In robotic-assisted total knee arthroplasty, manual stress and gap spacers underestimate the joint gap

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INTRODUCTION:

Robotic-assisted total knee arthroplasty (TKA), which simultaneously adjusts ligament balance and bone resection, is becoming increasingly widespread. In robotic-assisted TKA, the amount of bone resection and the cutting angles are determined based on intraoperative ligament balance measurements. Currently, two methods have been used to assess ligament balance during surgery: (1) manually applying varus and valgus stress, and (2) inserting curved gap spacers into the medial and lateral joint compartments. However, these methods have been reported to exhibit low reproducibility. Assessing ligament balance using such unreliable techniques and determining bone resection based on these measurements may result in postoperative poor ligament balance and malalignment, potentially compromising the outcomes of robotic-assisted TKA. Importantly, prior to bone resection, conventional tensioners could not be inserted into the joint. To address this limitation, we developed a novel tensioning device that can be inserted into both the medial and lateral joint compartments before bone resection (Figure 1). The aim of this study was to compare ligament balance measurements obtained using three methods: manual stress, gap spacers, and the newly developed tensor device.

METHODS:

This study included consecutive 59 primary TKAs performed for medial compartment osteoarthritis using a robotic-arm assistance system. A medial parapatellar approach was used, and the cruciate ligaments, menisci, and osteophytes were excised. Pin trackers were placed for registration. The medial and lateral joint gaps were measured at full extension (0°) and at 90° flexion using the robotic system, under the following three conditions (Figure 2); 1) Manual application of varus and valgus stress, 2) Insertion of curved gap spacers into the medial and lateral joint compartments, 3) Insertion of the tensor device into both compartments with 60 N of distraction force applied to each. Each measurement was performed twice, and the average values were used for analysis.

RESULTS:

The joint gap measurements are summarized in Table 1. In extension, the medial joint gap was significantly smaller when using the gap spacers compared to both the tensor and manual methods ($p < 0.05$). Significant differences among the three methods were also observed in the lateral joint gap at extension, the medial joint gap at flexion, and the lateral joint gap at flexion (all $p < 0.05$). The tensor device consistently yielded the largest gap measurements, followed by the manual method, with the gap spacers producing the smallest gaps. Although intraclass correlation coefficients (ICCs) were high across all methods, the tensor device demonstrated the highest reproducibility, followed by the manual method. The gap spacer method showed the lowest reproducibility (Table 1).

DISCUSSION AND CONCLUSION:

This study indicates that both the manual stress and gap spacer methods may underestimate the actual joint gap compared to the 60 N tensor for medial and lateral side. This underestimation is particularly evident in flexion, where the joint may be 2–3 mm looser than anticipated. Since approximately 1 mm of bone resection corresponds to a 1° change in resection angle, underestimating the joint gap by 2–3 mm may result in significant imbalance. Therefore, using manual stress or gap spacers for soft tissue assessment may lead to inaccurate bone resection and compromised ligament balance. For robotic-assisted TKA, the use of a tensor device is recommended over manual stress or gap spacers, as it provides a more reliable and reproducible assessment of intraoperative ligament balance.

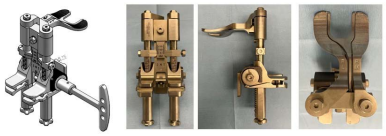

Figure 1: This novel tensor device features curved thin paddles, enabling tensioning of both the medial and lateral compartments prior to bone resection. The offset design prevents impingement on the patellar tendon following patellar reduction.

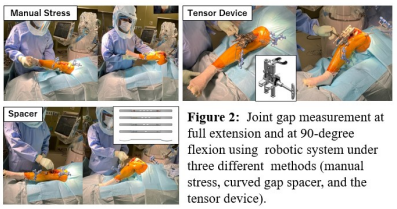

Figure 2: Joint gap measurement at full extension and at 90-degree flexion using robotic system under three different methods (manual stress, curved gap spacer, and the tensor device).

Table 1: Joint Gaps (mm) and ICC measured using three different methods

Position	Curved Gap Spacer	Manual Stress	Tensor Device
Extension Medial	2.4 ± 2.1 (ICC = 0.885)	4.1 ± 2.5* (ICC = 0.909)	5.0 ± 2.4** (ICC = 0.963)
Extension Lateral	1.6 ± 1.6 (ICC = 0.939)	2.5 ± 1.6 † (ICC = 0.900)	3.9 ± 2.3 † (ICC = 0.942)
Flexion Medial	2.2 ± 2.1 (ICC = 0.940)	3.4 ± 2.2 † (ICC = 0.934)	4.4 ± 1.8 † (ICC = 0.947)
Flexion Lateral	1.6 ± 1.4 (ICC = 0.844)	2.9 ± 2.0 † (ICC = 0.898)	5.5 ± 2.1 † (ICC = 0.956)

*p<0.05: between manual stress and spacer,
**p<0.05: between tensor device and spacer,
†p<0.05: between three methods.