

Extensor Mechanism Kinematics in Hinged Knee Systems: A Comparison of a Posterior and Central Hinge

Azhar Ali¹, Oliver Jenner¹, Geoffrey Westrich²

¹Stryker, Mahwah, NJ, 07430; ²Hospital for Special Surgery, 535 E 70th St, New York, NY 10021
Azhar.Ali@stryker.com

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INTRODUCTION: Hinge knee systems are used in complex primary knee reconstruction with gross ligamentous insufficiency, neuromuscular conditions, or oncology cases as well as complex revision reconstructions involving significant bone or soft tissue loss [1]. Two main hinge designs exist: the posterior hinge design where the hinge mechanism is located across the posterior condyles of the distal femur, and the central intercondylar hinge design where the hinge mechanism is located centrally around the intercondylar notch. This study compares extensor mechanism function between a posterior hinge system and a central hinge system using patient-specific finite element (FE) model simulating knee extension.

METHODS: A previously validated, force-driven FE model of a healthy subject was leveraged for comparison of extensor mechanism function between the natural condition, posterior hinge system, and central hinge system. The model simulated seated knee extension captured using 50 Hz dynamic bi-plane fluoroscopy, motion capture, and electromyography. Posterior and central hinge components were virtually aligned using a mechanical alignment approach by an experienced surgeon to achieve clinically relevant fit between femoral/tibial boss and canal (Figure 1). The patella was resurfaced using a 36mm dome patella and aligned with the goal of maximizing coverage and restoring native patellar thickness. The simulation applied a PID-controlled quadriceps force calibrated to match the subject's fluoroscopic flexion, enabling prediction of patellofemoral kinematics, extensor loads, patella tracking, and effective moment arm.

RESULTS: The posterior and central hinge restored native patellar medial-lateral (ML) tracking from 0-120° flexion by an average root mean square error of 3.2 mm and 5.5 mm, respectively (Figure 2C). Peak quadriceps forces occurred at full extension and were 22.8% lower in the posterior hinge (1,313.8 N) than the central hinge (1,690.6 N) (Figure 3A). Similarly, peak patellar tendon forces were 12.9% lower in the posterior hinge (1,225.3 N) than the central hinge (1,497.5 N) (Figure 3B).

DISCUSSION: The posterior hinge system with a posteriorly placed hinge axis increased the moment arm in extension resulting in a 22.8% reduction in peak forces required to extend the knee relative to the central hinge thus increasing quadriceps efficiency. The posterior hinge design demonstrated improved quadriceps function and patellar tracking relative to the central hinge system, which may help enable improved function during activities of daily living.

SIGNIFICANCE/CLINICAL RELEVANCE: The posterior hinge design reduced extensor mechanism loading and improved patellar tracking relative to the central hinge, which may support complex primary and revision knee reconstruction for patients with limited quadriceps strength or compromised soft tissue. By enhancing mechanical efficiency and patellofemoral kinematics with improved patella tracking, this design has the potential to enhance postoperative function, and support return to activities of daily living.

REFERENCES: [1] Rodríguez-Merchán EC. Total knee arthroplasty using hinge joints: Indications and results. *EFORT Open Rev.* 2019;4(4):121-132.

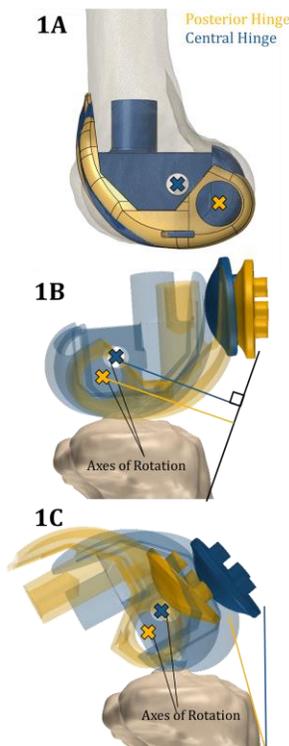


Figure 1: An overlay of the central hinge and posterior hinge assembled onto the femur (1A), central and posterior hinge aligned to the finite element model in extension (1B) and flexion (1C)

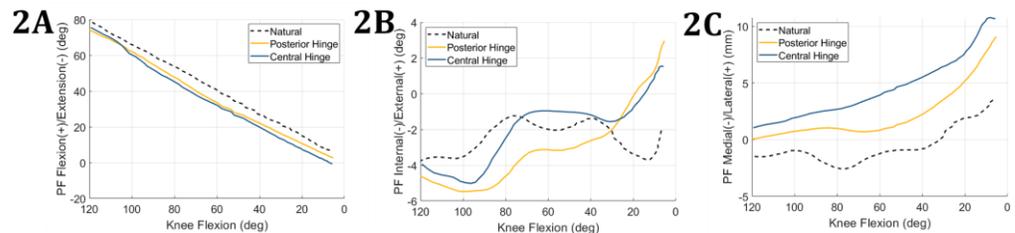


Figure 2: Patellofemoral (PF) kinematics of the central hinge, posterior hinge, and natural knee: PF flexion/extension (2A), PF internal/external (2B), and PF medial/lateral (2C)

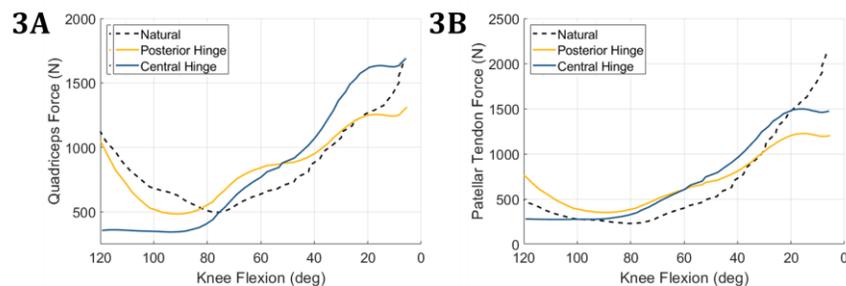


Figure 3: Quadriceps (3A) and patellar tendon force (3B) of the central hinge, posterior hinge, and natural knee through the range of flexion for the knee extension activity.