

Original Research Article

Optimizing soft tissue balance through medial tibial reduction osteotomy in tight varus deformity during total knee replacement

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ABSTRACT

Background: Achieving appropriate soft-tissue balance during total knee replacement (TKR) in varus deformities is essential to prevent instability and optimize surgical outcomes. Medial tibial reduction osteotomy (MTRO) serves as a bony technique to reduce the need for extensive medial soft-tissue release in knees with tight varus deformity.

Methods: This prospective clinical study involved patients with osteoarthritic knees and significant varus malalignment scheduled for TKR. After initial bone cuts, persistent medial tightness prompted MTRO by removing a portion of the medial tibial plateau. The extent of resection was guided by intraoperative gap balancing aiming for equalized flexion and extension gaps. Deformity correction was assessed using clinical examination and postoperative radiographs. Functional outcomes were measured via the Knee Society Score (KSS) preoperatively and at follow-up.

Results: Fifty knees underwent MTRO with an average medial bone resection of 7.4 ± 2 mm, resulting in an average varus correction of $3.4^\circ \pm 1^\circ$. A positive correlation was noted between the degree of osteotomy and varus correction, especially in knees with deformities less than 15° . MTRO effectively enabled balanced joint gaps without extensive medial ligament release. Mean KSS improved significantly from 47 ± 9 before surgery to 93 ± 3 postoperatively. There were no increased rates of complications or joint instability.

Conclusions: MTRO is a valuable adjunct technique for correcting deformity and balancing soft tissues in tight varus knees during TKR, yielding favorable clinical results and minimal complications.

Keywords: Total knee replacement, Varus deformity, Medial tibial reduction osteotomy

INTRODUCTION

Osteoarthritis (OA) is a progressive joint disorder that leads to the deterioration of cartilage along with nearby tissues and stands as the predominant cause of disability in older people worldwide. Osteoarthritis may involve any joint, but the knee is usually the joint most commonly affected, with the hands and hips also being frequently involved.^{1,2} Current evidence suggests that knee osteoarthritis affects a substantial portion of the global population aged 40 and above, with prevalence estimates indicating that nearly one in five to one in four individuals in this age group is impacted worldwide.^{1,3} The prevalence of OA knee increases with age and is more common in

women.⁴ Knee osteoarthritis is one of the most frequently diagnosed disabling joint conditions among older adults in India.⁵ Research has shown that in those aged 55 and above, its prevalence can range from about 16% to nearly 27% and may be higher when using more sensitive diagnostic criteria. Furthermore, older Indian women tend to have a higher prevalence than men of similar age, and the condition is more common in urban populations and among people who engage in less physical activity. These osteoarthritic knees frequently are associated with both varus deformity and prominent osteophytes in the medial side of knee.⁶ These will thus lead to tenting of the soft tissue (including medial collateral ligament) on the medial aspect of the knee.^{7,8} The most effective treatment for end-

stage knee osteoarthritis still is total knee arthroplasty. While doing the total knee replacement removing medial osteophytes helps relax the medial soft tissue structures and partially corrects varus deformity, fully correcting the deformity and balancing the medial and lateral gaps may require performing a reduction osteotomy.⁹ This procedure involves excising the posteromedial bony flare of the proximal tibia to relieve tension on the medial soft tissues that remain taut despite osteophyte removal.¹⁰⁻¹² Reduction osteotomy had been previously identified as a technique to achieve deformity correction and balance between the medial and lateral gaps in varus arthritic knees, the extent to which reduction osteotomy contributes to this correction has not been quantitatively established in total knee arthroplasty (TKAs) performed for varus deformities. To our knowledge, no precise measurement of the degree of correction effected by this osteotomy in such procedures has been reported. In this study, we will be using various intra-operative measurements to identify the amount of reduction osteotomy required to achieve the ideal varus correction and the association between degree of deformity correction to amount of bone osteotomized.

The objective of the study is to determine the amount of varus deformity correction achieved through reduction osteotomy during TKA in varus knees and to determine the relationship between the degree of deformity correction, the amount of bone removed by Medial Tibial Reduction Osteotomy, and the initial severity of the varus deformity.

METHODS

After taking clearance to conduct the study from the local Human Research Ethics Committee. Informed consent was taken from all patients involved in our study and a case series of 50 cases was conducted. A knee surgeon performed the procedure on 50 primary conventional total knee arthroplasties (TKAs) over a 24-month interval from December 2023 to December 2025 in Belagavi Institute of Medical Sciences, Belagavi, Karnataka, India. These comprised 48 total knee arthroplasties performed on varus arthritic knees and 2 on valgus arthritic knees, as identified on preoperative full-length hip-to-ankle radiographs. Knees with a hip-knee-ankle angle of 180° or less were categorized as varus, while those with an angle greater than 180° were classified as valgus. This approach allowed precise tracking of surgical parameters during the conventional TKR procedures to optimize alignment and outcomes in varus knees. All primary total knee arthroplasty included in the study were performed to treat varus arthritic knees resulting from primary osteoarthritis, rheumatoid arthritis, or posttraumatic arthritis. All patients who had fully correctible varus deformities intraoperatively or varus deformities correctible to within 2° of the ideal hip-knee-ankle axis (i.e., 180°) were excluded from the research. In accordance with the exclusion criteria, 11 patients were excluded from the analysis, as their deformities were fully correctable and did not necessitate a reduction osteotomy. Out of the 50 that were finally selected 22 were bilateral who had a mean age

of 67 years which ranged from (42-75 years) and a mean BMI of 29 kg/m² (24-32 kg/m²) at the time of surgery.

All surgeries were performed using an anterior longitudinal incision combined with a medial parapatellar arthrotomy under tourniquet control. In every case, cruciate-substituting prosthesis was implanted and held in position with cement. Resurfacing of patella was not done in any of the cases.

The intraoperative protocol for this study involved several careful steps. Initially, both cruciate ligaments, menisci, and medial femoral osteophytes were removed to facilitate joint exposure. Soft tissue releases were avoided during early exposure, with medial release limited specifically to the anteromedial capsule and deep medial collateral ligament attached to the proximal tibia to allow anterior dislocation of the tibial plateau.

Varus deformity severity and correctability were assessed by applying maximal valgus stress to the fully extended knee with neutral limb rotation for Medial joint line tightness, a reduction osteotomy was planned. The medial resection amount was based on prior observations correlating 2 mm of bone removal to 1° of deformity correction. The osteotomy site was marked on the medial proximal tibia referencing tibial tray margins.

Tray size was selected based on femoral size and osteotomy to avoid oversizing after bone removal. After osteotomy, correction was measured by clinical examination; residual deformity ≤2° led to release of the semi-membranous attachment, whereas >2° deformity required further medial soft tissue release. Bone resections and soft tissue balance techniques were tailored based on deformity severity and laxity with aiding alignment, positioning, and sizing of components. Final alignment was confirmed after cementation. The analysis in this study was based exclusively on intraoperative data. During surgery, the degree of varus deformity was recorded both before and after the reduction osteotomy. Additionally, the amount of bone resected during the osteotomy and the final alignment achieved following prosthesis implantation were documented intra-operatively. Sample size was calculated using the Statistical Power Analysis formula for estimating required sample size.

$$n = \frac{2(Z_{\alpha} + Z_{\beta})^2 S^2}{d^2}$$

Z_{α} =1.96,

Z_{β} =0.84,

S=SD=12.3,

d=difference between means=1.29

$n=2(1.96+0.84)^2 \times$

$(12.3)^2 / (1.29)^2 = 7520.28 / 151.29 = 49.7 = 50.$

Total sample size:50.

RESULTS

On average, a medial tibial reduction osteotomy of approximately 2 mm produced about 1° of varus correction. In the cohort, a mean osteotomy of 7.4±2 mm resulted in a mean angular correction of 3.4°±1° during total knee arthroplasty.

Table 1: Patient demographics and perioperative parameters.

Parameters	Mean±SD	Range
Age (years)	66.4±7.0	52-82
BMI (kg/m ²)	27.8±3.5	20-36
Blood loss (ml)	301±90	120-520
Hospital stays (days)	5.3±1.1	3-9
Varus correction (°)	4.7±2.0	1-10

Case 1: 63y/M right OA knee (Kellgren Lawrence grade 4)

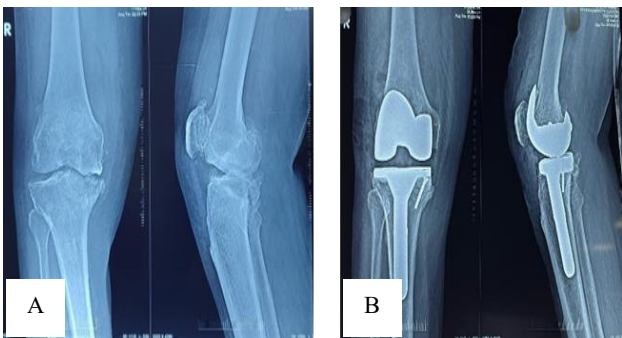


Figure 1 (A and B): Pre-operative X-ray and post-operative X-ray.

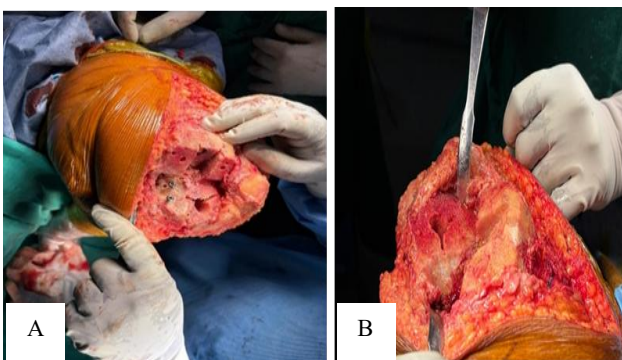


Figure 2 (A and B): Intraoperative.

A clear positive correlation existed between the amount of bone removed and the degree of correction achieved ($r=0.49, p<0.001$). This association was stronger among knees with preoperative varus deformity $<15^\circ$ ($r=0.58, p<0.001$) compared with those having $\geq 15^\circ$ deformity ($r=0.53, p<0.001$).

The pre-osteotomy residual varus also showed a strong positive correlation with the extent of correction obtained

($r=0.78, p<0.01$). Multivariate regression analysis showed that the extent of correction achieved was mainly determined by two key factors: the amount of osteotomy performed and the degree of residual varus present prior to the osteotomy.

Case 2: 52y/F right OA knee (Kellgren Lawrence grade 4)

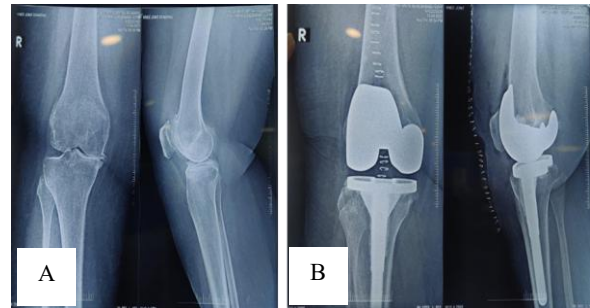


Figure 3 (A and B): Pre-operative X-ray and post-operative X-ray.

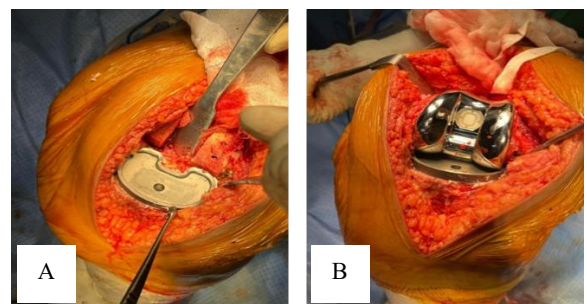


Figure 4 (A and B): Intraoperative.

Case 3: 63y/M left OA knee (Kellgren Lawrence grade 4)

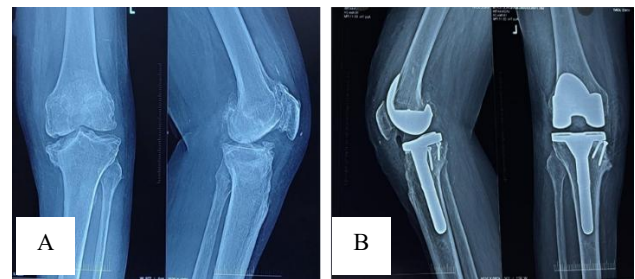


Figure 5 (A and B): Pre-operative X-ray and post-operative X-ray.

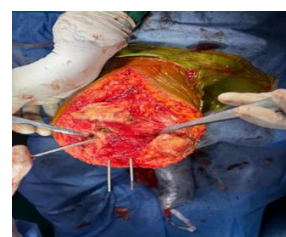


Figure 6: Intraoperative.

Fifty knees underwent MTRO with an average medial bone resection of 7.4±2 mm, resulting in an average varus correction of 3.4°±1°. A positive correlation was noted between the degree of osteotomy and varus correction, especially in knees with deformities less than 15°. MTRO

effectively enabled balanced joint gaps without extensive medial ligament release. Mean KSS improved significantly from 47±9 before surgery to 93±3 postoperatively. There were no increased rates of complications or joint instability.

Table 2: Functional outcomes (preoperative vs postoperative at 12 months).

Outcome	Preoperative (mean±SD)	Postoperative (mean±SD)	Mean improvement	P value
Knee society score (KSS)	46.3±10	84.1±9	+37.8	1.7×10 ⁻³⁶
Range of motion (°)	81.3±14	104.9±12	+23.6°	6.3×10 ⁻²⁸
VAS pain score	7.3±1.1	2.2±1.0		

Table 3: Complication profile.

Complication type	Number of patients	(%)
No complications	42	84
Minor complications	6	12
Major complications	2	4

DISCUSSION

In the present study, medial tibial reduction osteotomy (MTRO) was evaluated as an adjunctive technique to optimize soft tissue balance in patients with tight varus deformity undergoing total knee arthroplasty. The demographic profile of the study population, with a mean age of 66.4±7.0 years and mean BMI of 27.8±3.5 kg/m², is consistent with the typical population affected by degenerative osteoarthritis presenting with varus alignment.

These findings are comparable with previously published studies, were elderly patients with moderate to high BMI commonly present with medial compartment overload and varus deformity Insall et al.²

Perioperative parameters in the present study demonstrated that the addition of MTRO did not significantly increase surgical morbidity. The mean blood loss (301±90 ml) and hospital stay (5.3±1.1 days) were within acceptable limits for standard total knee arthroplasty procedures. Similar observations have been reported by Mullaji et al Who noted that reduction osteotomy can be safely performed without increasing perioperative complications, thereby supporting its feasibility as an adjunct procedure.²⁰

The mean varus correction achieved in the present study was 4.7±2.0°, indicating that MTRO allows controlled and predictable deformity correction. This is in accordance with the findings of Mullaji et al Who reported correction values ranging from 3° to 6° using medial tibial reduction osteotomy.¹³ The ability to achieve gradual and controlled correction is particularly important in tight varus knees, where excessive soft tissue release may lead to instability. Functional outcomes in the present study showed significant improvement following surgery. The Knee

Society Score improved from 46.3±10 preoperatively to 84.1±9 postoperatively, with a mean improvement of 37.8 points. This degree of improvement is comparable to that reported in previous studies evaluating outcomes after total knee arthroplasty, where improvements of 30-40 points have been consistently observed Ritter et al.¹⁶ The favorable functional outcome in the present study can be attributed to improved alignment and balanced soft tissue tension achieved through MTRO.

Range of motion in the Present study improved from 81.3°±14 preoperatively to 104.9°±12 postoperatively, with a mean gain of 23.6°. This is comparable with the range of motion gains reported in the literature, typically between 15° and 25° following Tka Dennis et al.¹⁷ The relatively higher improvement observed in the present study may be due to the preservation of soft tissue integrity and avoidance of excessive medial release, which facilitates better postoperative rehabilitation.

Pain assessment using the visual analogue scale demonstrated a significant reduction from 7.3±1.1 preoperatively to 2.2±1.0 postoperatively. This finding is consistent with previously published studies, where effective restoration of alignment and load distribution following TKA results in substantial pain relief. The improved pain outcomes in the present study further support the effectiveness of MTRO in achieving balanced knee mechanics.

A key observation in the present study was the quantifiable relationship between the amount of medial tibial reduction and the degree of varus correction achieved. On average, approximately 2 mm of osteotomy resulted in 1° of correction. A statistically significant positive correlation (r=0.49, p<0.001) was observed between osteotomy thickness and angular correction. This finding closely parallels the observations of Mullaji et al, who also reported a similar relationship between bone resection and deformity correction.¹² Such quantification provides a valuable intraoperative guideline for surgeons in achieving desired alignment.

Further analysis revealed that the correlation between osteotomy thickness and correction was stronger in deformities less than 15° (r=0.58) compared to those with

greater deformity ($r=0.53$). This suggests that MTRO is more predictable in mild to moderate varus deformities, while severe deformities may require additional balancing techniques. Similar trends have been reported in previous studies, where increasing deformity severity was associated with reduced predictability of correction.

The present study also demonstrated a strong positive correlation between pre-osteotomy residual varus alignment and the final correction achieved ($r=0.78$, $p<0.01$). This highlights the importance of intraoperative assessment and stepwise correction in achieving optimal outcomes. Mullaji et al reported a comparable strong correlation, emphasizing that residual deformity prior to osteotomy plays a crucial role in determining final alignment.¹³

Multivariate regression analysis in the present study identified the amount of osteotomy and pre-osteotomy residual varus alignment as the primary predictors of correction achieved. This finding reinforces the concept that both bony resection and intraoperative alignment assessment are critical in optimizing outcomes. While traditional techniques have focused primarily on soft tissue release, the present study highlights the importance of bone-based correction as an equally significant factor.

The complication profile observed in the present study was comparable to standard total knee arthroplasty outcomes, with 84% of patients having no complications, 12% experiencing minor complications, and only 4% developing major complications. These findings are consistent with previously published data, indicating that MTRO does not significantly increase the risk of complications when performed in a controlled manner.

Traditional management of varus deformity during total knee arthroplasty relies heavily on medial soft tissue release. However, excessive release may lead to instability, flexion-extension mismatch, and suboptimal outcomes. In contrast, MTRO provides a bone-based method of correction, allowing controlled realignment while preserving soft tissue integrity. Previous studies have emphasized that reduction osteotomy can reduce the need for extensive ligament release and improve joint stability Bellemans et al.¹¹ Thus, the findings of the present study is in agreement with existing literature and further strengthen the role of medial tibial reduction osteotomy as an effective adjunct in managing tight varus deformities during total knee arthroplasty.

CONCLUSION

The present study demonstrates that medial tibial reduction osteotomy is an effective and reliable technique for optimizing soft tissue balance in tight varus knees undergoing total knee arthroplasty. It provides controlled and predictable deformity correction, with a clear correlation between osteotomy thickness and angular alignment achieved. Compared to conventional soft tissue

release methods, MTRO minimizes the risk of instability while maintaining excellent functional outcomes and a low complication rate. By quantifying the relationship between bone resection and correction, this study enhances surgical precision and contributes valuable evidence to the existing literature on the management of complex varus deformities.

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Conflict of interest: None declared

Ethical approval: The study was approved by the Institutional Ethics Committee

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