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Impact of Restoring Native Posterior Tibial Slope on Functional Outcomes After Anterior Stabilized Knee Surgery.

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Abstract:

Background: This retrospective study examined the impact of posterior tibial slope (PTS) on functional outcomes and range of motion (ROM) following primary cruciate-retaining (CR) total knee arthroplasty (TKA) utilizing an anterior stabilized (AS) insert. We hypothesized that restoration of native PTS would positively influence functional status.

Materials and Methods: Ninety primary TKAs in 70 patients (56 women, 14 men; mean age 63.01 years) were analyzed. Pre- and post-operative PTS were measured radiographically. Functional status was assessed using the Oxford Knee Score (OKS), and ROM was evaluated with a goniometer at the final follow-up, all performed by a single orthopedic surgeon.

Results: The mean pre-operative PTS was 14.58°, and the mean post-operative PTS was 10.5°. Patients with a post-operative PTS < 8° exhibited a mean OKS of 39.5, while those with PTS > 8° had a mean OKS of 37.04 (p=0.204). Patients with a PTS difference (pre- to post-op) < 6° showed a mean post-operative OKS of 38.3, compared to 37.4 for those with a difference > 6° (p=0.456). Mean post-operative ROM was 113° for PTS difference < 6° and 115.8° for PTS difference > 6° (p=0.260).

Conclusions: While statistically insignificant, our findings suggest that a post-operative PTS difference < 6° in AS TKA may be associated with slightly improved functional outcomes compared to differences > 6°. Restoration of the native PTS appears acceptable for AS inserts, and a slope cut performed for CR knees is generally tolerated. Further research with larger sample sizes and longer follow-up is warranted to confirm these observations and delineate optimal PTS parameters for AS TKA.

Keywords: Anterior stabilized, Cruciate-retaining, Oxford Knee Score, Posterior tibial slope, Range of motion, Total knee arthroplasty.

Introduction:

Total knee arthroplasty (TKA) is a cornerstone of orthopedic surgery, providing effective pain relief and functional restoration for patients suffering from end-stage knee osteoarthritis. The evolution of TKA has witnessed significant advancements in implant design, surgical techniques, and rehabilitation protocols, all aimed at optimizing patient outcomes. Among the critical factors influencing TKA success, the restoration of proper knee kinematics and biomechanics stands paramount. Achieving this necessitates meticulous attention to various surgical parameters, including component positioning, ligament balancing, and, notably, the posterior tibial slope (PTS). The PTS, defined as the angle between the tibial plateau and the mechanical axis of the tibia, plays a crucial role in determining knee stability, kinematics, and load distribution. A native PTS is essential for maintaining physiological knee function, influencing factors such as anterior-posterior stability, flexion-extension balance, and patellofemoral joint mechanics. Alterations in PTS, either inadvertently or intentionally during TKA, can disrupt these biomechanical parameters, potentially leading to suboptimal functional outcomes, including pain, instability, and limited range of motion (ROM). Historically, TKA designs have evolved from constrained to more kinematic-preserving designs. Cruciate-retaining (CR) TKA, which aims to preserve the posterior cruciate ligament (PCL), has gained popularity due to its potential for improved proprioception and more natural knee kinematics. However, in cases where the PCL is deficient or its function is compromised, anterior stabilized (AS) TKA designs, which substitute for the PCL with a cam-post mechanism, become necessary. The AS design relies on the cam-post interaction to provide posterior stability during flexion, mimicking the function of the PCL. Despite the established importance of PTS in knee biomechanics, its precise influence on functional outcomes in AS TKA remains a subject of ongoing investigation. The restoration of native PTS in AS TKA presents a unique challenge, as the cam-post mechanism interacts differently with the tibial slope compared to the PCL in CR designs. While a native PTS is generally considered desirable, the optimal PTS parameters for AS TKA, particularly in relation to functional outcomes and ROM, are not fully elucidated. Deviations from the native PTS in AS TKA can have significant clinical implications. An excessive anterior slope can lead to increased anterior tibial translation, potentially resulting in instability and pain. Conversely, an excessive posterior slope can increase posterior tibial translation and alter the kinematics of the cam-post mechanism, potentially affecting flexion and overall knee function. Moreover, alterations in PTS can influence the load distribution across the tibial plateau, potentially contributing to implant wear and loosening. Previous studies have explored the relationship between PTS and TKA outcomes, but the findings have been inconsistent. Some studies have suggested that restoring the native PTS is crucial for optimal functional outcomes, while others have reported no significant correlation. Furthermore, the existing literature predominantly focuses on CR TKA, with limited research specifically addressing the impact of PTS in AS TKA. The rationale for investigating the relationship between PTS and functional outcomes in AS TKA stems from the need to optimize surgical techniques and implant selection for this specific patient population. AS TKA is often performed in patients with more complex knee pathologies, including PCL deficiency, severe deformity, or previous ligament injuries. Understanding the influence of PTS in these patients is crucial for achieving predictable and satisfactory outcomes. The current study aims to address this knowledge gap by retrospectively analyzing a cohort of patients who underwent primary CR TKA with an AS insert. The primary objective is to investigate the relationship between PTS and functional status, as measured by the Oxford Knee Score (OKS), and ROM. We hypothesize that restoration of native PTS will positively influence functional outcomes and ROM in AS TKA. The findings of this study will contribute to a better understanding of

the role of PTS in AS TKA and provide valuable insights for orthopedic surgeons performing these procedures. By elucidating the optimal PTS parameters for AS TKA, we can potentially improve patient outcomes, reduce complications, and enhance the overall success of TKA. This research will also serve as a foundation for future studies investigating the biomechanical and clinical implications of PTS in AS TKA, ultimately leading to evidence-based guidelines for surgical planning and implant selection. The research will examine the pre- and post-operative PTS, and relate that to the patient's functional outcome. The Oxford Knee Score (OKS) will be used to assess functional improvement. Range of motion will be measured with a goniometer. Through this study, we aim to determine if a specific change in PTS correlates with better functional results in patients who have undergone a AS TKA. This study will add to the body of knowledge and provide insights to surgeons performing these procedures. Ultimately, we hope to improve patient outcomes and enhance the overall success of TKA.

Materials and Methods:

Study Design and Patient Selection: This retrospective study analyzed data from patients who underwent primary total knee arthroplasty (TKA) for osteoarthritis year b/w 2018 to 2019. A comprehensive review of electronic medical records and radiographs was conducted.

Inclusion Criteria:

Patients included in the study met the following criteria:

- Primary TKA performed for osteoarthritis.
- Utilization of an anterior stabilized (AS) total knee system (Biorad Genius prosthesis).
- Complete pre- and post-operative radiographic data available.
- Final follow-up clinical assessment performed by the same orthopedic surgeon.

Exclusion Criteria:

Patients were excluded if they presented with:

- Posterior stabilized (PS) or cruciate-retaining (CR) TKA without AS insert.
- Rheumatoid arthritis.
- Post-traumatic arthritis.
- TKA with extra-articular deformities.
- Valgus knee deformities.
- Prior history of TKA revision.
- Prosthetic joint infection.

Based on these criteria, 90 knees in 70 patients were identified for inclusion in the study.

Surgical Technique: All surgical procedures were performed by a single senior consultant orthopedic surgeon. A standard midline vertical incision and midvastus approach were utilized.

The anterior cruciate ligament (ACL) and menisci were resected. The posterior cruciate ligament (PCL) was preserved if deemed intact and under appropriate tension.

Tibial osteotomy was performed using an extramedullary tibial jig, guided by anatomical and mechanical alignment principles. The initial posterior tibial slope (PTS) cut was made using a freehand technique, aiming to recreate the native slope, as no specific PTS-guiding instruments were utilized. Flexion and extension gap balancing were achieved through bony resections and, if necessary, soft tissue releases, including anteromedial and posteromedial releases, and reduction osteotomies. In cases of persistent flexion gap tightness, PCL island osteotomy or PCL resection was performed.

Following gap balancing, femoral and tibial components were cemented in place. Patellar resurfacing was not routinely performed; marginal osteophytes were removed, and lateral patellar facetectomy was performed when indicated.

Outcome Measures:

- **Posterior Tibial Slope (PTS) Assessment:**
  - Pre- and post-operative PTS were measured using digital lateral radiographs.
  - Two orthopedic surgeons independently performed the measurements, and the average was used for analysis.
  - Lateral radiographs were obtained with superimposition of the femoral condyles.
  - The anterior cortical line (ACL) was used as a reference, defined by a line connecting two points 5 cm and 15 cm distal to the joint line on the anterior tibial cortex.
  - A second line was drawn connecting the most prominent points on the anterior and posterior tibial plateau.
  - The PTS was calculated as 90 degrees minus the angle between these two lines.
- **Oxford Knee Score (OKS):**
  - Pre- and post-operative OKS were recorded for each patient to assess functional outcomes.
  - Scores were assigned according to the standard OKS criteria.
- **Range of Motion (ROM):**
  - Knee flexion ROM was measured using a universal standard goniometer with the patient in a supine position.
  - Measurements were performed by the same orthopedic surgeon during the final follow-up visit.

Data Analysis:

- Statistical analysis was performed using SPSS software version 27.
- Descriptive statistics were used to summarize patient demographics and outcome measures.
- Independent samples t-tests were used to compare mean ROM and OKS between groups with different PTS values.
- Box plots were used to represent the pre and post operative OKS values.
- A p-value of < 0.05 was considered statistically significant.

Review of Literature:

Total knee arthroplasty (TKA) has revolutionized the treatment of end-stage knee osteoarthritis, providing substantial pain relief and improved function. However, achieving optimal clinical outcomes remains a multifaceted challenge, requiring meticulous attention to various surgical and biomechanical factors. Among these, the posterior tibial slope (PTS) has emerged as a critical determinant of knee kinematics, stability, and functional performance. This review of literature aims to synthesize existing knowledge regarding the influence of PTS on TKA outcomes, with a particular focus on anterior stabilized (AS) designs.

The Significance of Posterior Tibial Slope: The PTS, defined as the angle between the tibial plateau and the mechanical axis of the tibia, plays a pivotal role in knee biomechanics. Physiologically, it contributes to anterior-posterior stability, influences knee kinematics, and affects load distribution across the tibiofemoral joint. A native PTS is considered essential for maintaining normal knee function, and deviations from this optimal range can lead to adverse clinical outcomes. Early studies highlighted the importance of PTS in the context of anterior cruciate ligament (ACL) function. An increased PTS has been associated with increased anterior tibial translation, potentially placing excessive stress on the ACL. Conversely, a decreased PTS can limit anterior tibial translation and reduce ACL strain. These findings underscore the critical role of PTS in maintaining knee stability and preventing ligament injuries.

PTS in Cruciate-Retaining TKA: In cruciate-retaining (CR) TKA, the PCL is preserved, aiming to replicate native knee kinematics. Research on PTS in CR TKA has yielded mixed results. Some studies have reported a significant correlation between PTS and functional outcomes, with restoration of the native PTS associated with improved range of motion (ROM) and patient-reported outcomes. For instance, studies have shown that maintaining a physiological PTS in CR TKA can optimize flexion-extension balance and improve patellofemoral tracking. However, other studies have found no significant relationship between PTS and functional outcomes in CR TKA. These discrepancies may be attributed to variations in surgical techniques, implant designs, and patient populations. Furthermore, the influence of other factors, such as ligament balancing and component positioning, may confound the relationship between PTS and TKA outcomes.

The Unique Challenges of PTS in Anterior Stabilized TKA: Anterior stabilized (AS) TKA designs are employed when the PCL is deficient or its function is compromised. In these designs, a cam-post mechanism substitutes for the PCL, providing posterior stability during flexion. The interaction between the cam and post is directly influenced by the PTS, making the restoration of an appropriate slope crucial for optimal function. Unlike CR TKA, where the PCL provides a degree of inherent stability, AS TKA relies heavily on the cam-post mechanism to control posterior tibial translation. This reliance makes AS TKA more sensitive to variations in PTS. An excessive anterior slope can lead to increased anterior tibial translation and potential instability, while an excessive posterior slope can alter the kinematics of the cam-post mechanism, affecting flexion and overall knee function.

Limited research has specifically addressed the influence of PTS in AS TKA. Some biomechanical studies have investigated the impact of PTS on cam-post engagement and knee kinematics. These studies have shown that variations in PTS can significantly alter the contact mechanics and forces within the cam-post mechanism, potentially leading to implant wear and

loosening. Clinical studies on PTS in AS TKA are scarce. However, preliminary findings suggest that restoring a near-native PTS may be beneficial for functional outcomes. The optimal PTS parameters for AS TKA, particularly in relation to ROM and patient-reported outcomes, are not fully elucidated.

Factors Influencing PTS in TKA: Several factors can influence the PTS achieved during TKA, including surgical technique, implant design, and patient anatomy. Surgical techniques, such as the use of extramedullary or intramedullary tibial jigs, can affect the accuracy of PTS restoration. Implant designs, including the tibial baseplate and insert, can also influence the final PTS. Patient anatomy, including pre-existing deformities and bone morphology, can further complicate PTS restoration.

Clinical Implications and Future Directions: The findings of this review highlight the complex interplay between PTS and TKA outcomes, particularly in AS designs. While restoration of a near-native PTS is generally considered desirable, the optimal parameters for AS TKA remain a subject of ongoing investigation.

Future research should focus on:

- **Prospective clinical studies:** Evaluating the impact of different PTS ranges on functional outcomes in AS TKA.
- **Biomechanical studies:** Investigating the influence of PTS on cam-post mechanics and knee kinematics using advanced imaging and simulation techniques.
- **Longitudinal studies:** Assessing the long-term effects of PTS on implant survival and patient satisfaction.
- **Development of surgical techniques and instruments:** Improving the accuracy of PTS restoration during TKA.
- **Personalized surgical planning:** Employing patient-specific imaging and modeling to optimize PTS based on individual anatomy and biomechanics.

Results

Patient Demographics:

The study included 90 knees in 70 patients who underwent primary total knee arthroplasty (TKA) with an anterior stabilized (AS) insert. The mean age of the patients was 63.1 years. The cohort consisted of 56 women (80%) and 14 men (20%).

Posterior Tibial Slope (PTS):

The mean pre-operative PTS was 14.58°. The mean post-operative PTS was 10.5°.

Oxford Knee Score (OKS):

The mean pre-operative OKS was 12.7. The mean post-operative OKS was 38.1 standard deviation. The pre- and post-operative OKS values demonstrated a statistically significant improvement ($p < 0.001$).

Analysis of PTS and Functional Outcomes:

- **Post-operative PTS < 8° vs. > 8°:**
  - The mean post-operative OKS for patients with a PTS < 8° was 39.5 (standard deviation).
  - The mean post-operative OKS for patients with a PTS > 8° was 37.04 (standard deviation).
  - The independent samples t-test revealed no statistically significant difference in post-operative OKS between these two groups (p = 0.204).
- **PTS Difference (Pre-op to Post-op) < 6° vs. > 6°:**
  - The mean post-operative OKS for patients with a PTS difference < 6° was 38.3 (standard deviation).
  - The mean post-operative OKS for patients with a PTS difference > 6° was 37.4 (standard deviation).
  - The independent samples t-test revealed no statistically significant difference in post-operative OKS between these two groups (p = 0.456).

Range of Motion (ROM):

- **Post-operative PTS < 8° vs. > 8°:**
  - The mean post-operative ROM for patients with a PTS < 8° was 113.3° (standard deviation).
  - The mean post-operative ROM for patients with a PTS > 8° was 113.89° (standard deviation).
  - The independent samples t-test revealed no statistically significant difference in post-operative ROM between these two groups (p = 0.825).
- **PTS Difference (Pre-op to Post-op) < 6° vs. > 6°:**
  - The mean post operative ROM for patients with a PTS difference < 6° was 113°(standard deviation:).
  - The mean post operative ROM for patients with a PTS difference > 6° was 115.8° (standard deviation).
  - The independent samples t-test revealed no statistically significant difference in post-operative ROM between these two groups (p = 0.260).

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