Received: 25 Feb 2025 | **Accepted:** 12 Aug 2025 **Genel Tıp Derg. Volume** 35/**Issue** 5 (October), 854-862

DOI: 10.54005/geneltip.1647003

ORIGINAL ARTICLE

Does an Increase in the Tibial Slope Angle Increase the Risk of Anterior Cruciate Ligament Re-rupture?

Tibial Eğim Açısındaki Artış, Ön Çapraz Bağ Rekonstrüksiyonunda Re-ruptür Riskini Artırır Mı?

[1]Okan ATEŞ, [2]Ahsen OĞUL,

[1]M.D., Gazi Yasargil Education and Research Hospital, Orthopedic and Traumatology Deparment, 21010, Diyarbakır,Turkey,
E-mail: atesokan@msn.com
[2]M.D., Eskişehir City Hospital, Sports Medicine, 26080, Eskişehir/Turkey
E-mail: ahsenogul91@gmail.com

Correspondence

Okan ATEŞ,
Gazi Yasargil Education and Research Hospital, Orthopedic and Traumatology Deparment, 21010, Diyarbakır,Turkey

E-Mail: atesokan@msn.com

How to cite ?

Ateş O., Oğul A., Does an Increase in the Tibial Slope Angle Increase the Risk of Anterior Cruciate Ligament Re-rupture?, Genel Tıp Derg. 2025;35(5):854-862

ABSTRACT

Aim: Despite the improvements in Anterior cruciate ligament recontruction (ACLR) surgery, results of revision surgeries are not satisfactory. One of the most current reasons that increases the risk of revision surgery after ACLR is the posterior tibial slope angle (PTSA). In this study, the relationship between posterior tibial slope angle and rupture after primary and revision surgery was investigated.
Methods: Patients over 18 years of age who underwent primary ACLR (primary group), patients with re-rupture (revision group) and individuals without any ligament injury (control group) were included in the study. Knee joint images of the participants were obtained by retrospective archive search. The posterior tibial slope angles in the included knee radiographs were measured using the anterior tibial cortex method.
Results: The study evaluated knee joint images of 124 patients in the primary group, 39 patients in the revision group and 100 participants in the control group. Intra-observer and inter-observer reliability of PTSA measurements was found to be appropriate. A statistically significant difference was observed between the mean tibial slope angle measurement of the control, primary and revision groups. (p=0,0001). It was found that the risk of primary anterior cruciate ligament (ACL) injury and ACL re-rupture for an individual with PTSA>11.4 was 7.6 times and 9.58 times higher, respectively, than for an individual with PTSA<11.4°.
Conclusions: Higher PTSA was observed to be an anatomical risk factor for primary and secondary ACL injuries. Patients with higher PTSA should be evaluated for additional risk factors and slope-reducing surgeries should be applied to these patients when necessary.

Keywords: Anterior cruciate ligament, graft failure, reconstruction, revision surgery, tibial slope angle.

ÖZ

Amaç: Ön çapraz bağ rekonstrüksiyonu (ÖÇBR) cerrahisindeki gelişmelere rağmen revizyon cerrahilerinin sonuçları tatmin edici değildir. ÖÇBR sonrası revizyon cerrahisi riskini artıran nedenlerden en güncel olanların başında posterior tibial eğim açısı (PTSA) gelmektedir.. Bu çalışmada, posterior tibial eğim açısı ile primer ve revizyon cerrahisi sonrası meydana gelen rüptür arasındaki ilişki incelenmiştir.
Gereç ve Yöntemler: Primer ÖÇBR geçiren 18 yaş üstü hastalar (primer grup), rerüptür olan hastalar (revizyon grubu) ve herhangi bir bağ yaralanması olmayan kişiler (kontrol grubu) çalışmaya dahil edilmiştir. Katılımcıların diz eklemi görüntüleri retrospektif arşiv aramasıyla elde edilmiştir. Dahil edilen diz radyografilerindeki posterior tibial eğim açıları anterior tibial korteks yöntemi kullanılarak ölçülmüştür.
Bulgular: Çalışmada primer gruptaki 124 hastanın, revizyon grubundaki 39 hastanın ve kontrol grubundaki 100 katılımcının diz eklemi görüntüleri değerlendirilmiştir. PTSA ölçümlerinin gözlemci içi ve gözlemciler arası güvenilirliğinin uygun olduğu bulunmuştur. Kontrol, primer ve revizyon gruplarının ortalama tibial eğim açısı ölçümü arasında istatistiksel olarak anlamlı bir fark gözlendi. (p=0,0001). PTSA>11,4 olan bir bireyde primer ön çapraz bağ (ÖÇB) yaralanması ve ÖÇB tekrar kopması riskinin sırasıyla PTSA<11,4° olan bir bireye göre 7,6 kat ve 9,58 kat daha yüksek olduğu bulundu.
Sonuçlar: Daha yüksek PTSA'nın primer ve sekonder ÖÇB yaralanmaları için anatomik bir risk faktörü olduğu gözlemlendi. Daha yüksek PTSA'ya sahip hastalar ek risk faktörleri açısından değerlendirilmeli ve gerektiğinde bu hastalara eğim azaltıcı cerrahiler uygulanmalıdır.

Anahtar Kelimeler: Ön çapraz bağ, greft yetmezliği, rekonstrüksiyon, revizyon cerrahisi, tibial eğim açısı.

Peer-Review: Double anonymized - Two External
Plagiarism Checks: Yes - intihal.net
Complaints: geneltip@selcuk.edu.tr

Selcuk University Press
Genel Tıp Dergisi | e-ISSN: 2602-3741
https://dergipark.org.tr/tr/pub/geneltip
https://yayinevi.selcuk.edu.tr/

INTRODUCTION

An increase in the incidence of anterior cruciate ligament (ACL) rupture is being observed due to the increase in the number of individuals participating in sports (1). With advancements in surgical techniques, the widespread use of arthroscopy and an increase in the incidence of ACL injuries, there has been a similar increase in the number of ACL reconstruction (ACLR) surgeries. Despite the improvements in surgical techniques and graft options, the failure rate of ACLR still varies between 3-10% (1). Unfortunately, ACL revision surgery does not provide as impressive results as primary ACLR surgery (2).

It is known that the likelihood of re-injury after ACLR depends on various risk factors (2). These risk factors are classified as extrinsic (modifiable) and intrinsic (difficult to modify) factors (3). Although developments in reconstruction surgery are being aimed at limiting extrinsic factors that may cause graft failure, there is less data available on the improvement of intrinsic factors (4).

In recent studies, it has been found that posterior tibial slope angle (PTSA) is related to strain that occurs in ACL (5). In cadaver studies, it has been shown that increasing posterior tibial slope increases the shifting of the tibia to the front of the femur (5). Thus, it is thought that increased PTSA is related to primary ACL injury and graft failure after ACLR. In a prior study, it has been reported that the risk of ACL graft failure is 7 times higher in adults with PTSA>12° (6).

Reducing the rate of ACL re-rupture is important for improving the rates of return to sports and daily activities without pain after ACL revision surgery. (7,8). In this study, it was aimed to compare PTSA of knees with ACL injuries requiring revision surgery and knees that did not suffer re-injury after primary surgery. The hypothesis of the study is that PTSA will be higher in knees that need revision surgery.

MATERIALS and METHODS

Patients were evaluated after approval was obtained Ethics Committee (Decision No: 879-03.09.2021). The study was conducted under the principles of the Declaration of Helsinki. After the approval of the ethics committee was obtained, knees that had suffered an ACL injury and subsequently underwent surgery (primary group) and knees in need of revision surgery (revision group) were identified by a retrospective scan of the last 4 years. Images of patients over the age of 18 that were taken at least 9 months after surgery were included in the study. All of the selected primary ACLRs were performed with hamstring autografts. All primary surgeries were performed using the anatomical technique. Secondary interventions applied to the patients included in surgery notes were identified and noted. A total of 163 patients over the age of 18 who underwent ACLR or correction ACLR, were regularly followed up and followed the protocols. Patients with advanced osteoarthritis, those who had no follow-up and radiological imaging, those who underwent HTO in the same session, those with multiligament injuries, and those with ACL injuries from the other knee were excluded from the study. The control group included patients who had not undergone any orthopedic surgery, had magnetic resonance imaging (MRI), did not require additional surgery, did not have osteoarthritis, and were asked for an

MRI due to suspected meniscal injury but did not detect any pathology. From the available knee radiographs, images that allowed measuring the tibial slope angle (true lateral radiographs with femoral condyles overlapping) were selected for evaluation (Figure 1,2). In addition, PTSA of knee radiographs obtained from patients who did not have ligament and meniscus injuries were measured and included in the study as a control group. Measurements included in the study were performed blindly to each other by an orthopedics and traumatology specialist and a sports medicine specialist. To measure intraclass correlation, measurements were made twice, 4 weeks apart. PTSA measurements of images obtained from lateral knee radiographs were made via the built-in ruler in the Extreme Pacs v.3858 software system using the anterior tibial cortex method. First, a tangent line was drawn to the anterior cortex proximal to the tibia to represent the longitudinal axis of the tibia. A second line perpendicular to the longitudinal axis was drawn. Lastly a third line tangential to the tibia plateau was drawn. PTSA was accepted as the angle between 2nd and 3rd lines. (9).

Statistical Analysis

The statistical analyses of the data included in the study were performed using NCSS (Number Cruncher Statistical System) 2007 Statistical Software (Utah, USA) package program.

Figure 1: Figure of PTSA measurement in a patient undergoing ACLR

Figure 2: Figure of PTSA measurement in a patient undergoing revision ACLR

Table 1. Intra-rater reliability

	Rater 1	Rater 2
	Intraclass Correlation Coefficient (95% CI)	Intraclass Correlation Coefficient (95% CI)
Control Group	0,989 (0,983-0,992)	0,985 (0,977-0,990)
Primary Group	0,985 (0,979-0,990)	0,985 (0,978-0,989)
Revision Group	0,975 (0,953-0,987)	0,969 (0,940-0,984)
All Groups	0,991 (0,989-0,993)	0,990 (0,987-0,992)

Table 2. Inter-rater reliability

	Inter-Class Correlation Coefficient (95% CI)
Control Group	0,981 (0,975-0,986)
Primary Group	0,977 (0,970-0,982)
Revision Group	0,962 (0,940-0,976)
All Groups	0,987 (0,984-0,989)

Table 3. Evaluation of mean tibial slope angle measurements

	N	PTSA Measurement
Control Group	200	8,52±2,55
Primary Group	248	12,88±3,05
Revision Group	78	16,37±3,79
	p	0,0001

PTSA: Posterior tibial slope angle (Since the measurements were made twice, the total number in the two measurements is stated in the median value)

Table 4. Comparison of mean tibial slope angle measurements between groups using Tukey's multiple comparison test

Tukey's Multiple Comparison Test	p
Control Group / Primary Group	0,0001
Control Group / Revision Group	0,0001
Primary Group / Revision Group	0,0001

Table 5. Evaluation of the correlation between age and PTSA

	Group		PTSA Measurement
Age	**Control Group**	r	0,010
		p	0,889
	Primary Group	r	0,066
		p	0,301
	Revision Group	r	0,069
		p	0,546

PTSA: Posterior tibial slope angle

Table 6. Examining the distribution between groups when PTSA≥12º

		Control Group		Primary Group		Revision Group		p
Measurement	<12º	187	93,50%	87	35,08%	11	14,10%	0,0001
	≥12º	13	6,50%	161	64,92%	67	85,90%	

PTSA: Posterior tibial slope angle

Besides descriptive statistical methods (mean, standard deviation), the distribution of variables was examined with the Shapiro – Wilk test of normality as part of the evaluation of the data. One-way analysis of variance was used for comparing normally distributed variables. Tukey's multiple comparison test was used for comparing subgroups. Independent t test was used for comparing pairs of groups. Chi-square test was used for comparing qualitative data. Pearson correlation test was used to determine the relationships between variables. For differential diagnosis of primary surgery and revision surgery measurements, areas under the ROC Curve were calculated and sensitivity, specificity, positive predictive value, negative predictive value and LR (+) values and cut-off values of the variables were determined. A level of significance of $p<0.05$ was accepted as significant.

RESULTS

Measurements of 124 knee radiographs belonging to the primary group, 39 belonging to the revision group, and

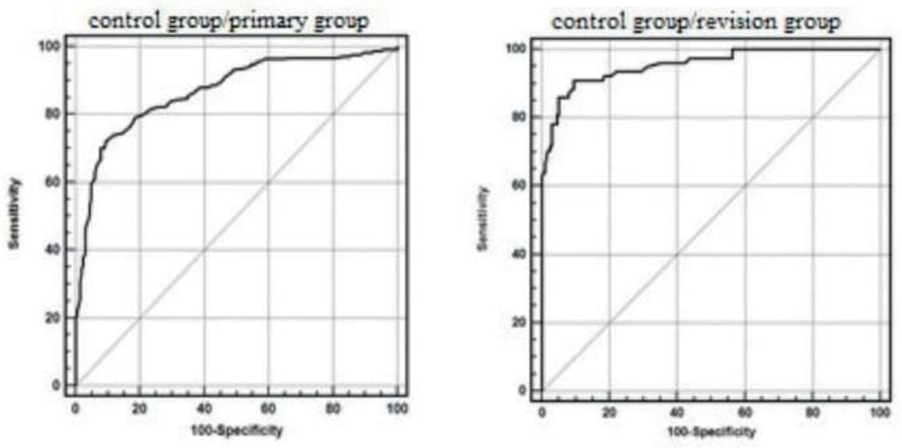

Figure 3: Figure of ROC curve of the tibial slope for the control group: primer group and control group:revision group (Vertical part sensitivity horizontal part specificity)

100 belonging to the control group were included in the study. The mean age of the primary group was 27.91±8.09, the mean age of the revision group was 29.18±7.25, and the mean age of the control group was 35.32±8.63. There was no statistically significant difference between the groups in terms of age (p>0.05). The average time elapsed after surgery in the primary group was found to be 24.15±8.51.

When the 1st and 2nd measurements of the evaluators were evaluated for reliability, all measurements were found to be above the accepted value of 0.700, meaning inter-rater reliability was high (Table 1-2).

A statistically significant difference between the mean tibial slope angle measurements of the control, primary and revision groups was observed (p=0,0001), (Table 3). When Tukey's multiple comparison test results were evaluated, the measurement averages of the control group were found to be statistically significantly lower than the measurement averages of the primary and revision groups (p=0.0001). The mean measurements of the primary group was observed to be statistically significantly lower than the mean measurements of the revision group (p=0,0001), (Table 4).

There was no statistically significant difference between the age and tibial slope angle measurements of all groups (Table 5).

When the distributions of the measurement results of the control, primary and revision groups were evaluated, a statistically significant difference was observed between measurement results (p=0,0001), (Table 6). The distribution of measurement results ≥12° in the control group was found to be lower than the primary and revision groups, and the distribution of measurement results ≥12° in the primary group was found to be lower than the revision group.

The area under the ROC curve of the measurement value of the primary group was found to be 0.870 (0.835-0.899). Sensitivity, specificity, positive predictive value, negative predictive value and LR(+) value for a predictive value of >11.4° were found to be 72.18, 90.50, 90.4, 72.4 and 7.60, respectively. The risk of primary ACL injury was found to be 7.6 times higher in individuals with PTSA>11.4° when compared to individuals with PTSA<11.4°.

The area under the ROC curve of the measurement value of the revision group was found to be 0,955 (0,920 -0,976). The risk of ACL re-rupture was found to be 9.58 times higher in individuals with PTSA>11.4º when compared to individuals with PTSA<11.4º (Fıgure 3).

DISCUSSION

It is known that increased tibial slope due to increased compressive axial load generates a greater anterior shear force in the tibiofemoral joint (3). An increase in PTSA increases the load on the ACL, the primary restraint against anterior tibial translation, increasing the risk of a potential ACL rupture (3). Studies on the extent of the effect increased PTSA has on ACLR re-ruptures are limited in number. In this study, the PTSA measurement of the control group was found to be lower than the primary group and revision group, and the PTSA measurement of the primary group was found to be lower than the revision group. No correlation between age and PTSA was found.

The relationship between PTSA and ACLR has been studied quite frequently in the literature in recent years. The studies conducted are mostly primary ACLR patients or revision ACLR studies, and we wanted to contribute to this area, which has less information in the literature, by comparing these two groups in our study.

To date, very few studies have addressed the relationship between tibial slope and re-injury. In a study by Dæhlin et al. examining PTSA in 728 patients, it has been shown that increased tibial slope is not associated with revision surgery, but knees that have suffered injuries have higher PTSA values than healthy knees (10). In their study which followed-up patients under the age of 21 after ACLR, Cooper et al. have found that the population requiring revision surgery had more patients with PTSA>12º. However, this finding was not statistically significant (11). The authors noted that further studies were needed to find out which angle distinguishes patients at the highest risk for revision surgery. However, it should be taken into account that obtaining data from a large database, in which the number of surgeons, their level of expertise and the volume of surgery were unknown, may have affected the results of the aforementioned study. In their study, Gwinner et al. have also reported that the risk of recurrent graft failure increased by 11.6 times in patients with PTSA>12º (7). In a review study by Liu et al., in which 20 studies were included, it has been reported that a relationship between increased PTSA and ACL graft failure has been found in 15 of the studies (12). Arguing that a higher PTSA is associated with risk of ACL graft failure, the authors have noted that although there are highly reliable methods for measuring PTSA, there is no consensus about which values are risky. In this study, PTSA values of the primary group and the revision group were also found to be higher than the PTSA values of the control group. These results are similar to previous studies and confirm that increased PTSA is a risk factor for primary injury and re-injury.

In another study conducted by Lee et al., PTSA of patients in need of revision surgery has been found to be significantly higher compared to patients without re-injury ($p<0.01$). Lee et al. have reported that the probability of ACL graft rupture increases 3.48 times in knees with PTSA≥11º, and the risk increases 4.52 times in knees with PTSA≥12º (13). Salmon et al. have followed-up 200 ACLR patients (operated on by a single surgeon) for 20 years, and observed that graft rupture occurred in 37 of 179 patients whose follow-up was completed. During these 20 years, it has been found that ACL graft survival was 22% for adolescents with PTSA≥12º, and the risk of rupture was 11 times higher in adolescents with PTSA≥12º compared to adults with PTSA<12º. The authors have indicated that PTSA≥12º is a strong predictor of recurrent ACL injury (6). In a study by Webb et al., in which they included the results of 15 years of follow-ups, it has been found that the probability of suffering another ACL injury after reconstruction increased by 5 times in patients with a tibial slope ≥12º (14). In their study, Ahmed et al. have found that PTSA of patients who had more than 3 ACL injuries was significantly higher compared to patients who had less than 3 ACL injuries (p=0.002), (2). Napier et al. have also found that an increase in tibial slope angle poses a risk for a third injury. The authors have also associated increased PTSA with re-injury rates after ACL revision surgery (3). In this study, it was also found that increased PTSA was associated with re-injury and that re-rupture rate increased by 9.58 times in patients with PTSA>11.4. PTSA, despite having a strong correlation with risk of re-rupture, is rarely taken into account in surgical decision-making in revision ACLR surgery. Studies on which PTSA values should be considered as a risk factor are ongoing (2). In their current study, Luke V. Tollefson et al.(15) found patients with PTSA≥12º to be a risk factor for ACL injuries and reported that yto surgery should be added.

In the study of Lee et al., no significant correlation between PTSA and age has been found (p=0,241). In the same study, it has been found that PTSA did not have a correlation with body mass index either (p=0.613), (13). Through their measurements obtained from 1090 tibia belonging to cadavers, Weinberg et al. have also determined that PTSA was not affected by age (16). In this study, there was no significant correlation between PTSA and age in all 3 groups. Age-related correction is not a concern for the group of patients that are recommended slope-reducing surgery, for whom PTSA is considered a risk factor.

In their study conducted on cadavers, Bernhardson et al. have found that increased slope angle leads to an increase in the force applied on the ACL graft, and that low slope angles have a protective effect on the ACL graft (17). In their study, Sonnery-Cottet et al. followed-up combined ACL revision surgery and proximal tibia anterior closing wedge osteotomy performed on patients with PTSA>12º, and in a follow-up period of 31.5 months, the mean PTSA of patients has been found to be 9.2º, and no other injuries have been observed in the knee that underwent surgery (18). However, the authors noted that the functional results of these surgeries were less positive and the risk of potential morbidity was higher when compared to primary ACLR. In their study discussing the results of 2-year follow-up of 9 patients who underwent revision ACL reconstruction and tibial deflexion osteotomy, Dejour et al. have found that the PTSA value of patients decreased from 13.2º ± 2.6º to 4.4º ± 2.3º after surgery and have argued that tibial slope correction decreases the risk of ACL re-injury (19). The authors have emphasized the importance of careful analysis of risks of failure before ACL reconstruction and recommended correction surgery if the tibial slope of the patient exceeds 12º in order to reduce the risk of graft failure. In a systematic review examining high tibial osteotomy (HTO) and ACLR surgery, it has been observed that re-rupture rate was 0% after the mentioned procedures (8). However, the authors have reported that there are limitations to these estimates due to limited number of patients, short follow-up periods and selective reporting. In their study retrospectively examining the results of 2-yer follow-up of 30 patients who underwent ACLR and medial opening wedge osteotomy, Arun et al. have shown that a correction surgery decreasing the tibial slope by >5º has a functionally positive effect on the restructured ACL graft (20). According to a review conducted by Nazzal et al., high tibial osteotomy reducing high PTSA can lower the risk of failure for ACLR (21). However, decision for surgery should be made by considering the risks, complications and technical difficulties, the long-term healing process of wedge osteotomy and its possibility of complicating future total knee replacement if necessary. In addition, combining HTO with the already technically demanding ACLR revision procedure can also lead to increased technical failures (8). Further studies are required in order to elucidate abnormal PTSA values and to determine the appropriate PTSA values that are indicative of an osteotomy surgery that reduces tibial slope for primary ACLR. How to utilize information on PTSA remains effectively unknown.

The population of the study being composed of only males, and, due to the retrospective nature of the study, information such as how much of the patients had contact injuries, the activity level of the individuals, the extent of compliance to pre/post-operative sports rehabilitation, the rate of return to sports activities and patient-reported outcome measures not being known were limitations of this study.

The strengths of this study were its inclusion of a control group composed of patients without ACL injuries and its retrospective period being as short as possible, taking into account the developing and changing surgical techniques and materials. Most of prior studies included in the literature have examined primary injuries, and a minority of these studies have studied multiple graft failures. According to our observations, this study is the only study on this subject that included a healthy control group for comparison.

CONCLUSION

High PTSA is significantly associated with possible graft failure. The causes of re-injury are multifactorial, but evaluations in this study support that there may be an anatomical predisposition to re-injury related to increased posterior tibial slope. It should be noted that predisposition to graft failure depends not only on anatomical conditions, but also on age, acquired injuries, graft tissue, graft position, treatment of secondary peripheral instabilities and postoperative rehabilitation. When the results related to risk of graft failure following primary and revision ACL surgery and the possible future consequences of tibial slope correction surgery are considered, it is seen that identifying patients who are at risk is important for the appropriate selection of patients for corrective surgery.

Conflict of Interest

The authors have no conflicts of interest to declare.

Financial Support

The authors declared that this study has received no financial support.

Acknowledgement

The authors have no funding to report.

REFERENCES

1. Cirdi Y, Ergün S, Başcı O, Karahan M. Ön çapraz bağ rekonstrüksiyonu revizyonu. In: Taşer ÖF, Mahiroğulları M, Karahan M, Taşkıran E, Emin B, editors. Diz eklemi bağ ve tendon sorunları. İstanbul; 2016. p. 189–201.

2. Ahmed I, Salmon L, Roe J, Pinczewski L. The long-term clinical and radiological outcomes in patients who suffer recurrent injuries to the anterior cruciate ligament after reconstruction. Bone Joint J. 2017 1;99B(3):337–43.

3. Napier RJ, Garcia E, Devitt BM, Feller JA, Webster KE. Increased Radiographic Posterior Tibial Slope Is Associated With Subsequent Injury Following Revision Anterior Cruciate Ligament Reconstruction. Orthop J Sports Med. 2019 1;7(11).

4. Cruz CA, Mannino BJ, Pike A, Thoma D, Lindell K, Kerbel YE, et al. Increased posterior tibial slope is an independent risk factor of anterior cruciate ligament reconstruction graft rupture irrespective of graft choice. J. ISAKOS. 2022;

5. Zee MJM, Keizer MNJ, Dijkerman L, van Raaij JJAM, Hijmans JM, Diercks RL. The correlation between posterior tibial slope and dynamic anterior tibial translation and dynamic range of tibial rotation. J Exp Orthop. 2021 1;8(1):1–8.

6. Salmon LJ, Heath E, Akrawi H, Roe JP, Linklater J, Pinczewski LA. 20-Year Outcomes of Anterior Cruciate Ligament Reconstruction With Hamstring Tendon Autograft: The Catastrophic Effect of Age and Posterior Tibial Slope. Am J Sports Med. 2017 15;46(3):531–43.

7. Gwinner C, Janosec M, Wierer G, Wagner M, Weiler A. Graft Survivorship After Anterior Cruciate Ligament Reconstruction Based on Tibial Slope. Am J Sports Med. 2021 1;49(14):3802–8.

8. Gupta A, Tejpal T, Shanmugaraj A, Horner NS, Simunovic N, Duong A, et al. Surgical Techniques, Outcomes, Indications, and Complications of Simultaneous High Tibial Osteotomy and Anterior Cruciate Ligament Revision Surgery: A Systematic Review. HSS J. 2019 15;15(2):176–84.

9. Chen Y, Ding J, Dai S, Yang J, Wang M, Tian T, et al. Radiographic measurement of the posterior tibial slope in normal Chinese adults: a retrospective cohort study. BMC Musculoskelet Disord. 2022 1;23(1):1–11.

10. Dæhlin L, Inderhaug E, Strand T, Parkar AP, Solheim E. The Effect of Posterior Tibial Slope on the Risk of Revision Surgery After Anterior Cruciate Ligament Reconstruction. Am J Sports Med. 2021 18;50(1):103–10.

11. Cooper JD, Wang W, Prentice HA, Funahashi TT, Maletis GB. The Association Between Tibial Slope and Revision Anterior Cruciate Ligament Reconstruction in Patients ≤21 Years Old: A Matched Case-Control Study Including 317 Revisions. Am J Sports Med. 2019 21;47(14):3330–8.

12. Liu Z, Jiang J, Yi Q, Teng Y, Liu X, He J, et al. An increased posterior tibial slope is associated with a higher risk of graft failure following ACL reconstruction: a systematic review. Knee Surg Sports Traumatol Arthrosc. 2022 30:7. 2022 6;30(7):2377–87.

13. Lee CC, Youm YS, Cho S Do, Jung SH, Bae MH, Park SJ, et al. Does Posterior Tibial Slope Affect Graft Rupture Following Anterior Cruciate Ligament Reconstruction? Arthroscopy. 2018 1;34(7):2152–5.

14. Webb JM, Salmon LJ, Leclerc E, Pinczewski LA, Roe JP. Posterior Tibial Slope and Further Anterior Cruciate Ligament Injuries in the Anterior Cruciate Ligament–Reconstructed Patient. Am J Sports Med. 2013 13;41(12):2800–4.

15. Tollefson L V., Rasmussen MT, Guerin G, LaPrade CM, LaPrade RF. Slope-Reducing Proximal Tibial Osteotomy Improves Outcomes in Anterior Cruciate Ligament Reconstruction Patients With Elevated Posterior Tibial Slope, Especially Revisions and Posterior Tibial Slope ≥12. Arthroscopy. 749.24 (2024).

16. Weinberg DS, Williamson DFK, Gebhart JJ, Knapik DM, Voos JE. Differences in Medial and Lateral Posterior Tibial Slope: An Osteological Review of 1090 Tibiae Comparing Age, Sex, and Race. https://doi.org/101177/0363546516662449. 2016 1;45(1):106–13.

17. Bernhardson AS, Aman ZS, Dornan GJ, Kemler BR, Storaci HW, Brady AW, et al. Tibial Slope and Its Effect on Force in Anterior Cruciate Ligament Grafts: Anterior Cruciate Ligament Force Increases Linearly as Posterior Tibial Slope Increases. Am J Sports Med. 2019 14;47(2):296–302.

18. Sonnery-Cottet B, Mogos S, Thaunat M, Archbold P, Fayard JM, Freychet B, et al. Proximal Tibial Anterior Closing Wedge Osteotomy in Repeat Revision of Anterior Cruciate Ligament Reconstruction. Am J Sports Med. 2014 1;42(8):1873–80.

19. Dejour D, Saffarini M, Demey G, Baverel L. Tibial slope correction combined with second revision ACL produces good knee stability and prevents graft rupture. Knee Surg Sports Traumatol Arthrosc.. 2015 23:10. 2015 23;23(10):2846–52.

20. Arun GR, Kumaraswamy V, Rajan D, Vinodh K, Singh AK, Kumar P, et al. Long-term follow up of single-stage anterior cruciate ligament reconstruction and high tibial osteotomy and its relation with posterior tibial slope. Arch Orthop Trauma Surg. 2015 136:4. 2015 31;136(4):505–11.

21. Nazzal EM, Zsidai B, Pujol O, Kaarre J, Curley AJ, Musahl V. Considerations of the Posterior Tibial Slope in Anterior Cruciate Ligament Reconstruction: a Scoping Review. Curr Rev Musculoskelet Med 2022 15:4. 2022 2;15(4):291–9.