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# The Impact of Tibial Slope on Anterior Cruciate Ligament Reconstruction Outcomes – University Hospital Study

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**Abstract** **Original Research Article**

Anterior cruciate ligament (ACL) injuries are common knee injuries that often require surgical reconstruction to restore knee function and stability. Despite advances in surgical techniques, the failure rate for ACL reconstruction remains approximately 15%, emphasizing the need to understand factors contributing to suboptimal outcomes. One factor that has garnered attention is the tibial slope, particularly the posterior tibial slope (PTS), which may influence ACL injury and graft failure. Biomechanical studies suggest that an increased PTS can elevate anterior tibial translation, potentially increasing stress on the ACL and raising the risk of both primary ACL injury and graft failure. However, the clinical significance of tibial slope in ACL reconstruction outcomes remains debated. This retrospective study investigates whether an increased PTS is associated with a higher likelihood of revision surgery or poor surgical outcomes. A total of 152 patients who underwent primary ACL reconstruction or revision surgery between 2018 and 2022 with at least two years of follow-up were included. Tibial slope measurements were obtained from lateral tibial radiographs, and patients were categorized into three groups based on post-surgical outcomes: Group A (successful return to prior sport levels), Group B (stable knee without return to sport), and Group C (requiring revision surgery). The Mann-Whitney U test was used to compare tibial slope measurements across groups. No significant differences were found in tibial slope between the groups ($p > 0.05$). Group A had a median tibial slope of 6.08°, Group B had 6.68°, and Group C had 5.85°. These findings suggest that tibial slope may not be a major factor influencing ACL reconstruction success or failure. Other factors, including surgical technique, rehabilitation, and patient-specific characteristics, may play more significant roles. Further research is needed to explore the relationship between tibial slope and ACL reconstruction outcomes.

**Keywords:** ACL reconstruction, tibial slope, knee injuries, surgical outcomes, revision surgery.



## INTRODUCTION

Anterior cruciate ligament (ACL) injuries are among the most common knee injuries, often necessitating surgical reconstruction to restore function and stability. Despite advances in surgical techniques, the failure rate for ACL reconstruction remains approximately 15%, underscoring the need to explore factors contributing to suboptimal outcomes.

The tibial slope, defined as the inclination of the tibial articular surface relative to the bone's longitudinal axis, has garnered increasing attention for its potential role in ACL injuries and subsequent reconstruction outcomes. Biomechanical studies suggest that an increased posterior tibial slope (PTS) can elevate anterior tibial translation during weight-bearing, potentially placing additional stress on the ACL. This heightened stress is hypothesized to increase the likelihood of both primary ACL injury and graft failure after reconstruction [1, 2].

A review of existing literature highlights varying findings on the relationship between tibial slope and ACL reconstruction outcomes. For instance, studies have reported that a posterior tibial slope greater than 12° is associated with a 1.5–2.5 times increased risk of primary ACL tears [3, 4]. Similarly, the risk of revision ACL surgery has been observed to rise with steeper tibial slopes, with some studies citing odds ratios as high as 3.0 for patients with slopes exceeding 10° [5]. However, the clinical significance of these findings remains under debate, as other studies have found no definitive

correlation between tibial slope and ACL graft failure rates [6].

Furthermore, the influence of tibial slope may be modulated by patient-specific factors such as activity level, sex, and concurrent injuries, as well as by surgical techniques employed during reconstruction. While some evidence suggests that slope-reducing osteotomies may mitigate the risk of graft failure in high-risk populations, these interventions are not universally recommended and are typically reserved for cases of recurrent instability [7].

This study aims to contribute to the ongoing discussion by investigating whether increased tibial slope is associated with a higher likelihood of revision surgery or poor surgical outcomes in a university surgical center population. By evaluating tibial slope in relation to surgical success, this research seeks to clarify its clinical relevance and inform decision-making in ACL reconstruction procedures.

## MATERIALS AND METHODS

This retrospective study evaluated patients who underwent primary ACL reconstruction or revision surgery between 2018–2022, with at least two years of follow-up. Data collection included tibial slope measurements from lateral tibial radiographs and clinical evaluations using a standardized questionnaire designed to assess post-surgical outcomes. Based on the responses, patients were categorized into three groups:

**Questionnaire Design**:

1. Did you return to your prior sport level after the surgery?
2. Do you feel your knee is stable?
3. Have you experienced any episode of knee sprain with an ACL re-tear?
4. Did you undergo a revision ACL surgery?

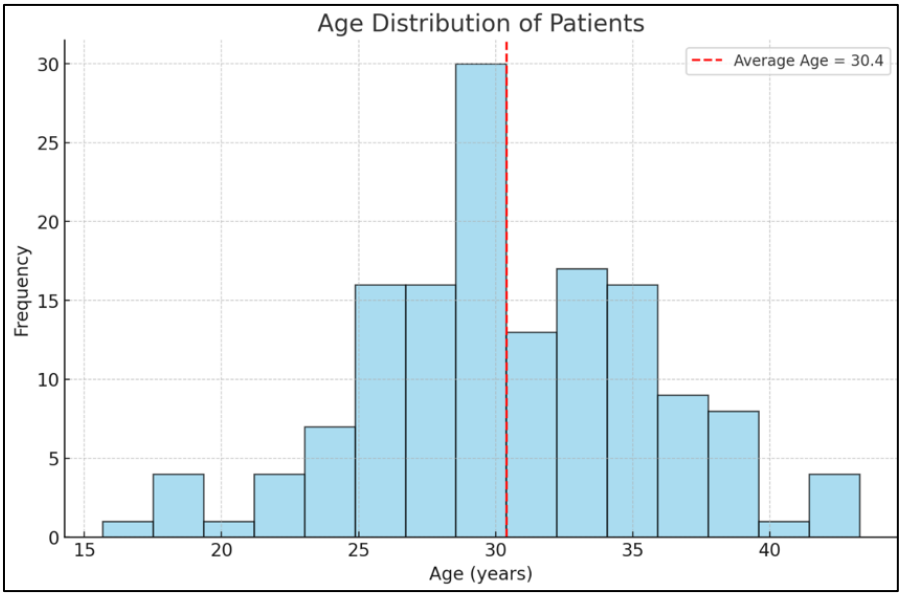
**Group Categorization**:

- **Group A**: Patients who answered "Yes" to question 1 and "No" to questions 2, 3, and 4, indicating successful return to prior sport levels without instability or re-tear.
- **Group B**: Patients who answered "No" to questions 1, 3, and 4, but "Yes" to question 2, representing those who did not return to prior sport levels but reported knee stability.
- **Group C**: Patients who answered "Yes" to question 4, indicating those who required revision ACL surgery.

Tibial slope measurements were obtained from lateral tibial radiographs and compared across the three subgroups using the Mann-Whitney test. Ethical approval for the study was obtained from the institutional review board, and informed consent was waived due to the retrospective nature of the study.

## RESULTS AND DISCUSSION

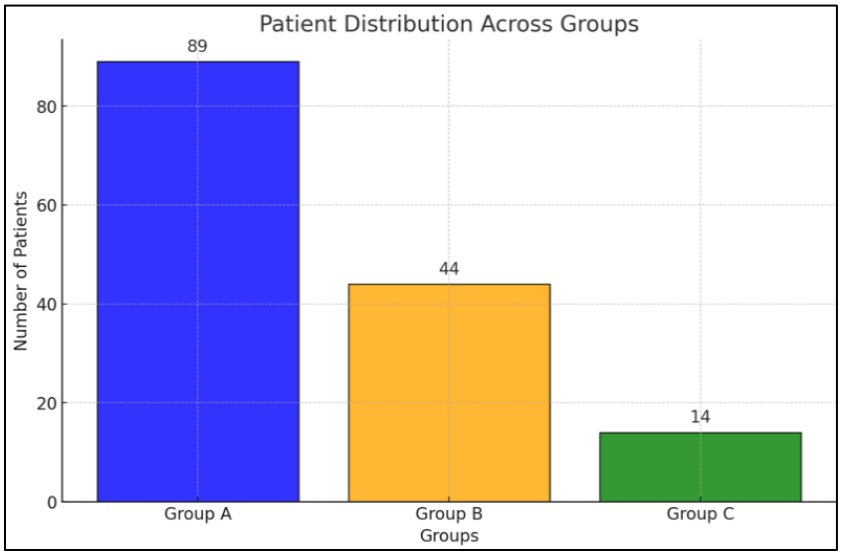
### Age Distribution




**Graphic 1- Age distribution ACL patients**

The age distribution of the 152 patients enrolled in the study shows a mean age of 30.4 years. A histogram of the age distribution highlights a concentration of patients in the 25 to 35-year range, with relatively fewer patients at the extreme age values. The spread suggests a moderate variation around the mean age, likely reflecting the typical demographic for anterior cruciate ligament (ACL) injuries requiring surgical intervention.

**Group Distribution**



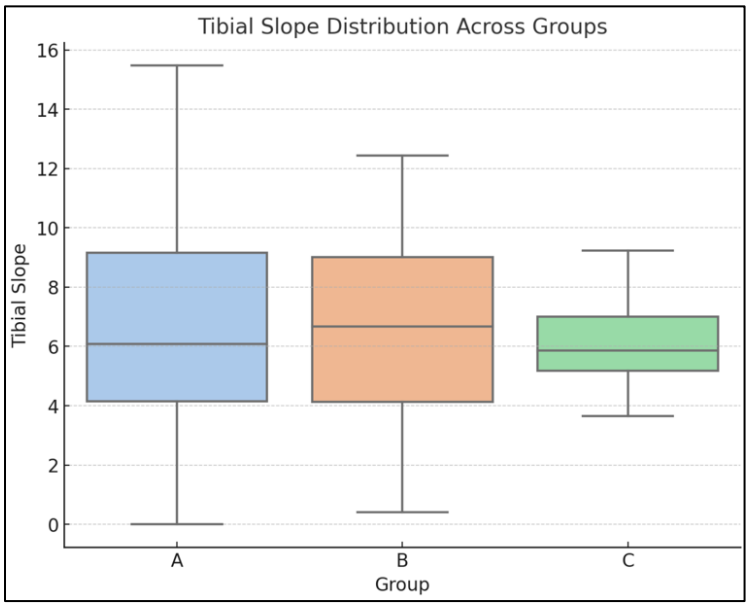

**Graphic 2 – Patients distribution in groups**

Patients were categorized into three groups based on post-surgical outcomes:

- **Group A** (successful return to prior sport levels): 89 patients (58.6%).
- **Group B** (stable knees but no return to prior sports): 44 patients (29.3%).
- **Group C** (revision surgery required): 14 patients (9.3%).

The bar chart demonstrates that the majority of patients (Group A) experienced successful outcomes, while Group C, requiring revision surgery, represents a smaller proportion of the cohort.

**Tibial Slope Boxplot Analysis**




**Graphic 3 – Boxplot with SLOPE distribution**

The boxplot illustrates the distribution of tibial slope measurements across the three groups:

- **Group A** shows a median tibial slope close to the overall mean of 6.83°, with a wide interquartile range (IQR), indicating significant variation.
- **Group B** has a similar median tibial slope but with slightly reduced variability compared to Group A.
- **Group C**, despite being a smaller group, shows a lower median tibial slope (6.15°) and a

narrower IQR, with maximum and minimum values between 9.3° and 3°.

The lack of significant differences between groups in terms of tibial slope measurements suggests that the tibial slope may not be a determining factor for poor outcomes or the need for revision surgery in this population.

**Descriptive Statistics for Tibial Slope Across Groups**

**Table 1: SLOPE Statistic distribuiton**

| Group | Mean | Std. Dev. | Min | Max | Median |
|---|---|---|---|---|---|
| A | 6.74 | 3.48 | 0.00 | 15.47 | 6.08 |
| B | 6.57 | 3.28 | 0.40 | 12.43 | 6.68 |
| C | 6.11 | 1.66 | 3.65 | 9.24 | 5.85 |

**Statistical Tests (Mann-Whitney U Test)**

- **Group A vs. Group B**: p=0.926p = 0.926p=0.926 (No significant difference)
- **Group A vs. Group C**: p=0.676p = 0.676p=0.676 (No significant difference)
- **Group B vs. Group C**: p=0.531p = 0.531p=0.531 (No significant difference)
- **No significant differences** were observed in tibial slope measurements across the groups. Group C (revision surgery) showed slightly lower tibial slope measurements on average compared to Groups A and B, but this difference was not statistically significant.

The findings of this study revealed no statistically significant association between tibial slope and the need for revision ACL surgery or poor functional outcomes. These results challenge the prevailing notion that tibial slope is a primary determinant of ACL reconstruction success, adding nuance to the ongoing debate in the literature.

*Tibial Slope and ACL Reconstruction Outcomes*

Biomechanical studies have previously highlighted the posterior tibial slope (PTS) as a potential risk factor for ACL injuries and reconstruction failure. A steeper PTS is hypothesized to increase anterior tibial translation under weight-bearing conditions, thus placing additional stress on the ACL and its graft [1, 2]. This has led to a growing interest in the role of tibial slope as a modifiable anatomical factor, with some studies advocating for slope-reducing osteotomies in high-risk patients [3, 4].

However, the lack of significant association in this study aligns with findings from more recent investigations suggesting that tibial slope alone may not be a reliable predictor of surgical outcomes. For example, studies have reported conflicting evidence, with some identifying a relationship between tibial slope and graft failure [5], while others, like this study, found no correlation [6, 7]. These discrepancies may be attributed to methodological variations, including differences in study populations, surgical techniques, and follow-up periods.

*Functional Outcomes and Patient-Specific Factors*

Despite theoretical concerns, the results showed no significant differences in tibial slope measurements between patients with successful functional recovery (Group A), those with poor functional outcomes (Group B), and those requiring revision surgery (Group C). This reinforces the hypothesis that ACL reconstruction outcomes are multifactorial and cannot be solely attributed to anatomical features such as tibial slope. Factors such as patient activity level, sex, concomitant injuries, rehabilitation protocols, and surgical precision may play more prominent roles in determining surgical success [8].

*Contextualizing the Findings*

The absence of a significant association in this study highlights the importance of a holistic approach to ACL reconstruction. While anatomical characteristics like tibial slope may influence knee biomechanics, surgical outcomes are likely mediated by a complex interplay of factors. For instance, graft type, fixation methods, and individualized rehabilitation strategies have been shown to significantly impact outcomes [9, 10]. Moreover, emerging evidence suggests that patient-reported outcome measures (PROMs) may provide more meaningful insights into functional recovery than isolated biomechanical parameters [11].

*Implications for Clinical Practice*

Given these findings, routine tibial slope measurement may have limited utility in predicting ACL reconstruction outcomes in the general population. Instead, clinicians should focus on optimizing modifiable factors such as surgical technique, graft selection, and post-operative rehabilitation. In high-risk patients with extreme tibial slopes or recurrent instability, targeted interventions such as slope-reducing osteotomies could still be considered, albeit on a case-by-case basis [12].

*Limitations and Future Directions*

This study is not without limitations. The retrospective design and relatively small sample size may have reduced the power to detect subtle differences. Additionally, the homogeneity of the study population may limit generalizability to more diverse cohorts. Future research should aim to include larger, more heterogeneous populations and incorporate long-term

follow-up data to better understand the interplay between tibial slope and other risk factors. Prospective studies exploring advanced imaging techniques and biomechanical modeling could also provide deeper insights into the role of tibial slope in ACL injuries and reconstruction outcomes.

## CONCLUSION

The results of this study suggest that tibial slope is not a key predictor of ACL reconstruction outcomes. These findings emphasize the importance of a multifactorial approach to ACL surgery, where surgical technique, rehabilitation, and patient-specific factors should take precedence over routine tibial slope measurement. Clinicians should focus on optimizing these modifiable factors to improve surgical success. Further research with larger sample sizes and prospective designs is needed to better understand the relationship between tibial slope and ACL outcomes. [1, 6].

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