comparision of reliability between paddle and valgus and varus forces to evaluate the gap in pre-resection balancing in robotic-assisted total knee arthroplasty

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INTRODUCTION:

Osteoarthritis of the knee is a degenerative condition that significantly impairs mobility and quality of life. When non-surgical options such as physical therapy or activity modification fail, Total Knee Arthroplasty (TKA) becomes necessary. While conventional TKA is effective, Robotic-Assisted TKA (RA-TKA) has emerged as an alternative with improved surgical precision, enhanced implant alignment, and reduced early postoperative complications.

A key step in RA-TKA is intraoperative gap assessment, which guides bone resection and soft tissue balancing. Two common techniques include the use of a paddle and manual varus-valgus stress application. The gap can vary based on the magnitude and direction of the applied force, potentially affecting consistency. To date, no consensus exists regarding the most reliable method. This study aims to compare the reliability of both techniques by evaluating the intraclass correlation coefficients (ICCs) between staff surgeons and adult reconstructive surgery fellows.

METHODS:

This prospective study included 75 knees undergoing RA-TKA. Patients with complex primary or revision TKA were excluded. The mean patient age was 69.13 ± 7.14 years, with a mean BMI of 26.80 ± 4.18. Right-sided procedures accounted for 52%. The study was approved by the Institutional Review Board (IRB No. 222/2567) and registered with the Thai Clinical Trials Registry (TCTR20250411006).

All patients received spinal anesthesia and underwent a medial parapatellar approach. Signal transmitters were attached to the femur and tibia for robotic tracking. Fellows performed gap assessments first using the varus-valgus force method at 10° and 90° of knee flexion, applying force until joint resistance. The paddle method was then used by inserting progressively larger paddles until joint space was filled. Staff surgeons independently repeated both methods.

Medial and lateral gaps at each position were recorded. ICCs were calculated to assess interobserver reliability, and a >2 mm difference was considered clinically significant. A sample size of 75 knees was based on an expected ICC of 0.75 with a 95% confidence interval.

RESULTS:

Both methods were used on all 75 knees. For the stress technique, ICCs at 90° flexion were 0.840 (medial) and 0.810 (lateral), and at 10° extension were 0.896 (medial) and 0.928 (lateral). The paddle technique yielded superior reliability at 90° flexion: 0.938 (medial) and 0.877 (lateral), and similar results at 10° extension: 0.918 (medial) and 0.928 (lateral).

Subgroup analysis revealed that right knees showed higher agreement across both techniques. The paddle method in right knees achieved ICCs of 0.972 (medial) and 0.916 (lateral) at 90° flexion. In contrast, left knees evaluated using the stress method showed lower ICCs, particularly in flexion: 0.718 (medial) and 0.717 (lateral).

Gap size comparisons revealed that the paddle technique produced significantly larger lateral gaps in both extension and flexion and larger medial gaps in flexion when assessed by staff surgeons ($p < 0.05$). Clinically relevant interobserver differences (>2 mm) were more frequent with the stress technique, especially in flexion: 10.7% (medial and lateral). With the paddle method, differences >2 mm occurred in only 1.3% (medial) and 10.7% (lateral) in flexion.

DISCUSSION AND CONCLUSION:

This study demonstrated that both techniques provided high interobserver reliability for gap assessment during RA-TKA. The paddle method consistently showed higher ICCs in flexion, likely due to its passive design and standardized joint space filling. The stress technique introduced more variability, especially in flexion and in knees contralateral to the surgeon's dominant hand.

Our findings align with previous studies highlighting the simplicity and reproducibility of the paddle method. The stress technique, while still reliable in extension, is influenced by manual force inconsistencies and may result in greater interobserver variability.

The results suggest that the paddle technique is more dependable for assessing flexion gaps, while the stress method may be better suited for extension gaps when applied with consistent force. A hybrid approach could enhance surgical planning and soft tissue balancing.

In conclusion, both paddle and stress techniques are effective for intraoperative gap assessment in RA-TKA. The paddle method offers superior reproducibility in flexion and consistently larger gap values. The stress technique remains reliable in extension but shows increased variability, especially with knee contralateral to the surgeon's dominant hand. Employing

both techniques strategically may optimize soft tissue balance and surgical outcomes in robotic-assisted knee arthroplasty.