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Research Article

Functional Outcomes of Measured Resection vs. Gap Balancing in Total Knee Arthroplasty

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Abstract

Background: Total knee arthroplasty (TKA) is the gold standard surgical intervention for treating end-stage knee osteoarthritis (OA). Measured resection (MR) and gap balancing (GB) are the primary surgical techniques that are employed to achieve these outcomes. Each of these procedures has its own distinct principles and advantages; MR is completely based on predetermined bone cuts and femoral rotation whereas GB is truly based on native knee anatomy. Their comparative impact on short-term recovery, implant alignment, and long-term outcomes remains debated, highlighting the need for evidence-based guidance. This study was conducted to compare the functional outcomes, complications, and patient-related outcomes of these two different techniques in the hands of a single surgeon.
Methods: A prospective randomized study was carried out with 60 patients undergoing TKA. They were categorized as the MR group (Group MR) or the GB group (Group GB). Functional recovery was the primary outcome and was assessed using the Knee Society Score (KSS) and the Western Ontario and McMaster Universities Arthritis Index (WOMAC) score. Secondary outcomes included tourniquet times, postoperative visual analogue scale (VAS) score, and postoperative knee flexion at various intervals.
Results: The GB subset demonstrated statistically significant improvement one month following surgery in both KSS Part 1 ($P < 0.001$) and KSS Part 2 ($P = 0.004$) and larger reduction in WOMAC score ($P < 0.001$), suggesting rapid and comprehensive functional recovery and early improvement in pain and joint stiffness. However, the difference between the two groups was not statistically significant at 12 and 24 months post-operatively.
Conclusion: GB offers superior short-term outcomes, but the choice of surgical technique should take into account individual patient profile or patient-specific factors, the surgeon's operative experience, and implant survivorship.

Keywords: Knee Arthroplasty; Osteoarthritis of Knee; Outcome Measures; Range of Motion

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Background

Total knee arthroplasty (TKA) has become a cornerstone procedure in orthopedic surgery, offering a reliable solution for end-stage osteoarthritis (OA) of the knee (1, 2). The success of TKA depends upon restoration of limb alignment, accurate placement of implant, and optimal flexion and extension gap balancing (GB). Malpositioning of the femoral or tibial component can lead to early loosening, increased polyethylene wear, and poor patellar tracking (3-5).

Broadly, the main methods of prosthesis implantation to attain a well-balanced knee joint are measured resection (MR) and GB (6).

The MR procedure involves resection of bone equal in thickness to the prosthetic components. The distal femur is resected at a specific angle, relative to the femoral shaft (7) and bony landmarks guide femoral component rotation during other anterior and posterior cuts (8, 9). Tibial resection is performed perpendicular to the tibial axis. Finally, ligament balancing is done after the trial components are in situ.

On the other hand, in the GB technique, initial cuts made to the distal femur and proximal tibia are minimal, which allows soft tissue access. The ligaments are balanced in extension to obtain equal and rectangular gaps (Figure 1). The knee is then flexed, and the joint space is distracted using lamina spreaders, tensor balancers, or joint distractors. Subsequently, the posterior femoral cut is made parallel to the tibial cut (10). This ensures a rectangular flexion gap that matches the extension gap (11, 12).

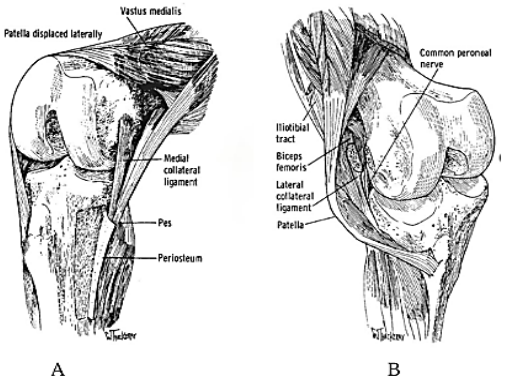

Figure 1. Soft tissues around the knee; A. Medial release, B. Lateral release (9)

This study evaluates the relative effectiveness of these two widely employed surgical techniques via a comprehensive analysis of a range of postoperative

outcomes including range of motion (ROM), implant alignment, patient-reported measures [e.g., Western Ontario and McMaster Universities Arthritis Index (WOMAC)], and complication rates. The intent is to provide valuable insights that may help refine surgical technique based on patient-specific anatomical or functional needs and enhance early recovery in TKA.

Methods

A prospective, randomized comparative study was conducted at a tertiary care center: GMERS Medical College and Hospital, Vadodara, Gujarat, India. It spanned two years, from 2022 to 2024, following approval from the Institutional Ethics Committee. A total of 60 patients who were planning to undergo primary unilateral TKA were enrolled in the study. They were randomly assigned to either group MR or group GB with 30 participants in each group. Randomization was based on the sequence of registration (even numbers for group MR and odd numbers for group GB). Allocation concealment was used.

Sample size was calculated assuming a pooled standard deviation (SD) of 7.9 units; accordingly, the study would require a sample size of 30 subjects for each group. So, the study included a total of 60 patients, with 30 in each group, as per the sample size calculation to achieve a power of 70% and a level of significance of 5% (two sided), for detecting a true difference in means between the test and the reference group of 5.9 units.

Inclusion criteria were: 1) all the patients undergoing unilateral primary TKA for advanced arthritis of knee, 2) patients giving consent for planned follow-up protocol, and 3) patients giving consent for study.

Exclusion criteria were: 1) patient unfit for surgery, 2) patient with mental illness or cognitive dysfunction, and 3) case with neurovascular deficit of the affected limb.

Preoperative clinical work-up included plain radiographs in anteroposterior (AP) (erect posture) and lateral views of the affected knee, plain radiographs of the spine and pelvis (to rule out referred pain or arthritis in other joints), scanograms to study limb alignment, preoperative knee flexion range assessment, visual analogue scale (VAS) score, Knee Society Score (KSS), and WOMAC score. Routine preoperative investigations and preanesthetic check-ups were carried out, and written informed consent was taken in accordance with institutional protocol. For the MR group, the implant used was the DESTIKNEE™ (Meril Life Sciences, Vapi, Gujarat, India), while for the GB group, the Buechel-Pappas™ Total Knee System (TTK Healthcare, India) was used. All the surgeries were performed under spinal anesthesia by using the standard midline parapatellar approach with the aid of a tourniquet by a single surgeon having over twenty years of experience in hip and knee arthroplasty.

Technique: In the MR group, a distal femoral cut at 5° valgus was performed using an intramedullary guide (Figure 1A), and a perpendicular tibial cut using an extramedullary guide (Figure 1B), both independently based on implant sizing. Extension gaps were balanced with selective ligament releases – typically the medial collateral ligament (MCL) in varus knees (Figure 2) to achieve a rectangular gap. Femoral component rotation was determined using anatomical landmarks, such as the transepicondylar axis or Whiteside's line (Figure 3), and generally fixed at 3° external rotation. Subsequently, anterior, posterior, and chamfer femoral cuts were completed with an appropriately sized cutting block. Osteophytes were removed from both femur and tibia, followed by tibial sizing. Trial components were inserted, and soft tissue balance was assessed intraoperatively by evaluating collateral ligament tension through the full ROM.

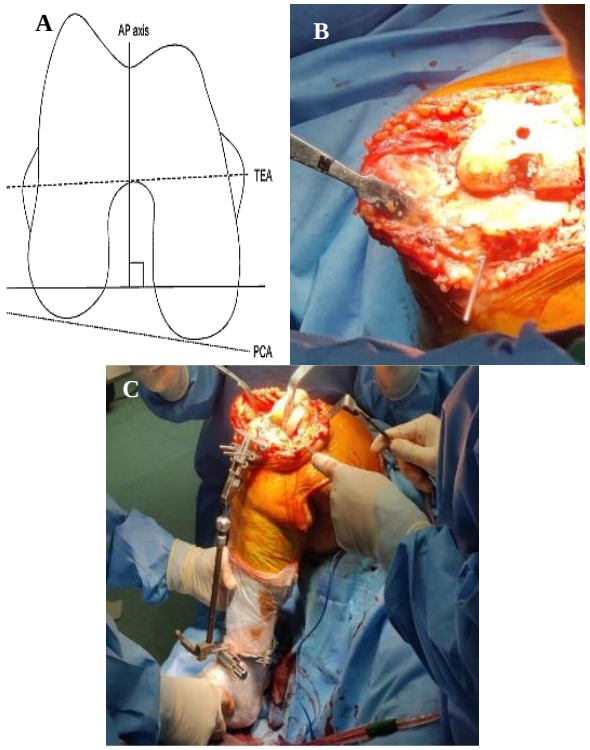

Figure 2. Measured resection (MR); A. Different landmark for distal femur cut, B. Entry point for intramedullary femur guide, C. Extramedullary tibial cutting guide (8)

In the GB group, preliminary cuts were made on the distal femur and proximal tibia to allow soft tissue access. These were not final cuts. Osteophytes were thoroughly removed from both femur and tibia prior to any ligament releases. Tight structures – typically the MCL in varus knees were released in extension until neutral alignment and a symmetric extension gap was achieved (Figure 3A, B). With the knee flexed, the joint was distracted to create a rectangular flexion gap matching the extension gap. Femoral component rotation was then determined based on the tibial cut, independent of the transepicondylar or AP axes, and only the posterior femoral cut was performed at this stage (Figure 3C).

Once balance was confirmed, anterior and chamfer cuts were made, and final components were cemented following trial reduction.

Ranawat cocktail was injected into the soft tissue in the knee and the wound was closed over a negative suction drain (13). Adequate dressing was applied over the wound after deflating the tourniquet.

Post-operative management consisting of intravenous (IV) antibiotics and analgesics was administered for two days, which was replaced by oral medications for ten days. The patients were discharged after a change in dressing after two days. Deep vein thrombosis (DVT) prophylaxis was administered using low-molecular-weight heparin (LMWH, 40 mg/0.4 ml subcutaneously) for seven days followed by aspirin 150 mg orally after dinner for three weeks and DVT pump during hospital stay.

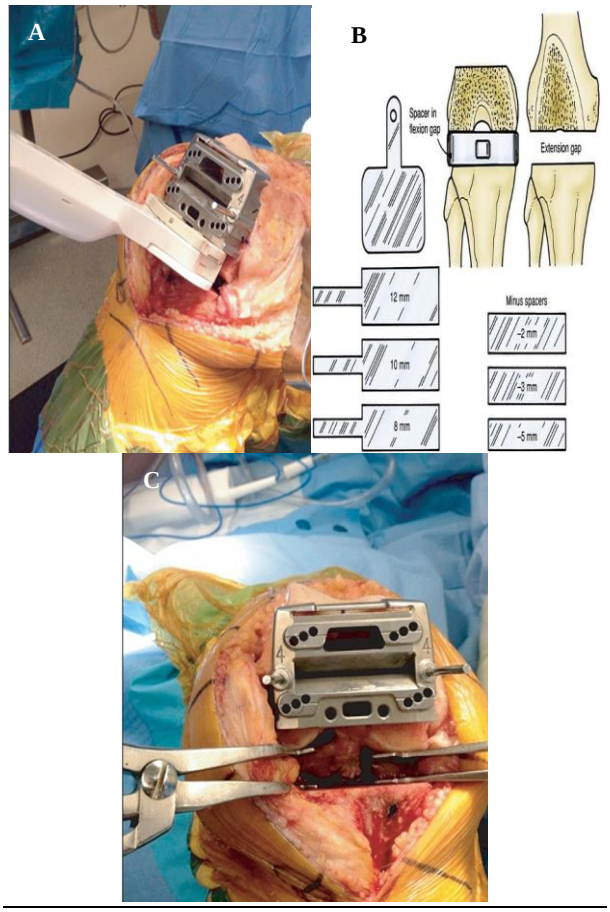

Figure 3. Gap balancing (GB); A. Spacer block in place, B. Different size spacer block, C. Lamina spreader giving equal tension on medial and lateral ligaments and anteroposterior (AP) femur cut taken parallel to cut tibia (10)

Physiotherapy was initiated immediately after the anesthesia effect wore off in the form of isometric quadriceps and vastus medialis oblique (VMO) strengthening and ankle-calf pumping. ROM exercises for the knee with high sitting and dynamic quadriceps exercises along with straight leg raises and hip adductor and abductor strengthening and full weight-bearing with walker support in a long knee brace began from the second postoperative day.

Outcome Measures: Pain was assessed using the VAS at 12, 24, and 48 hours post-operatively. Functional outcomes were evaluated using WOMAC and KSS scores at 1 month, 12 months, and 24 months post-operatively. The data were analyzed using unpaired t-tests for continuous variables, with the statistical significance set at $P < 0.05$.

Results

Improvement in KSS Score (Table 1): Preoperative KSS (Part 1 and Part 2) revealed no statistically significant difference between the two groups. However, at one month post-operatively, the GB group demonstrated a statistically significant improvement in both parts of the KSS compared to the MR group ($P < 0.05$). However, at 12 and 24 months post-operatively, the disparity between these groups was no longer statistically significant ($P > 0.05$). These findings indicate that the GB technique provides a more rapid and comprehensive functional recovery in knee function and patient-reported outcomes.

Table 1. Comparison of Knee Society Score (KSS) between two groups

Post-operative KSS score	Group MR (mean ± SD)	Group GB (mean ± SD)	P-value
KSS 1			
1 month	73.50 ± 5.09	78.30 ± 3.80	< 0.001
12 months	79.30 ± 5.93	80.00 ± 3.65	0.584
24 months	80.90 ± 4.32	81.80 ± 6.02	0.508
KSS 2			
1 month	73.70 ± 5.03	77.90 ± 5.91	0.004
12 months	79.60 ± 4.65	80.60 ± 5.15	0.433
24 months	81.60 ± 4.79	83.20 ± 5.16	0.218

KSS: Knee Society Score; MR: Measured resection; GB: Gap balancing; SD: Standard deviation

Improvement in WOMAC Score (Table 2): Preoperative WOMAC scores between the two groups were comparable. At the one-month follow-up, the GB group had a significantly greater reduction in WOMAC score ($P < 0.05$), indicating a more substantial early improvement in pain, stiffness, and functional limitations. However, the distinction in WOMAC scores at 12 and 24 months was not statistically significant ($P > 0.05$), suggesting similar long-term outcomes. Overall, as evidenced by these results, GB offers superior short-term functional benefits, while both techniques provide comparable outcomes in the long run.

Table 2. Comparison of Western Ontario and McMaster Universities Arthritis Index (WOMAC) score

Post-operative WOMAC	Group MR (mean ± SD)	Group GB (mean ± SD)	P-value
1 month	43.90 ± 6.59	36.80 ± 4.84	< 0.001
12 months	35.80 ± 5.05	34.60 ± 5.83	0.398
24 months	30.88 ± 5.53	33.44 ± 5.47	0.099

WOMAC: Western Ontario and McMaster Universities Arthritis Index; MR: Measure resection; GB: Gap balancing; SD: Standard deviation

Pain Reduction over Time (Table 3): VAS scores were recorded at 12, 24, and 48 hours post-operatively. Both groups demonstrated a decrease in pain severity over time; however, the GB group consistently had lower pain scores at all three points in time. This suggests that the GB technique is more effective for managing early postoperative pain.

Table 3. Improvement in visual analogue scale (VAS) score

Post-operative KSS score	MR	GB
VAS at 12 hours	9.92	8.44
VAS at 24 hours	8.54	7.76
VAS at 48 hours	7.35	6.57

VAS: Visual analogue scale; MR: Measured resection; GB: Gap balancing

Tourniquet Time and Post-Operative Knee Flexion (Table 4): The average tourniquet time was slightly longer within the GB group (61.8 minutes) compared to the MR group (59.3 minutes), but this difference was not statistically relevant. Tapasvi et al. reported similar results ($P = 0.929$) (14).

Although the difference is relatively small, the slightly longer duration in the GB group may reflect the technique's complexity and the need for precise soft tissue balancing. Postoperative knee ROM improved significantly in both groups. However, the GB group demonstrated a greater increase in ROM than the MR group (36° vs. 26°, respectively), potentially indicating superior postoperative mobility. These findings are consistent with Zhang et al., who also reported significantly greater flexion within the GB group ($P < 0.05$) (15).

Table 4. Tourniquet time and post-operative knee flexion

	MR	GB
Tourniquet time (P > 0.05) (mean ± SD)	59.30 ± 13.30	61.80 ± 9.89
Knee flexion improvement	26 (from 100 to 126)	36 (from 98 to 134)

MR: Measured resection; GB: Gap balancing; SD: Standard deviation

Discussion

Comparison with Previous Studies: Our findings are congruent with several other previously published studies. While technical differences exist between the MR and GB techniques, meta-analyses by Moon et al. (1) and Huang et al. (16) suggest comparable outcomes in terms of gap symmetry and clinical outcomes which is in line with most of the existing research.

Matsumoto et al. discovered a better balance in cruciate-retaining TKA compared to posterior-stabilized designs when using the GB technique; however, this did not translate into a difference in clinical outcome (17). Singh et al. reported improved functional scores in the GB group although the differences were not statistically significant (18). Similarly, Churchill et al. found comparable outcomes at the three-year follow-up mark (19).

Contrary to this, Pang et al. observed significantly better functional outcomes in the GB group at six months and two years, a possible implication of the long-term benefit of soft tissue-driven techniques (3).

Limitations: This study has several limitations. Firstly, the sample size was relatively small, and the study was conducted at a single center. This may limit the generalization of findings. There is also a potential for surgeon-related bias, as all procedures were performed within the same center and by the same surgeon which could influence the outcomes.

Secondly, patient follow-up was limited to 24 months; long-term data are required to assess the durability of outcomes and the possibility of late complications associated with each technique.

Additionally, the study did not account for possible confounding variables such as body mass index (BMI), pre-operative disease severity, or differences in the implant design. Furthermore, variability in patient compliance with the prescribed course of physiotherapy should be factored in. Future studies involving larger, multicentric cohorts with long-term follow-up which have been appropriately adjusted for confounding variables are imperative to validate these findings.

Conclusion

GB technique provides considerably better short-term outcomes in terms of knee function, patient-reported outcomes (KSS and WOMAC scores), and early reduction in pain and joint stiffness in comparison to MR. However, at 12 and 24 months post-operatively, this distinction is lost and is not significant statistically, indicating that both procedures offer analogous long-term outcomes.

MR demands less technical expertise and is associated with shorter operative times (as indicated by the tourniquet times), potentially reducing the risk of complications. Therefore, the choice of surgical technique should take into account a personalized or hybrid approach to TKA, taking into consideration the individual patient profile, the surgeon's operative experience, and implant survivorship.

Conflict of Interest

The authors declare no conflict of interest in this study.

Acknowledgements

The protocol used to evaluate data was approved by our institution's scientific review board and Institutional Human Ethics Committee (IHEC/22/OUT/SRPG037) on September 22, 2022.

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