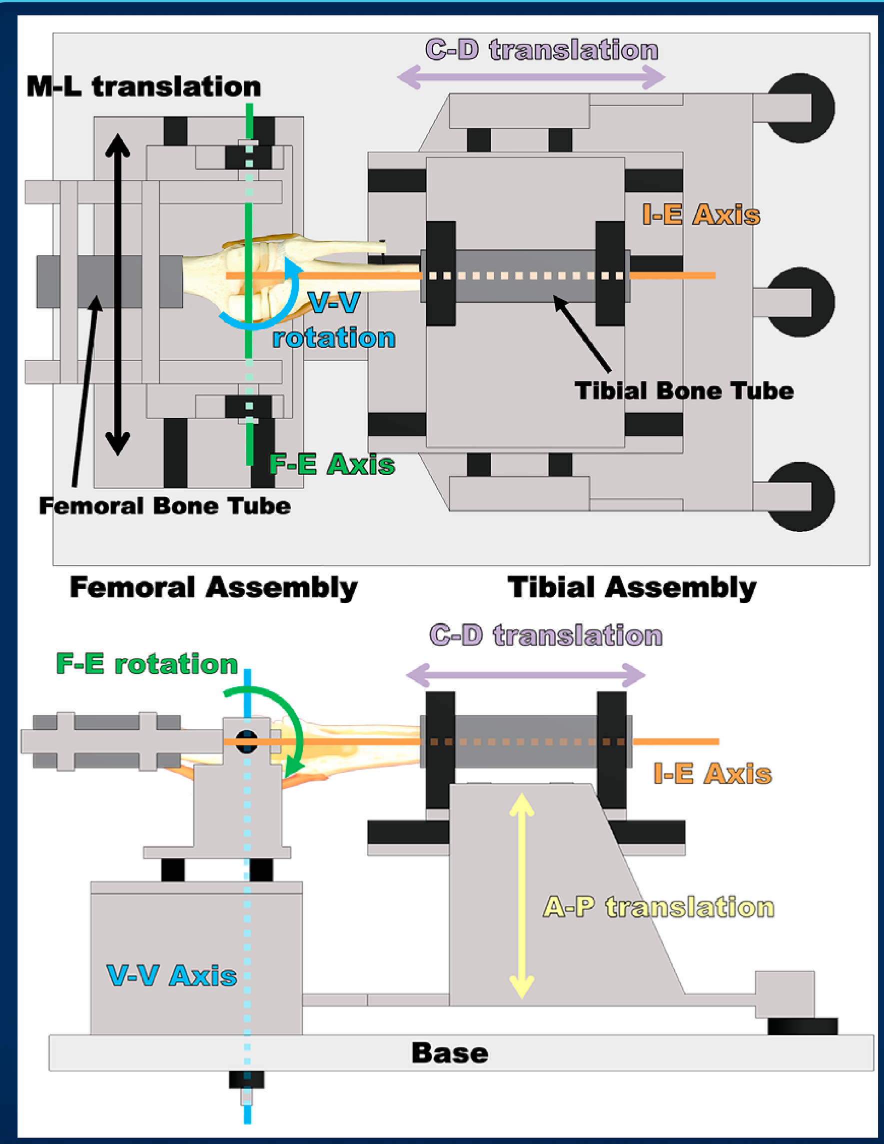

Figure 1. Schematic of the six DOF load application system[11] (LAS) used to determine the laxities and neutral positions. Each knee specimen is mounted with the patella towards the base. A functional alignment procedure is used to align the flexion-extension (F-E) and I-E rotation axes of the tibiofemoral joint with the F-E and I-E axes of the LAS. The DOFs follow the coordinate system of Grood and Suntay so that the F-E axis is fixed to the femoral assembly and the I-E axis is fixed to the tibial assembly. Accordingly, the femoral assembly provides two DOFs, F-E and medial-lateral (M-L) translation. The tibial assembly provides the remaining four DOFs including I-E, V-V, A-P, and C-D. Stepper motor actuators (omitted for clarity) are used to apply loads in all DOFs except M-L. Unconstrained motions in all DOFs are enabled through the use of low-friction bearings.

RESULTS

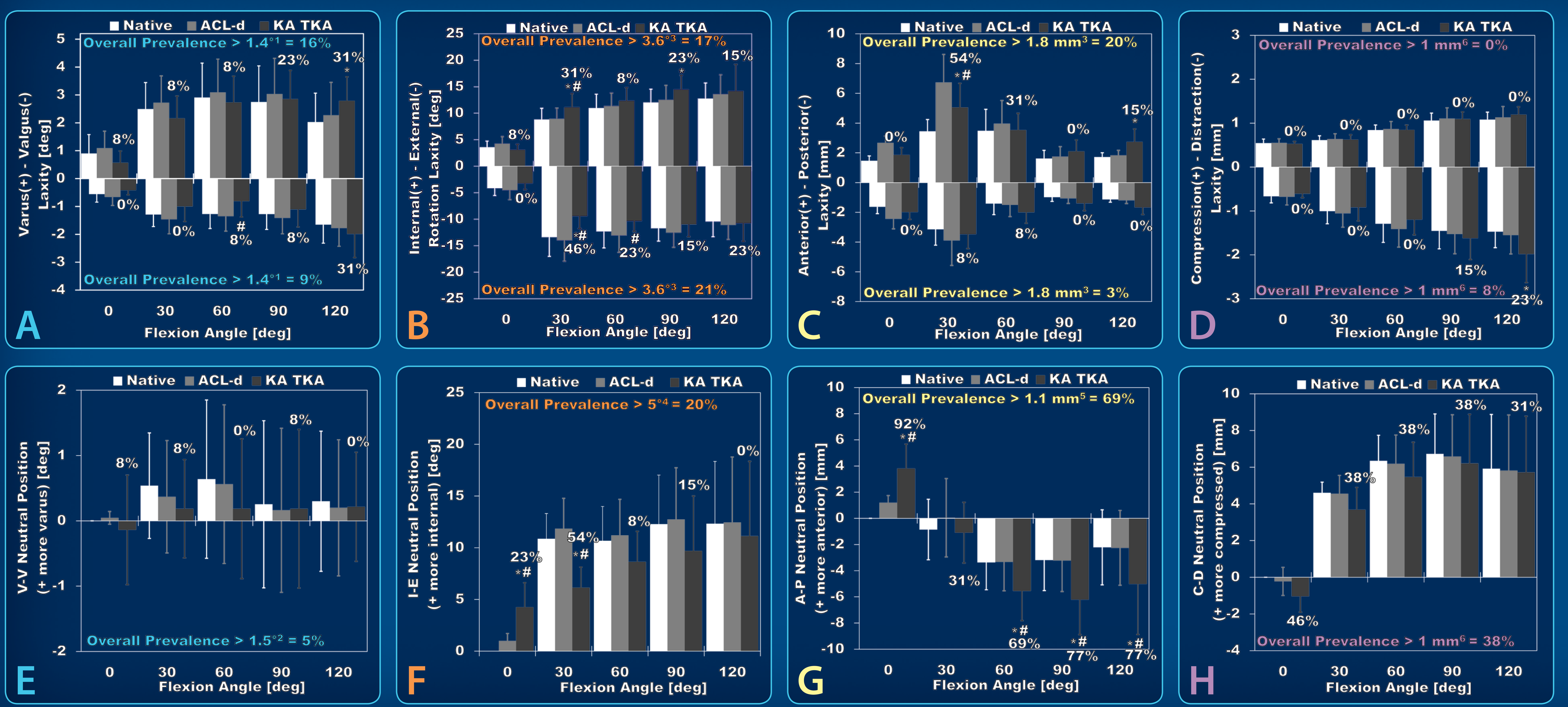

Figure 2. Vertical bar charts show the mean (bars) and standard deviation (error bars) of the V-V (A&E), I-E (B&F), A-P (C&G), and C-D (D&H) laxities and neutral positions of the knee in each of the three conditions: native, ACL-d, and KA TKA. The results of the *post hoc* pairwise comparisons using the Bonferroni method at individual flexion angles are denoted by an asterisk (*) when the change/shift after KA TKA was significantly different ($p < 0.005$) from that of the native knee and by a number sign (#) when the change/shift after KA TKA was significantly different ($p < 0.005$) from that of the ACL-d knee. The percentage value listed for each flexion angle indicates the prevalence of clinically important changes/shifts (Table 1) in the 13 KA TKAs. The overall prevalence is based on all 65 changes/shifts determined for each laxity/neutral position after KA TKA relative to native (13 knees × 5 flexion angles/knee).

CONCLUSION

The finding that KA TKA prevented clinically important changes/shifts in ≥ 79% of the measured values in ten of the twelve laxities/neutral positions indicates that KA TKA generally restored to native two important metrics of knee function despite the two unavoidable changes. This finding helps explain the clinical results that show KA TKA has a low risk of failure at 6 years[12] and leads to high patient satisfaction and function at 6 months to 6 years[13-16].

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