# Impact Of The Surgical Workflow And Technology Change On Early Clinical Outcomes In Total Knee Arthroplasty

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INTRODUCTION: One singularity of total knee arthroplasty (TKA) compared to other joint replacements relates to the large panel of surgical workflows depending on the order of the bone cuts as well as the definition of the alignment references used for the set-up of these bone cuts. In addition of the surgical workflow, there exits numerous variations of the instrumentation type ranging from conventional mechanical instrumentation to advanced enabling technology. Any change to the surgical workflow and/or the instrumentation type may have an impact on surgeons' habits and ultimately on patients' clinical outcomes. This study evaluates the clinical and technical impact of changing from a femur-first measured resection (MR) workflow to a tibia-first gap balancing (GB) workflow. Both workflows were performed using the same computer assisted orthopaedic surgery (CAOS) system, with the GB workflow further integrated with a force-controlled distractor. To capture the effect of the learning curve, the analysis compared two distinct time points to capture differences between the early adoption phase and the later refined phase of the GB workflow.

METHODS: A retrospective cohort of 225 consecutive primary TKAs performed by a single senior surgeon using the same CAOS platform was analyzed. Patients were divided into three groups: MR (n = 75), GB early (first 75 GB cases), and GB late (subsequent 75 GB cases). The MR workflow (Figure 1) prioritized mechanical alignment through landmark based distal and posterior femoral cuts prior to tibial resection, while the GB workflow (Figure 1) employed a tibia-first approach using a force-controlled distractor applying 90 N per compartment to acquire medial and lateral gap profiles dynamically across full arc of flexion. Knee injury and Osteoarthritis Outcome Score for Joint Replacement (KOOS Jr.) was collected preoperatively and at one-year follow-up. Intraoperative bone resection parameters (femur external rotation, femur varus/valgus, femur flexion, tibia varus/valgus, tibial slope, and tibial insert thickness), and both planned and final (checked) joint gaps were analyzed. Statistical analyses included Welch's t-tests, Mann–Whitney U, Fligner–Killeen variance tests, and one-way ANOVA with Tukey post hoc comparisons, with significance set at $p < 0.05$.

RESULTS SECTION: Demographic analysis showed no BMI differences across groups, although patients in the GB late group were slightly younger than those in GB early ($p = 0.0096$). Figure 2 presents KOOS Jr. results. KOOS Jr. outcomes were comparable preoperatively (MR: 48.2 ± 10.4; GB early: 48.2 ± 11.5; GB late: 45.5 ± 13.1; $p = 0.26$). At one year, all groups improved, but GB late achieved the highest score (79.6 ± 16.2), compared to GB early (75.9 ± 13.9) and MR (75.5 ± 15). Improvements were greatest in GB late (34.1 ± 20.9), significantly higher than both GB early (+6.4 points, $p = 0.036$) and MR (+6.8 points, $p = 0.025$). MR and GB early did not differ ($p = 0.89$). Technical analysis showed that GB adoption increased variability in femoral resections (Figure 3a). Planned femoral flexion increased over time, with GB late (2.8 ± 0.5°) significantly greater than MR (2.0 ± 0.3°) and GB early (2.2 ± 0.8°). Tibial slope increased progressively (MR: 3.0 ± 0.2°; GB late: 3.8 ± 0.3°; $p < 0.05$), while femoral varus/valgus alignment shifted closer to neutral. Tibial insert thickness remained consistent across cohorts indicating preservation of joint line height. Gap analysis (Figure 3b) revealed tighter and more symmetric balancing in GB late compared to GB early. Planned gaps were significantly reduced by 0.59 mm medially and 0.46 mm laterally, with similar but slightly attenuated differences preserved in checked gaps (–0.53 mm medial, –0.29 mm lateral). Median profiles confirmed uniformly tighter gaps across flexion in GB late knees, reflecting a deliberate reduction in laxity targets over time, reflecting increased surgical confidence and adaptation to soft tissue driven planning.

DISCUSSION: All cohorts showed significant improvement in KOOS Jr. scores at one year, confirming the overall effectiveness of TKA across workflows. The GB late group achieved the greatest gain, with a clinically meaningful advantage of 6.4 to 6.8 points compared to MR and GB early. The GB early cohort achieved outcomes equivalent to MR, suggesting that initial adoption of GB does not compromise results, while refinement over time yields superior outcomes. Transitioning to GB introduced greater variability and flexibility in femoral resections, particularly in external rotation and varus/valgus alignment, reflecting the philosophy of soft tissue guided planning. By the late phase, femoral flexion increased in a more consistent manner, supporting improved flexion gap control. Tibial slope also evolved, increasing over time as the surgeon moved from a fixed MR target toward more personalized adjustments. Gap analysis reinforced these trends, showing progressively tighter and more symmetric gaps in GB late. Such refinements likely reflect greater confidence in soft-tissue tensioning and contribute to improved proprioception, stability, and patient satisfaction. Together, the technical refinements of increased femoral flexion, steeper tibial slope, and tighter gap targets explain the superior KOOS Jr. outcomes observed in GB late. Beyond technical adjustments, the results also reflect a shift in surgical philosophy. MR is rooted in fixed mechanical alignment, while GB allows intraoperative adaptation based on dynamic gap data. The early GB phase represented a transitional stage where conventional alignment instincts remained influential. By the late phase, the surgeon demonstrated full confidence in gap-driven planning, resulting in more balanced, individualized outcomes.

SIGNIFICANCE/CLINICAL RELEVANCE: Clinically, these findings indicate that while early adoption of gap balancing achieves outcomes comparable to measured resection, refinement of the technique leads to superior clinical outcomes, underscoring the value of dynamic, soft tissue guided planning in total knee arthroplasty.

IMAGES AND TABLES:

Figure 1: Overview of workflows with CAOS and force-controlled distractor

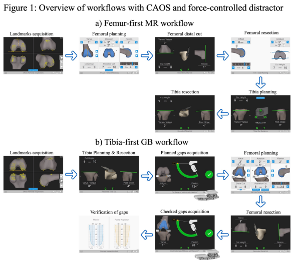

Figure 2: Preoperative (top), postoperative (middle), and improvement (bottom) in KOOS Jr. scores by surgical group

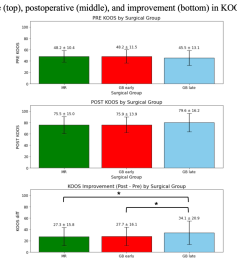

Figure 3: Comparison of a) planned bone resection parameters, b) planned and checked gaps across surgical cohorts