



Changes in Flexion and Extension Gaps After Tibial Tubercle Osteotomy and Quadriceps Snip During Total Knee Arthroplasty: A Sequential Cadaveric Study

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Purpose: Quadriceps snip (QS) and tibial tubercle osteotomy (TTO) are extensile exposure techniques used during revision total knee arthroplasty (TKA) and complex primary TKA. We evaluated whether QS and TTO alter intraoperative flexion and extension gaps in a cadaveric TKA model.

Methods: Six fresh cadaveric knees from three cadavers underwent medial parapatellar exposure and standardized bone resection. The flexion gap at 90° and extension gap at 0° were measured using a tensioning device applying 40 lb (178 N) of force. TTO was performed, and both gaps were remeasured. The tibial tubercle was anatomically fixed, after which QS was performed and the measurements were repeated. This was a sequential within-specimen design with a fixed procedural order. Changes after TTO and QS were compared using paired *t*-tests.

Results: Mean true flexion and extension gaps were 13.24 ± 3.06 mm and 9.47 ± 1.52 mm, respectively. TTO increased the flexion gap by 3.64 ± 1.48 mm, whereas QS increased it by 1.50 ± 1.13 mm. The mean difference in flexion-gap change was significant (2.14 mm; 95% CI, 0.89 to 3.38; *P* = 0.007). Extension-gap changes were small: 0.79 ± 1.20 mm after TTO and 0.20 ± 0.67 mm after QS, without a significant difference (0.59 mm; 95% CI, -0.41 to 1.60; *P* = 0.190).

Conclusions: In this sequential cadaveric TKA model, TTO produced a greater flexion-gap increase than the subsequent QS stage, whereas no significant difference in extension-gap change was detected. The fixed procedural sequence should be considered when interpreting these exploratory findings.

Keywords: tibial tubercle osteotomy, quadriceps snip, flexion gap, extension gap, total knee arthroplasty, extensor mechanism

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During revision total knee arthroplasty (TKA) or complex primary TKA, limited exposure can hinder component removal, bone preparation, and gap assessment, thereby increasing the risk of extensor mechanism injury. Della Valle et al. emphasized that adequate exposure constitutes a key principle of revision TKA ⁽¹⁾. During extensile exposure, the release of the extensor mechanism may alter the measured flexion gap, which can

affect intraoperative gap balancing. QS and TTO are commonly used extensile exposure techniques to improve surgical visualization during complex primary or revision TKA, particularly when standard approaches do not provide adequate access due to stiffness, prior surgery, or complex deformity. These techniques allow surgeons to mobilize the extensor mechanism safely and improve visualization of the joint surfaces, facilitating accurate component placement and soft-tissue balancing. Several studies have described their utility in complex primary and revision TKA, highlighting their role in managing challenging cases while seeking to minimize complications and preserve postoperative function ⁽²⁻⁵⁾.

Sun et al. compared QS and TTO in revision surgery for infected TKA and reported clinical outcomes after these exposure techniques ⁽⁶⁾. Bruni et al. performed a randomized prospective comparison of TTO and QS in two-stage revision for prosthetic knee infection ⁽⁷⁾. These reports mainly focused on exposure, clinical outcomes, and complications. Ismailidis et al. reported that a controlled increase in the flexion gap may influence postoperative knee flexion after TKA ⁽⁸⁾. Boettner et al. reported clinical outcomes after posterior-stabilized TKA using an increased flexion gap in patients with preoperative stiffness ⁽⁹⁾. However, the direct intraoperative effect of QS and TTO on flexion and extension gaps remains unclear.

The purpose of this cadaveric study was to compare changes in the flexion gap after TTO and QS during TKA. The secondary objective was to compare changes in the extension gap after the two techniques.

MATERIALS AND METHODS

Study Design and Specimens

This cadaveric study included six fresh cadaveric knees from three donors (one male and two female; mean age, 74 years; range, 55–91 years). A fixed sequential within-specimen protocol was used: baseline measurement, TTO, anatomic TTO refixation, and QS. The sequence was not randomized or counterbalanced. Eligible specimens had no history of trauma or surgery around the

knee, no obvious deformity, and intact surrounding muscles, bones, and ligaments. Radiographic or intraoperative osteoarthritis severity was not formally graded.

Exclusion criteria were isolated knee specimens that were not preserved as part of an intact limb segment, and knees with stiffness. Furthermore, specimens were excluded if they sustained intraoperative injury to the collateral ligaments or if the tibial tubercle, patellar tendon, patella, or quadriceps muscle was found to be incompetent. Bone resections and gap measurements were performed using a posterior-stabilized knee arthroplasty system.

Surgical Technique

Each knee underwent a medial parapatellar approach based on standard TKA exposure. Osteophytes, the menisci, the infrapatellar fat pad, the anterior cruciate ligament, and the posterior cruciate ligament were removed with the knee in flexion.

For femoral preparation, the entry point for the intramedullary drill was placed 10 mm anterior to the origin of the posterior cruciate ligament insertion, and a 9-mm distal femoral resection was performed at 5° of valgus ⁽¹⁰⁾. A posterior-referenced sizing guide was used to determine femoral component size, with the larger size selected when the femur was between two sizes. Femoral rotation was set at 3° of external rotation relative to the posterior condylar axis, followed by the completion of the anterior, posterior condylar, and chamfer cuts.

For tibial preparation, an extramedullary guide was aligned from the middle of the posterior cruciate ligament insertion to the medial one-third of the tibial tubercle. The posterior tibial slope was set to neutral. The proximal tibia was resected 9 mm from the most proximal point of the lateral tibial plateau. Before bone resection and extensile exposure, the patellar height was assessed, and no gross abnormality, including patella alta or patella baja, was identified in any specimen. As part of the standard medial parapatellar exposure, the deep medial collateral ligament was released. No additional soft-tissue release, including release of

the superficial medial collateral ligament or lateral structures, was performed before the baseline gap measurements were obtained.

TTO was performed by cutting along the tibial ridge to create an osteotomy fragment 6 cm in length, 2 cm in width, and 1.5 cm in thickness, while preserving the patellar tendon attachment (Figure 1). The flexion and extension gaps were measured under the same tension-device protocol and compared with the true gaps. The TTO fragment was anatomically reduced by direct visual confirmation that the cortical margins were restored to their original position and then fixed with two 4.5-mm cortical screws. Gap measurements were not repeated after TTO refixation and before QS.



Fig. 1 Osteotomy of the tibial tubercle.

QS was performed by cutting the quadriceps tendon 4 cm proximal to the superior pole of the patella at approximately 45° toward the vastus lateralis through the original wound (Figure 2). Flexion and extension gaps were then measured again under the same tension-device protocol and compared with the true gaps.

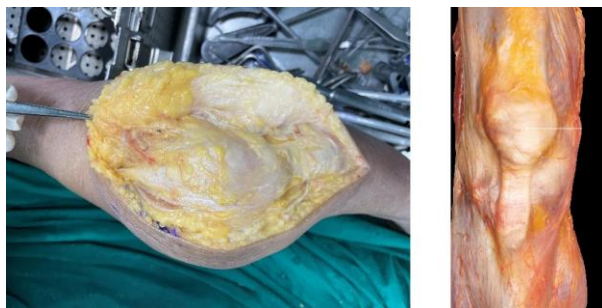


Fig. 2 Quadriceps snip.

Gap Measurement

The flexion gap was measured at 90° of knee flexion and recorded as the true flexion gap before TTO or QS (Figure 3). The extension gap was measured at 0° and recorded as the true extension gap (Figure 4). All measurements were performed using the same tension device with a total distraction force of 178 N (40 lb), and the gap was measured centrally using a vernier caliper⁽¹¹⁾. The patella was maintained in a laterally subluxed position and kept consistent across the baseline, post-TTO, and post-QS measurements. Each gap measurement was repeated three times by the same observer using an identical technique, and only the mean of the three measurements was retained for analysis. Blinding to the surgical stage was not possible because the operative condition was directly visible during measurement.

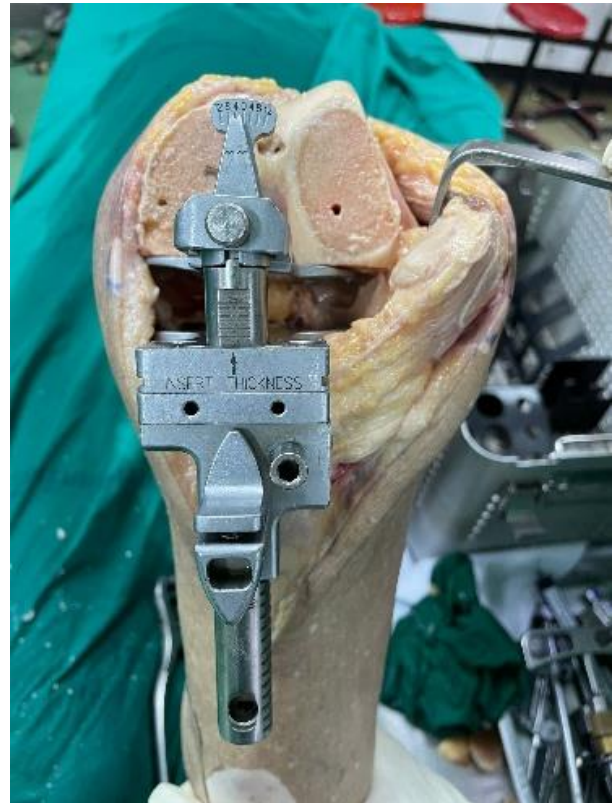


Fig. 3 Flexion-gap measurement using a tension device.



Fig. 4 Extension-gap measurement using a tension device.

Outcomes and Statistical Analysis

The primary outcome was the change in flexion gap after TTO and QS compared with the true flexion gap. The secondary outcome was the change in the extension gap after TTO and QS compared with the true extension gap.

Continuous variables are reported as mean $\pm$ standard deviation. Because TTO and QS were

assessed sequentially in the same cadaveric knees, paired *t*-tests were used to compare changes in flexion and extension gaps between stages. Mean differences, 95% confidence intervals (CIs), and *P* values were reported, with the threshold of statistical significance set at $P < 0.05$.

Ethics Approval

This cadaveric study was approved by the institutional review board of Lerdsin Hospital (IRB No. LH661073).

RESULTS

The mean true flexion and true extension gaps were 13.24 ± 3.06 mm and 9.47 ± 1.52 mm, respectively. After TTO and QS, the flexion gap increased by 3.64 ± 1.48 and 1.50 ± 1.13 mm, respectively. The mean difference in flexion-gap change between TTO and QS was 2.14 mm (95% CI, 0.89–3.38; $P = 0.007$).

The extension-gap changes were smaller than the flexion-gap changes. TTO increased the extension gap by 0.79 ± 1.20 mm, whereas QS increased the extension gap by 0.20 ± 0.67 mm. The difference in extension-gap change between TTO and QS was not statistically significant (mean difference, 0.59 mm; 95% CI, –0.41 to 1.60; $P = 0.190$; Table 1). The mean absolute flexion and extension gaps were 13.24 and 9.47 mm at baseline, 16.88 and 10.26 mm after TTO, and 14.74 and 9.67 mm after QS, which corresponded to mean flexion–extension mismatches of 3.77, 6.62, and 5.07 mm, respectively.

Table 1 Changes in flexion and extension gaps after TTO and QS.

Parameter	TTO, mean $\pm$ SD change (mm)	QS, mean $\pm$ SD change (mm)	Mean difference (95% CI)	<i>P</i> -value
Flexion gap	3.64 ± 1.48	1.50 ± 1.13	2.14 (0.89–3.38)	0.007
Extension gap	0.79 ± 1.20	0.20 ± 0.67	0.59 (–0.41 to 1.60)	0.190

Abbreviations: CI, confidence interval; QS, quadriceps snip; SD, standard deviation; TTO, tibial tubercle osteotomy.

DISCUSSION

The most important finding of this study is that extensile exposure changed the measured flexion gap in a sequential cadaveric TKA model.

TTO increased the flexion gap by 3.64 ± 1.48 mm, whereas the subsequent QS stage increased it by 1.50 ± 1.13 mm relative to the original baseline. However, the extension-gap changes were smaller.

As QS was performed after TTO and anatomic tubercle refixation, the fixed procedural sequence may have contributed to the observed difference between stages and should be considered when interpreting these findings.

These findings add a mechanical perspective to the existing literature. Della Valle et al. emphasized the need for adequate exposure in revision TKA ⁽¹⁾. DeHaan et al. described TTO as a useful method to improve exposure during revision TKA ⁽³⁾. Sun et al. compared QS and TTO in revision for infected TKA and reported clinical outcomes after each approach ⁽⁶⁾. In contrast, the present study directly measured how these approaches changed the flexion and extension gaps during TKA.

Flexion-gap control is clinically important. Ismailidis et al. reported that controlled flexion-gap imbalance may influence postoperative knee flexion after TKA ⁽⁸⁾. A possible explanation for the greater flexion-gap increase after TTO is that distal extensor-mechanism release reduces anterior soft-tissue restraint more than QS, which preserves the patellar tendon insertion and tibial tubercle continuity. However, this explanation should be considered hypothesis-generating. The relatively small extension-gap changes may reflect the limited contribution of the extensor mechanism to anterior restraint in full extension compared with 90° of flexion. Because these measurements were obtained before final repair, the observed gap changes should not be used directly to guide polyethylene thickness, component sizing, or final gap balancing. In clinical practice, gap assessment should be repeated after provisional repair of the extensile exposure and restoration of the intended patellar position before selecting the final insert.

The baseline flexion gap was larger than the extension gap (mean mismatch, 3.77 mm), which possibly reflects the standardized experimental preparation, including PCL resection and the absence of additional gap-balancing releases. Baseline flexion laxity may have influenced the magnitude of the observed response to extensor-mechanism release and should be considered when interpreting the findings.

This study has some limitations. First, the small sample size and lack of an *a priori* power analysis limit the ability to detect small differences, particularly in extension-gap change. Second, because QS was assessed after TTO and tubercle refixation, the fixed procedural sequence may have influenced the subsequent measurement and should be considered when interpreting the findings. Third, the six knees were obtained from three donors, and potential within-donor correlation should be considered when interpreting the analysis. Because only summarized values were retained, specimen-level reanalysis and formal nonparametric sensitivity analysis were not available. Furthermore, with only six paired observations, assessment of the normality assumption was limited. Although each gap measurement was repeated three times by the same observer under a standardized tensioning protocol and averaged, formal intraobserver reliability statistics were unavailable. Finally, as a cadaveric study, the findings may not fully reflect in vivo muscle tone, soft-tissue behavior, healing, or postoperative function. Osteoarthritis severity was not formally graded, and measurements were obtained using a single implant system, tension value, and surgical protocol. Further studies with larger samples and formal reliability assessment would help confirm these findings.

CONCLUSION

In this sequential cadaveric TKA model, extensile exposure was associated with changes in measured flexion gaps, with a greater increase observed during the TTO stage than the subsequent QS stage. The fixed procedural sequence should be considered when interpreting the comparison between stages. No significant difference in extension-gap change was detected. Nonetheless, these findings should be considered exploratory and warrant further validation before application in final implant sizing or gap-balancing decisions.

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