

The Impact of Implant Design and Surgical Alignment on Posterior Stabilized Knee Kinematics

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Introduction: Studies have recognized the presence of patient-perceived noise generation after posterior stabilized (PS) knee replacement¹. Such patients were more likely to report post-operative functional limitations and the presence of a limp, joint swelling and stiffness². In another fluoroscopic study, researchers recorded vibrations (sound) during deep knee bend (DKB) fluoroscopy³ and found high vibrations correlated with impact spikes and an irregular transition during initial CAM-post engagement³. Comprehensive analysis of the T-F joint kinematics and CAM-post engagement mechanics may shed more light on such irregularities. Therefore, the objective of this study was to investigate the impact of implant design and surgical alignment on the T-F kinematics of two PS-knee solutions and observe mechanism of the impact spikes during CAM-post engagement.

Methods:

A half-factorial design of experiments (DOE) was constructed to evaluate the impact of tibial implant slope (0° and 5°), femoral implant flexion (0° and 5°), and collateral ligament stiffness (normal and 50% reduced) on the kinematics of two different PS TKA solutions. A DKB simulation, from 0°-120°, of all configurations was conducted using a previously validated⁴ Forward Dynamics Model (FDM) (See Figure 1).

Two PS TKA solutions included, the Attune® PS (DePuy-Synthes) and Sigma® PS (DePuy-Synthes) total knee arthroplasty (TKA). The Attune® femoral component includes the GRADIUS™ (gradually reducing sagittal radius) geometry while the Sigma® has a multi-radii J-curve. The medial and lateral Femoral Lowest Point (LP) motions for all runs were reported during simulated DKB. From LP motion, four output parameters were calculated: anterior medial slide in mid flexion, post engagement angle, internal-external rotation in flexion, and screw-home rotation in extension.

Results: The LP kinematic for both TKAs are shown in Fig.-2. Tibial implant slope influenced the Femoral anterior slide, showing increase in anterior slide with increasing posterior slope. Whereas CAM-post engagement occurred at later flexion angles with higher posterior slope. Additionally, with 5°-tibial slope, the LP motion curve observed an abrupt change in direction when the post engaged. Comparing the two implant designs, Sigma® experienced posterior slide in early flexion ($\leq 20^\circ$ flexion), switched to anterior slide until CAM-post engagement, followed by abrupt reversal in motion to posterior until terminal flexion. In contrast, the Attune TKA demonstrates significantly less anterior translation and a smooth CAM-post engagement without abrupt changes in direction.

Conclusion: Previous clinical study found the incidence of hearing or feeling noise was less with the Attune¹ (compared to Sigma, 17.7% vs 30.9%; $P=0.02$). The smooth CAM-post transition may have reduced the occurrence of noise. Additionally, the interactive DOE approach highlighted Tibial posterior slope as the most influencing factors, amongst studied variables, to affect the CAM-post mechanics and potentially leading to patient perceived noises. Therefore, in summary, the study indicated criticality of both implant design and surgical alignment impact PS TKA kinematics. Thus, surgeons should consider the CAM-post engagement and the potential for impact spikes and/or noise generation when selecting tibial slope.

References:

1. Ranawat et.al-JOA 2016
2. Nam et.al-CORR 2017
3. Zingde PhD Dissertation 2015
4. Khasian et.al. J. Arthroplasty 2020
5. Fitzpatrick et al-JOR 2012

Figures

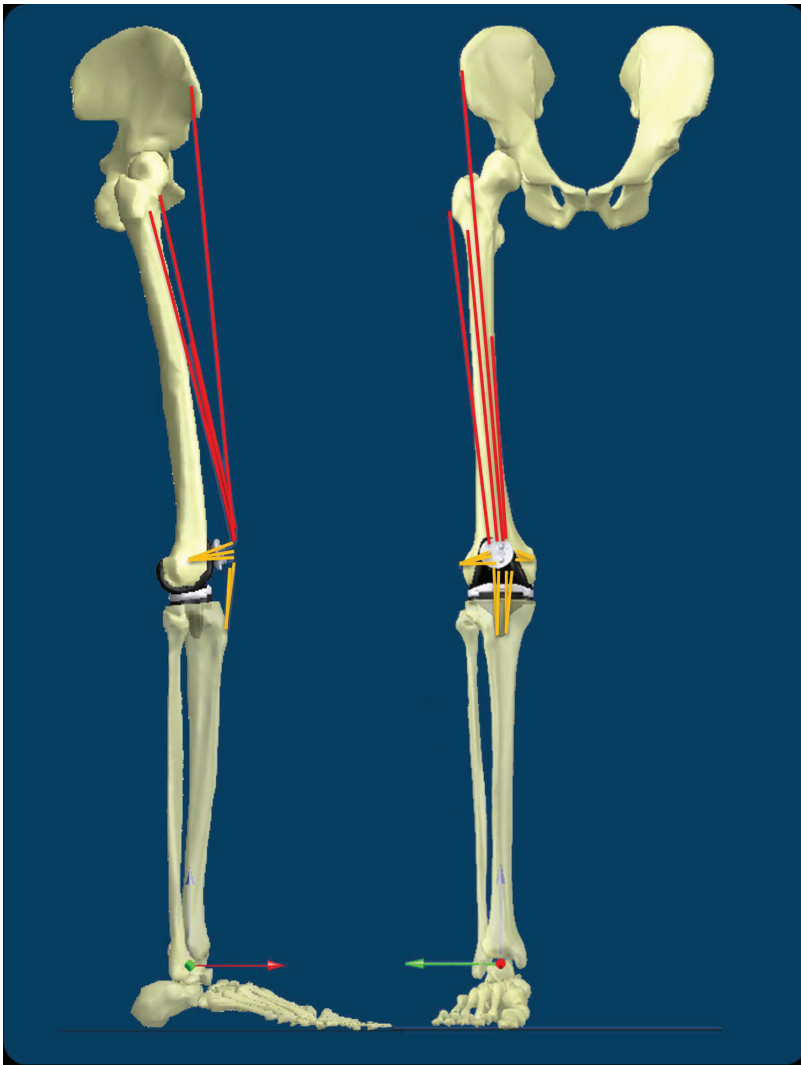


Figure 1: The Forward Dynamics Model used in this study. Including the major bones, muscles, ligaments, and implants of the knee joint.

Figure 1

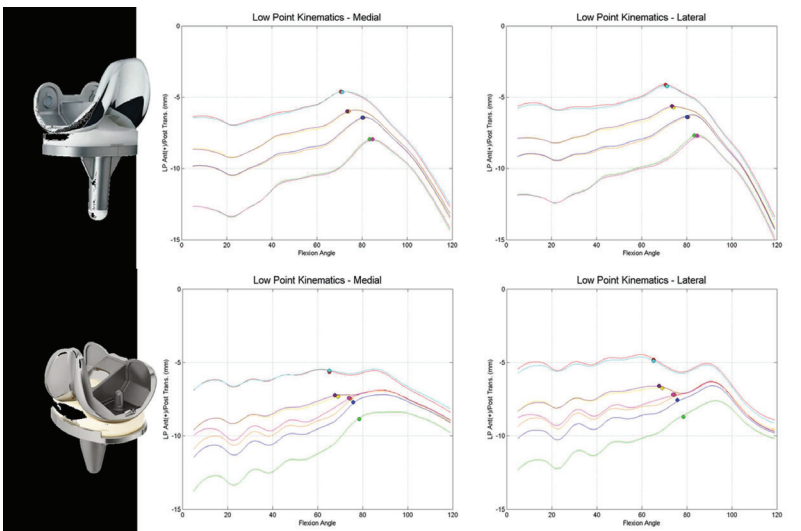


Figure 2: Low point kinematic for the Sigma (TOP) and Attune (BOTTOM) TKAs. The eight different colors represent the 8 DOE runs. The colored dots indicate the initial engagement of the CAM-post.

Figure 2