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Optimizing Medial Release Sequence in Varus Knee Arthroplasty: A Stepwise Approach

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ABSTRACT

Objective: Achieving optimal ligament balance in total knee arthroplasty (TKA) requires a precise sequence of medial release techniques. While medial collateral ligament (MCL) release is often considered the first step, there is no consensus regarding the subsequent steps and their effectiveness. This study examines a stepwise medial release protocol for varus knees to determine its efficacy in improving intraoperative ligament balance and post-operative outcomes.

Materials and Methods: A retrospective analysis was conducted on 60 patients (39 females, 21 males) who underwent primary TKA for varus deformity between January 2020 and December 2022. A structured medial release sequence was applied, consisting of the superficial MCL, deep MCL, posterior capsule, Pes Anserinus, and increased tibial resection. Gap balancer measurements were recorded at 0° and 90° flexion. Statistical analyses included paired t-tests and Chi-square tests to assess the impact of each release step on ligament balance.

Results: At 0° flexion, 85% of patients achieved optimal medial ligament balance after completing the release sequence. At 90° flexion, the optimal balance was achieved in 80% of cases. The mean Knee Society Score improved from 45.2±10.5 preoperatively to 88.7±8.9 at the 12-month follow-up ($p<0.05$). Range of motion increased from 95°±15° to 120°±10° ($p<0.05$).

Conclusion: The stepwise release protocol effectively improved medial ligament balance without excessive soft-tissue release, reducing the risk of post-operative instability. The sequence provided a reproducible and systematic approach, facilitating consistent intraoperative decision-making. The proposed stepwise medial release protocol effectively balances ligaments in varus knees during TKA, resulting in improved clinical outcomes and reduced post-operative complications. Future studies should assess the protocol's applicability in diverse patient populations and compare its effectiveness with robotic-assisted techniques.

Keywords: Arthroplasty, Knee, Knee prosthesis, Medial release, Total knee arthroplasty

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INTRODUCTION

Gonarthrosis is one of the most common degenerative joint diseases, particularly in the elderly population, and is characterized by pain, restricted movement, and functional loss in the knee joint. Total knee arthroplasty (TKA) is widely employed as an effective surgical intervention in advanced-stage knee osteoarthritis to alleviate pain and improve quality of life. However, knee deformities, particularly varus deformity, pose significant challenges in surgical planning and execution.

Varus knee deformity leads to degeneration in the medial compartment due to increased loading on the medial structures and is often accompanied by medial soft-tissue contractures.[1] During TKA, the release of these contractures (medial release) is crucial for achieving proper mechanical alignment and maintaining prosthetic stability. However, there are varying approaches in the literature regarding the sequence, targeted structures, and extent of medial release.

Soft-tissue balancing procedures performed during surgery play a fundamental role in achieving neutral alignment of the knee.[2] These procedures are typically carried out in a stepwise manner, targeting structures such as the deep medial collateral ligament (dMCL), osteophyte removal, Pes Anserinus insertion site, semimembranosus tendon, posteromedial capsule, and superficial medial collateral ligament (sMCL).[3] It is crucial to accurately determine the release sequence of each structure, as excessive release may increase the risk of medial instability, while inadequate release may result in difficulties in prosthesis placement.[4]

Recent advancements in surgical techniques and the increasing use of computer-assisted systems have enabled a more systematic approach to soft-tissue balancing strategies. However, the surgeon's experience and patient-specific anatomical variations remain critical in achieving optimal outcomes. Therefore, establishing an evidence-based, structured, and reproducible release sequence is essential for clinical success.

In this study, the stepwise approach to medial release in patients undergoing primary TKA for varus knees will be thoroughly examined. Various approaches and techniques reported in the literature will be compared to propose the most effective and safe sequence. The aim is to contribute to intraoperative decision-making processes for surgeons while also improving post-operative functional outcomes.

MATERIALS AND METHODS

Study Design and Patient Selection

A retrospective analysis was conducted on 60 consecutive patients with varus deformity who underwent primary TKA between January 2020 and December 2022. Inclusion criteria included primary osteoarthritis with varus deformity >10° and intact collateral ligaments. Exclusion criteria included previous knee surgery, severe valgus deformity, inflammatory arthritis, and varus deformity over 30°. This study was conducted in accordance with the principles outlined in the Declaration of Helsinki, ensuring the protection of participants' rights and welfare throughout the research process. Ethical approval for this study was obtained from the local institutional review board (Decision-22/146), and all procedures were carried out following the approved protocol.

Surgical Technique

All procedures were performed by a single surgeon using a medial parapatellar approach. After bone cuts, ligament balance was assessed using a gap balancer at 0° and 90° of flexion. Medial tightness was scored as follows:

- 1 point: Lateral entry only.
- 2 points: Medial and lateral entry with medial tightness.
- 3 points: Optimal medial laxity.

A stepwise medial release sequence was applied based on gap measurements:

1. MCL release at sagittal midline
2. Removal of medial tibial osteophytes
3. Posterior capsular release and posterior osteophyte removal
4. Pes anserinus tenotomy
5. Increased tibial resection

Data Collection

Intraoperative gap measurements were recorded at both 0° and 90° of flexion for each step of the release sequence. The data were categorized by gender (male: "m", female: "f") and the effectiveness of each release step was scored as described above.

Statistical Analysis

Data were analyzed using the Statistical Package for the Social Sciences version 25.0. Continuous variables, such as pre-operative and post-operative gap balancer scores and range of motion (ROM), were compared using paired *t*-tests to assess the effectiveness of the medial release steps in both 0° and 90° flexion. The effectiveness of each release step in achieving optimal medial ligament balance was further evaluated through chi-square tests to compare the distribution of gap

balancer scores across different patient groups and release steps. In addition, the overall improvement in Knee Society Scores (KSS) from pre-operative to post-operative follow-up was assessed using paired *t*-tests, with statistical significance set at $p<0.05$. Gender-based differences in achieving optimal ligament balance were also analyzed using Chi-square tests to determine potential disparities between male and female patients.

RESULTS

Demographics

The study included 60 patients (39 females, 21 males) with a mean age of 68.5±7.2 years. The mean pre-operative varus deformity was 12.3°±3.1° (Table 1).

Intraoperative Findings at 0° Flexion

The stepwise release sequence significantly improved medial ligament balance at 0° flexion ($p<0.05$) (Table 2). The distribution of gap balancer scores at each step was as follows:

- After dMCL release: 45% achieved score 3
- After osteophyte removal: 65% achieved score 3
- After posterior release: 75% achieved score 3
- After pes anserinus tenotomy: 80% achieved score 3
- After ıncreased tibial resection: 85% achieved score 3.

Intraoperative Findings at 90° Flexion

At 90° flexion, the stepwise release sequence also showed significant improvement in medial ligament balance ($p<0.05$). The distribution of gap balancer scores at each step was as follows:

- After dMCL release: 40% achieved score 3
- After osteophyte removal: 60% achieved score 3
- After posterior release: 70% achieved score 3
- After pes anserinus tenotomy: 75% achieved score 3
- After ıncreased tibial resection: 80% achieved score 3.

Gender-based Analysis

- Female patients (f): 85% achieved optimal balance (score 3) at 0° flexion, and 80% at 90° flexion
- Male patients (m): 80% achieved optimal balance (score 3) at 0° flexion, and 75% at 90° flexion.

Post-operative Outcomes

At 12-month follow-up, the mean KSS improved from 45.2±10.5 preoperatively to 88.7±8.9 postoperatively ($p<0.05$). The mean ROM improved from 95°±15° to 120°±10° ($p<0.05$) (Table 3).

DISCUSSION

The objective of this study is to evaluate the adequacy of medial release using a simple intraoperative method and to propose a protocol regarding the sequence of medial structure release, which remains a debated topic. Following the completion of bone resections and osteophyte excisions, we consider the order of medial structures to be released as the dMCL, posterior-oblique ligament (POL), posteromedial capsule, sMCL, Pes Anserinus, and Semimembranosus muscles. In addition, as a secondary outcome, we believe that the gap balancer utilized during surgery is sufficient for assessing ligament balance.

In arthritic varus knees, the tension of the medial soft tissues and the laxity of the lateral soft tissues are directly related to the degree of varus deformity. The objective of TKA is to achieve a rectangular gap that is equally balanced in both flexion and extension. Thus, releasing tight structures appears to be a necessary intervention. However, excessive release can result in severe complications, such as knee instability. Furthermore, recent advancements in robotic-assisted surgery have provided a more comfortable postoperative course compared to conventional techniques, particularly during

Table 1. Age distribution and outcomes analysis.

Age group	Gender	Number of patients	Mean KSS score (Postop)	Mean ROM (Degrees)
<60	Male	12	85	115
<60	Female	15	87	118
60–70	Male	10	90	120
60–70	Female	18	89	122
>70	Male	9	83	112
>70	Female	12	86	115

KSS: Knee society scores; ROM: Range of motion.

Table 2. Effect of release steps on medial balance.

Release step	Patients achieving optimal balance (%)	Average gap balancer score (0°)	Average gap balancer score (90°)
Medial collateral ligament release	45	2.1	2.0
Osteophyte removal	65	2.5	2.3
Posterior capsule release	75	2.8	2.6
Pes anserinus tenotomy	80	3.0	2.8
Increased tibial resection	85	3.0	3.0

Table 3. ***Complications based on release steps***

Number of release steps	Complications (%)	Instability cases	Joint stiffness cases
1–2 Steps	10	2	1
3–4 Steps	15	3	2
All 5 Steps	20	5	3

the initial 6-month period. This postoperative comfort has been attributed to the limited intervention on ligamentous structures. Therefore, achieving adequate but minimal release may lead to more favorable outcomes.

Furthermore, it should be noted that during TKA in varus knees, the dMCL is often inadvertently released as part of the standard surgical exposure. Specifically, when the medial meniscus is excised, the dMCL, which is anatomically connected to the joint capsule and the medial meniscus, is also necessarily disrupted. Therefore, this step typically precedes the removal of medial tibial osteophytes. In this context, the beginning sequence described in our study reflects the practical surgical order rather than a deliberate soft-tissue balancing strategy. Nonetheless, we agree that osteophyte removal plays a significant role in medial tension release and have clarified this point accordingly.

First and foremost, confirming medial-lateral ligament balance during surgery itself presents a significant contradiction. There are numerous perspectives on this matter, and several instruments developed by relevant companies are available, including the Zimmer offset-repo, Stryker's devices, and those from Smith and Nephew, all of which have been extensively studied and reported in the literature.[5,6] In addition, there is a study that assesses ligament balance intraoperatively using a computer-assisted system.[7]

Therefore, in the first stage of our study, we developed a simple, cost-effective, and easily applicable method specific to our approach. In this method, we utilized a carbon gap balancer, which is commonly available in every TKA set, to define a three-stage laxity scoring system. We assigned scores of 1, 2, and 3 based on the procedures performed during surgery, both in extension and at 90° flexion, after completing the bone cuts. Given the accessibility and cost-effectiveness of this method, we believe it has the potential for widespread clinical application.

Most orthopedic surgeons prefer to use the thinnest possible insert, as a smaller insert is associated with reduced wear.[4] We consider the size of the gap balancer to be irrelevant, as the primary objective in mechanically aligned TKA is not only to release the tight medial structures but also to balance the lax lateral structures, ultimately achieving medial-lateral ligament balance. Therefore, the insert size is not a determining factor for us. Even if a larger size is tested, we believe that the clinical interpretation should consider both medial and lateral engagement, which is ultimately influenced by the surgeon's intraoperative experience.

In their study, Keggi et al. [8] reported that the use of a digital balancebot device during robotic knee arthroplasty improved medial-lateral ligament balance at the end of the procedure. Although robotic knee arthroplasty ensures more precise bone cuts, progress in ligament balance remains limited. [9] Regarding ligament balance, kinematic alignment in TKA does not recommend medial release, preserving the patient's native soft-tissue balance.[10] Kinematically aligned TKA using the measured resection technique requires a high level of surgical expertise and presents significant challenges in non-robotic procedures. In our study, as we performed non-robotic surgeries, we did not opt for kinematic alignment, and therefore, ligament balance was achieved manually.[11] Supporting this notion, the study by Song demonstrated that sensor-assisted TKA is not superior to manual techniques.

[12] A study utilizing intraoperative load distribution sensors demonstrated that the sensor was found to be ineffective.[13]

In a study conducted by Geller et al., [14] it was reported that collateral ligament balancing did not differ postoperatively or at the 1-year follow-up following knee arthroplasty. We disagree with this perspective, as the post-operative follow-up period in this study was relatively short. In our clinical practice, we have observed a strong correlation between the intraoperative ligamentous balance achieved during surgery and the postoperative patient-reported outcome scores in patients we have followed over a longer duration. Another study suggests that robotic-assisted bone cuts performed without intervening in the soft tissues achieve more accurate intraoperative ligament balance.[15]

Recent advancements suggest that surgeons should adopt a conservative approach to ligament releases, as each ligament is proprioceptively effective.[16] Both the surgeon and the patient may require these ligaments in the future. In this study, our objective was to assess the optimal starting point for ligament releases and to determine which specific ligaments should be released to achieve perioperative balance in the most conservative manner.

A cadaveric study demonstrated that medial release, particularly of the sMCL, significantly affects anterior stability in ligament-preserving TKA. The study also emphasizes that surgeons should avoid excessive medial release and adopt a minimalist approach.[17] Recent trends indicate that minimal soft-tissue release has yielded satisfactory mid- to long-term outcomes.[18]

There are numerous proposed methods for medial release, each with its own recommended sequence. In our practice, we perform the classic dMCL release, sMCL release up to the Pes Anserinus, medial tibial osteophyte removal, posterior capsulotomy, and extension of the tibial cut. We do not utilize other methods, such as needle-assisted MCL release, which have been described in the literature, as we consider them to be ineffective.[19]

The medial structures to be released can be categorized as both static and dynamic. The static structures include the sMCL and dMCL, POL, and the posteromedial capsule. The dynamic structures encompass the Pes Anserinus and Semimembranosus muscles. In severe varus deformities, all of these structures may need to be released. However, in cases with moderate varus deformities, a stepwise and sequential approach is the most reasonable strategy. This approach ensures post-operative comfort and prevents instability issues.

Our findings have important clinical implications for surgeons performing TKA in varus-deformed knees. The stepwise medial release sequence based on intraoperative gap measurements provides a systematic and reproducible method for achieving optimal ligament balance. This approach can help reduce post-operative complications, such as instability and accelerated polyethylene wear, and improve patient outcomes.

In our study, we assessed medial-lateral ligament balance using a gap gauge both in extension and flexion. Our objective was to determine when, in which patients, and in what sequence these releases should be performed. In addition, we aimed to explore whether this method could potentially reduce mid-flexion instability, which remains one of the major challenges in knee arthroplasty.

Limitations

The limitations of our study include its retrospective design and the absence of robotic navigation methods. Second, the study was conducted at a single center, which may limit the generalizability of the findings. While we acknowledge that robotic navigation may provide more precise and accurate ligament balancing, we believe that its routine use is challenging due to its high cost and limited accessibility.

CONCLUSION

In varus knees, we followed a general approach to medial release, starting with osteotomy. Following the release of the dMCL and superficial anterior MCL and subsequent osteophyte removal, we achieved a satisfactory outcome. Posterior cruciate ligament (PCL) excision was routinely performed. We took care not to disturb the Pes Anserinus unless necessary. We did not find it necessary to release the posteromedial capsule, POL, or semimembranosus. In standard cases with moderate to mild varus deformities of 15° or less, which are the most common, satisfactory outcomes were achieved with the excision of the PCL along with the release of the dMCL and anterior sMCL. For such cases, multicenter studies could provide stepwise treatment algorithms that encompass fewer ligament releases and protect against excessive releases.

DECLARATIONS

Ethics Committee Approval: The study was approved by Metin Sabancı Baltalimanı Bone Diseases Training and Research Center Ethics Committee (No: 22/146, Date: 30/05/2024).

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