

# Biomechanical Comparison of Intra- versus Extra-Incisional Pin Placement in Robotic Total Knee Arthroplasty: A Cadaveric Study

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**INTRODUCTION:** Robotic-assisted total knee arthroplasty (rTKA) offers enhanced precision but introduces new challenges, including the risk of pin-site fractures from tracker fixation. This study aims to biomechanically evaluate the effects of intra-incisional versus extra-incisional pinning on torsional rigidity to failure and fracture propagation patterns in cadaveric femurs and tibias. We hypothesize that intra-incisional pinning confers higher torsional resistance strength.

**METHODS:** Twenty matched cadaveric femurs and tibias were randomized to intra-incisional (metaphyseal) or extra-incisional (diaphyseal) pinning. Specimens were cemented into jigs and subjected to torsional load-to-failure. Real-time data for torque, rotation, and time were recorded. Fracture patterns, pin-site involvement, and torsional rigidity, calculated as the slope of the linear elastic region (Nm/rad), were determined. Torque was defined using the equation:  $T = r \times F \times \sin(\theta)$ , where  $r$  is the lever arm,  $F$  is the applied force, and  $\theta$  is the angle of application.  $p$ -value  $< 0.05$  was considered statistically significant.

**RESULTS:** Extra-incisionally pinned femurs exhibited an 80% fracture rate, including 60% pin-site fractures, compared to 20% fractures with no pin-site involvement in the intra-incisional group. Mean femoral torsional rigidity was significantly higher ( $p=0.007$ ) in the intra-incisional group (13.7 Nm/rad, 95% CI: 9.32-18.1) versus the extra-incisional group (3.69 Nm/rad, 95% CI: -2.39-9.78). In the tibia, one pin-site fracture (20%) occurred in the extra-incisional group, with none in the intra-incisional group. Intra-incisional tibias also demonstrated higher mean torsional rigidity (8.24 Nm/rad, 95% CI: 6.68-9.81) compared to extra-incisional tibias (4.42 Nm/rad, 95% CI: -0.79-9.63). Overall, 80% of extra-incisional specimens fractured versus 30% in the intra-incisional group ( $p=0.0123$ ). We postulate: 1. Quantitatively, the tibial metaphysis, where intra-incisional pins are inserted, has a comparatively wider diameter, increasing the moment arm ( $r$ ) and thus torsional strength; 2. The metaphyseal region, rich in cancellous bone, also allows for improved load distribution and elastic deformation before failure.

**DISCUSSION:** Our intra-incisional pinning technique offers biomechanical advantages over extra-incisional pinning, including significantly greater torsional rigidity and reduced fracture risk. These findings support our intra-incisional pin placement technique being safer, particularly as post-operative patients undergo early full weight bearing mobilization and may experience high torsional forces when pivoting during ambulation, or from accidental falls.

**SIGNIFICANCE/CLINICAL RELEVANCE:** This study addresses the critical issue of pin-site fractures in rTKAs, which can significantly impact patient recovery and surgical outcomes. Our cadaveric study demonstrates that intra-incisional pinning is a biomechanically proven method to enhance surgical safety by directly reducing intra-operative risk of pin-site fractures, ultimately improve patient outcomes, making this study a valuable contribution to the advancement of rTKA procedures.