Do Varus-Valgus and Internal-External Malalignments of the Femoral Component in Kinematically Aligned TKA Cause Changes in Contact Force Imbalance and Laxities?

Jeremy A. Riley[1] , Stephen M. Howell[1,2], Maury L. Hull[1,2,3]

[1]Biomedical Engineering Graduate Group; [2]Department of Mechanical Engineering; [3]Department of Biomedical Engineering, University of California, Davis, Davis, CA

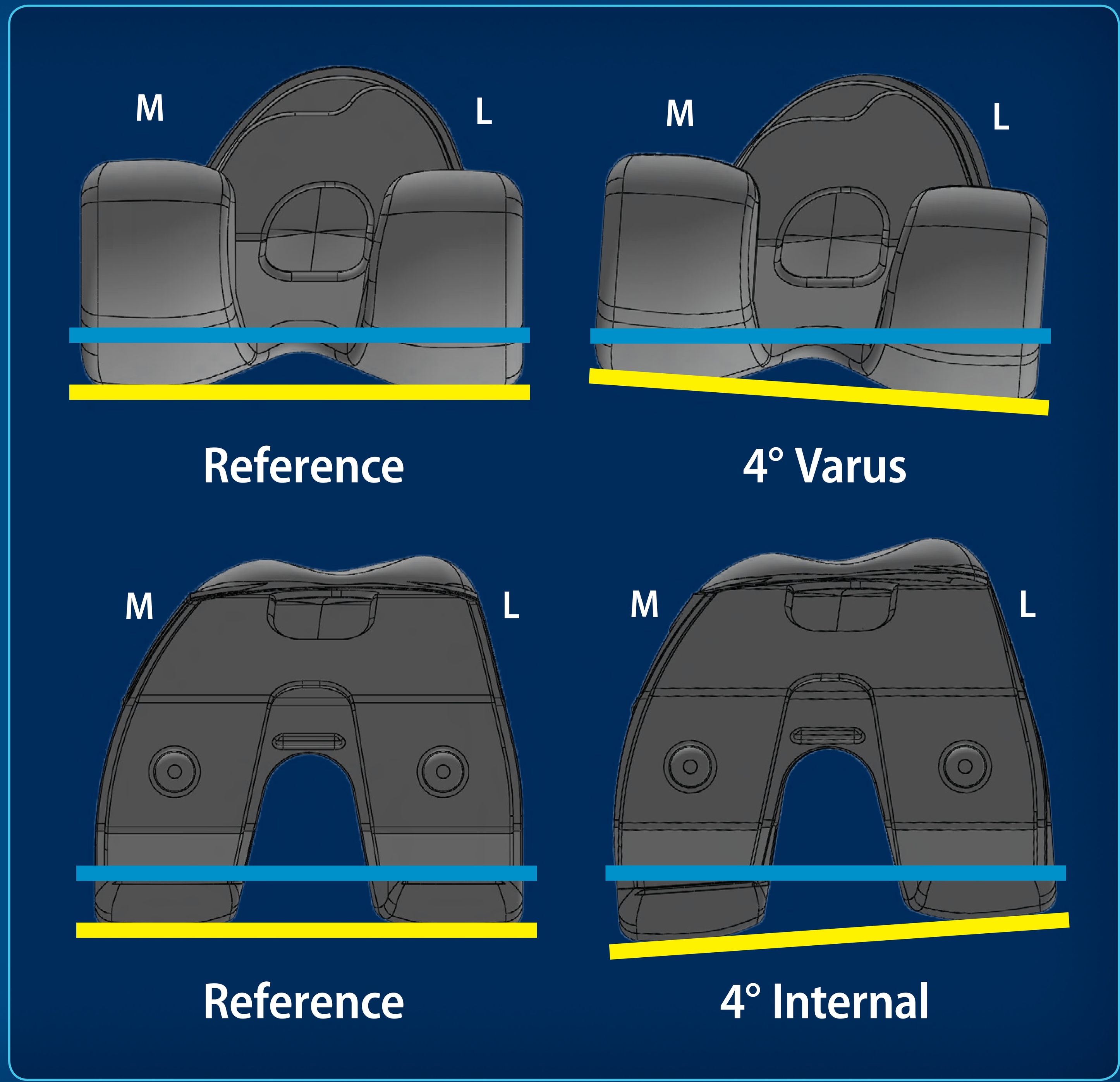
INTRODUCTION

Although the goal of kinematically aligned total knee arthroplasty (KA TKA) is to restore the native joint lines of the tibiofemoral joint, errors are possible when making the bone resections. Accordingly, one objective of this study was to determine whether 2° or 4° of varus-valgus (V-V) or internal-external (I-E) malalignment of the femoral component causes clinically important changes in contact force imbalance and laxities. A second objective was to mathematically determine the amount of V-V malalignment which causes clinically important changes in contact force imbalance.

METHODS

1. Ten fresh-frozen human cadaveric knees were included. KA TKA was performed on each knee.
2. V-V and I-E malalignment was introduced by modifying the design of the femoral component using 3D modelling software (Figure 1). Increments of 2° and 4° in each DOF and one non-malaligned reference component were 3D printed. All femoral components fit on the same cement mantle.
3. A custom tibial force sensor was used to measure medial and lateral contact forces from 0° to 120° flexion in 15° increments. A custom six degree-of-freedom load application system was used to measure laxities in I-E, V-V, anterior-posterior (A-P) , and compression-distraction (C-D) from 0° to 120° flexion in 30° increments.
4. A two-factor repeated measures ANOVA was performed. The two factors were femoral component malalignment at five levels and flexion angle at five levels. Tukey's test was used to compare the mean values from each malaligned femoral component to those of the reference femoral component.

Figure 1. CAD drawing showing the reference component in its coronal view (top left) and axial view (bottom left) compared with two malaligned components. Yellow lines show an exterior surface of each component. Blue lines show an interior surface of each component.



RESULTS

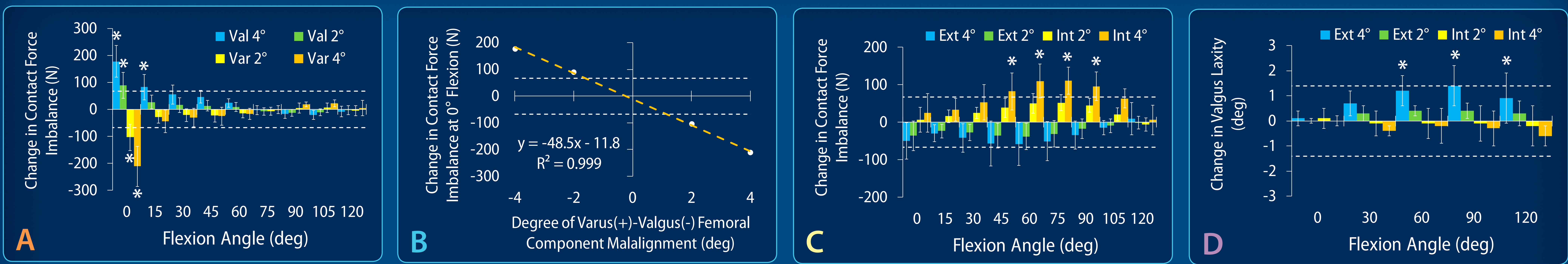


Figure 2. (A) Bar graph showing significant changes in contact force imbalance exceeding the 67 N clinically important threshold (Gustke et al., J Arthroplasty, 2014) at 0° flexion with 2° varus (-103 N), 4° varus (-211 N), 2° valgus (89 N), and 4° valgus (178 N) malaligned femoral components ($p < 0.001$). **(B)** Simple linear regression showing a near perfect straight line ($r^2 > 0.99$). Using the slope of -48.5 N/degree, a 67 N imbalance equates to 1.4° of V-V malalignment. **(C)** Bar graph showing significant changes in contact force imbalance with the 4° internal component, with the maximum of 125 N at 75° flexion ($p < .001$). **(D)** Bar graph showing a significant change in valgus laxity of 1.4° at 90° flexion with the 4° external component, equal to the 1.4° clinically important threshold (Creaby, BMC Musculoskelet Disord, 2013).

CONCLUSION

Keeping V-V and I-E alignment errors to less than 1.4° and 2°, respectively, can prevent clinically important changes in contact force imbalance and laxities. To obtain these tolerances, the distal and posterior femoral resection thicknesses, after correcting for cartilage wear and kerf of the saw blade, should be within approximately 0.5 mm and 0.8 mm, respectively, of the corresponding thicknesses of the distal and posterior condyles of the femoral component.

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