



Influence of Posterior Tibial Slope on the Risk of Recurrence After Anterior Cruciate Ligament Reconstruction

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Abstract

Background. Anterior cruciate ligament (ACL) graft rupture has multifactorial causes, with traumatic factors being the most prevalent. Modern literature presents conflicting data regarding the influence of the posterior tibial slope on the risk of traumatic ACL graft rupture.

Aim of the study – to determine if there is a correlation between the posterior tibial slope and ACL graft injury in patients who have previously undergone ACL reconstruction.

Methods. This was a single-center cohort retrospective study that included patients diagnosed with a complete ACL rupture and who had undergone ACL reconstruction using standard techniques without graft rupture at the last follow-up. Inclusion criteria for the first group included a diagnosis of traumatic ACL rupture followed by reconstruction, a graft composed of semitendinosus and gracilis tendons (St+Gr), femoral fixation with a cortical button, tibial fixation with a sleeve and screw, and the absence of graft rupture at the time of the study. This group included 30 consecutive patients (15 males and 15 females) with a mean age of 36.3 years (min 17, max 59). Inclusion criteria for the second group included an indirect traumatic mechanism of ACL graft rupture and subsequent revision ACL reconstruction. This group consisted of 33 patients (23 males and 10 females) with a mean age of 33.0 years (min 19, max 60). The lateral (LPTS) and medial (MPTS) posterior tibial slopes were measured on lateral knee radiographs.

Results. The median time from surgery to the last follow-up in the first group was 65 months (IQR 60; 66), while in the second group, it was 48 months (IQR 9; 84). The median MPTS in the first group was 7.8° (IQR 5.3; 9.4), while in the second group, it was 8.5° (IQR 7.5; 11). The median LPTS in the first group was 9.9° (IQR 8.4; 12.1), whereas in the second group, it was 12.0° (IQR 9; 15.4). There was no statistically significant difference in MPTS and LPTS based on gender in both groups and the entire sample ($p > 0.05$). When comparing LPTS values between both groups, a statistically significant difference ($p = 0.04$) was found, with higher LPTS values in patients in the second group (with ACL graft injury).

Conclusion. Increased posterior tibial slope, particularly LPTS, is identified as a potential predictor of ACL graft rupture. The study demonstrates the impact of LPTS on the risk of ACL graft rupture ($p < 0.05$) in cases of indirect traumatic injury.

Keywords: revision ACL reconstruction, anterior cruciate ligament, posterior tibial slope, ACL graft rupture.

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Влияние заднего наклона большеберцовой кости на риск рецидива после реконструкции передней крестообразной связки

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Реферат

Актуальность. Разрыв аутооттрансплантата передней крестообразной связки (ПКС) имеет многофакторную природу, причем травматический фактор превалирует над остальными причинами. В литературе имеются противоречивые данные относительно влияния заднего наклона большеберцовой кости на риск травматического разрыва трансплантата ПКС.

Цель исследования — определить, существует ли связь между задним наклоном большеберцовой кости и повреждением трансплантата передней крестообразной связки у пациентов, которым уже была проведена реконструкция передней крестообразной связки.

Материал и методы. В моноцентровое когортное ретроспективное исследование вошли пациенты, у которых был диагностирован полный разрыв ПКС и выполнена ее реконструкция по стандартной методике без разрыва аутооттрансплантата на момент последнего осмотра. Критерии включения в первую группу: диагностированный травматический разрыв ПКС с последующей реконструкцией; трансплантат из сложенных пополам полусухожильной и нежной мышц (St+Gr); бедренная фиксация кортикальной пуговицей, большеберцовая фиксация — гильза + винт; отсутствие разрыва трансплантата ПКС на момент проведения исследования. В эту группу были отобраны 30 последовательных пациентов (15 мужчин и 15 женщин), средний возраст 36,3 (min 17, max 59) лет. Критерии включения во вторую группу: непрямой травматический механизм разрыва аутооттрансплантата ПКС, выполненная ревизионная пластика ПКС. В эту группу вошли 33 пациента (23 мужчины и 10 женщин), средний возраст 33,0 (min 19, max 60) года. У всех пациентов измеряли латеральный (LPTS) и медиальный (MPTS) задний наклон большеберцовой кости на рентгенограммах в боковой проекции.

Результаты. Медиана времени, прошедшего с момента операции до последнего контрольного осмотра, в первой группе составила 65 мес. (IQR 60; 66); во второй — 48 мес. (IQR 9; 84). Медиана MPTS в первой группе составила 7,8° (IQR 5,3; 9,4); во второй — 8,5° (IQR 7,5; 11). Медиана LPTS в первой группе — 9,9° (IQR 8,4; 12,1); во второй — 12,0° (IQR 9; 15,4). Не было выявлено статистически значимой разницы между MPTS и LPTS в зависимости от пола в обеих группах и всей выборке в целом ($p > 0,05$). При сравнении значений LPTS в обеих группах получена статистически значимая разница ($p = 0,04$) с большим значением LPTS у пациентов второй группы (с повреждением трансплантата ПКС).

Заключение. Одним из возможных предикторов разрыва аутооттрансплантата ПКС является увеличенный задний наклон большеберцовой кости. Выявлено влияние латерального заднего наклона большеберцовой кости (LPTS) на риск разрыва аутооттрансплантата ПКС ($p < 0,05$) при непрямом механизме травмы.

Ключевые слова: передняя крестообразная связка, ревизионная пластика ПКС, задний наклон большеберцовой кости, разрыв трансплантата ПКС.

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BACKGROUND

The number of surgeries for anterior cruciate ligament (ACL) reconstruction annually increases [1, 2], leading to a rise in revision reconstructions [3, 4]. Literature reports a revision ACL surgery rate of 3.2-3.6% after 5-7 years, with young age being a predisposing factor [3, 5].

Repeat trauma is one of the main causes of autograft rupture. According to R. Magnussen et al., the proportion of traumatic autograft ruptures ranges from 46 to 56% [6].

There is evidence that an increased posterior tibial slope (PTS) may be a predisposing factor for autograft rupture of the ACL in the early postoperative period, especially in women [8], contralateral ACL rupture [7], and medial meniscus rupture (with PTS values $>13^\circ$) in an unstable knee joint [7, 8, 9]. An increased PTS affects rotational stability in patients with ACL rupture and leads to greater translation of the tibia after ligament reconstruction [10, 11]. Reducing the PTS significantly reduces the load on the ACL graft under axial loading by reducing anterior-posterior displacement of the tibia [12, 13].

Aim of the study to determine if there is a correlation between the posterior tibial slope and ACL graft injury in patients who have previously undergone ACL reconstruction.

METHODS

Study design: Single-center retrospective cohort.

The study included patients diagnosed with a complete ACL rupture who underwent ACL reconstruction at the European Clinic of Sports Traumatology and Orthopedics (ECSTO) using standard techniques without autograft rupture at the time of the last examination.

Inclusion criteria for the first group were: diagnosed traumatic ACL rupture followed by reconstruction at the clinic; a graft consisting of half-semi-tendinous and gracilis tendons (St+Gr); femoral fixation with a cortical button, tibial fixation with a sleeve and screw; no ACL graft rupture at the time of the study. Exclusion

criteria consisted of the use of a different graft or a different method of autograft fixation.

Inclusion criteria for the second group were: indirect traumatic mechanism of autograft ACL rupture, revision ACL reconstruction. Exclusion criteria consisted other reasons for instability after ACL reconstruction and the absence of revision ACL reconstruction.

An indirect mechanism of injury was defined as rotation, hyperextension, valgus/varus, or combinations of these single-plane forces in the absence of direct physical impact and external force applied directly to the knee joint.

After applying the inclusion and exclusion criteria, 30 consecutive patients (15 males and 15 females) were selected for the first group, and 33 patients (23 males and 10 females) were selected for the second group.

The lateral (LPTS) and medial (MPTS) posterior tibial slopes were measured on lateral knee radiographs.

Technique for measuring MPTS and LPTS on X-rays

Measurements were conducted using the Radiant DICOM Viewer, v. 2021.2 (Medixant, Poland). To minimize measurement errors, two senior physicians from the department independently performed measurements, and the average value of all measurements was determined.

The posterior tibial slope was determined on lateral-view knee radiographs relative to the anatomical axis of the tibia. This was determined by inscribing two circles on the proximal part of the shin, 5 and 15 cm distal to the joint surface, and drawing a line connecting their centers. The surface of the medial (blue line) and lateral (red line) tibial plateaus was determined (Fig. 1). The angle between the tangent and the central axis of the tibia was measured. MPTS and LPTS were determined using the formula:

$$\text{MPTS and LPTS} = 90^\circ - \text{the angle between the anatomical axis of the tibia and the tangent drawn along each plateau.}$$

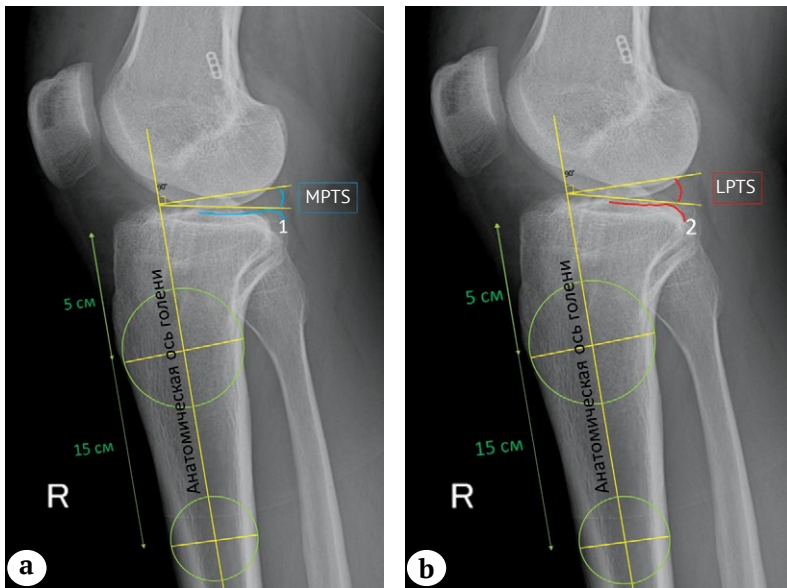


Fig. 1. Determination of the medial and lateral posterior tibial slope on lateral knee X-rays:
 a – medial tibial plateau surface (blue line);
 b – lateral tibial plateau surface (red line)

Statistical analysis

Statistical data analysis was carried out using IBM SPSS Statistics 21 (IBM corp.) and STATISTICA 12.0 (Stat Soft, Inc). Quantitative data are presented as box plots. Normality of distribution was assessed using the Kolmogorov-Smirnov test. For normally distributed data, means with minimum and maximum values are presented; for non-normally distributed data, the median (Me) with interquartile range (IQR) is provided. To compare data between two independent groups, the Mann-Whitney U-test was used, and for data comparison across multiple independent groups, the Kruskal-Wallis test was applied. A critical level of statistical significance was set at $p \leq 0.05$.

RESULTS

At the time of surgery, the two groups were comparable in all parameters (Table 1). MPTS and LPTS values for both groups of patients are presented in Figure 2.

Upon data analysis, no statistically significant difference was found between MPTS and LPTS based on gender in both groups and in the overall sample ($p > 0.05$). When comparing MPTS values, no statistically significant difference was observed between the groups ($p = 0.2$). However, when comparing LPTS values, a statistically significant difference was observed ($p = 0.04$), with higher values in the second group of patients (with ACL graft damage).

Table 1

Characteristics of patients in both groups

Indicator	First group	Second group
Mean age, years	36.3 (min 17, max 59)	33.0 (min 19, max 60)
Time between surgery and examination, months	37.5 (IQR 62;66)	48.0 (IQR 9;84)
MPTS, °	7.8° (IQR 5.3;9.4)	8.5° (IQR 7.5;11.0)
LPTS, °	9.9° (IQR 8.4;12.1)	12.0° (IQR 9.0;15.4)

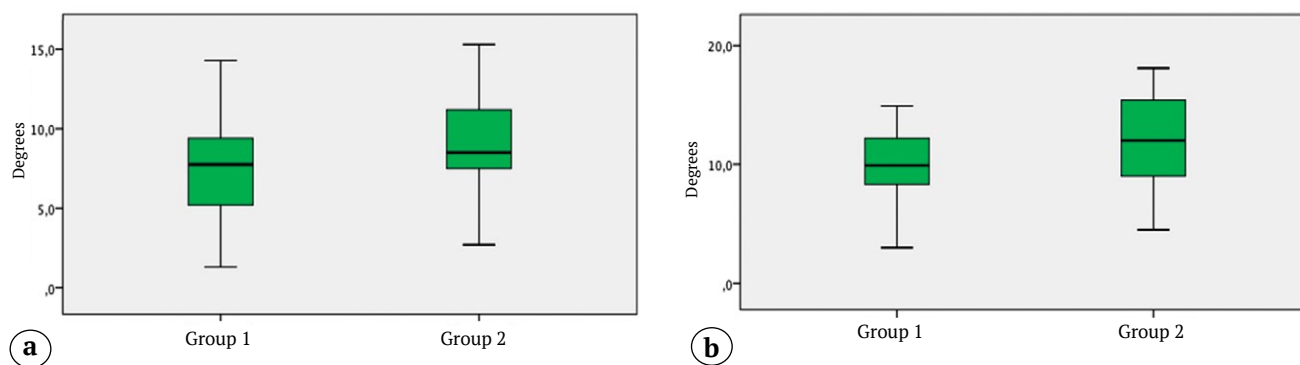


Fig. 2. Posterior tibial slope measurements in two groups of patients based on lateral knee X-rays: a – medial tibial slope; b – lateral tibial slope

DISCUSSION

Reconstruction of the anterior cruciate ligament (ACL) is a reproducible procedure with good long-term outcomes [2]. However, graft rupture leads to the need for revision surgery, increases the risk of additional intra-articular injuries, and revision surgery is technically more challenging for the surgeon with worse outcomes compared to primary ACL reconstruction [4, 14, 15]. The main cause of graft rupture is repeat trauma, with an indirect mechanism of injury predominating (60% of cases) [16].

The potential influence of an increased posterior tibial slope (PTS) on ACL autograft rupture is actively discussed in the literature [7, 10, 12, 17, 18]. There is an opinion that PTS increases the load on the ACL due to an increase in anterior tibial translation [11]. The results of a study by E. Hohmann et al. showed that increasing MPTS and LPTS increases the risk of non-contact ACL graft rupture [17]. K.M. Bojicic et al. identified the influence of PTS on ACL graft rupture regardless of BMI [19]. A study by J. Webb et al. showed that the risk of graft rupture increases when PTS is greater than 12° [18]. However, F. Blanke et al. did not find a relationship between PTS and graft rupture with an indirect mechanism of injury [20].

Different methods for measuring PTS exist: via radiographs, CT, and MRI [21]. This complicates the comparison of results obtained between studies.

Z. Ye et al. assessed PTS on MRI using mechanical (mechanical PTS) and anatomical (anatomical PTS) axes of the tibia and found a significant difference in values between patients with

and without ACL graft rupture: mechanical PTS – $10.7^\circ \pm 2.9^\circ$ vs. $8.7^\circ \pm 1.9^\circ$ ($p = 0.003$) and anatomical PTS – $13.2^\circ \pm 2.8^\circ$ vs. $10.5^\circ \pm 2.5^\circ$ ($p < 0.001$) [22].

In our study, we used the measurement method proposed by R.J. Napier et al. based on lateral-view knee radiographs [7]. This method was chosen due to its good reproducibility and the availability of radiographs in patients with a capture of more than 15 cm of the proximal tibia.

A study by Rahnemai-Azar et al. showed that an increased lateral PTS of the femoral condyle is a predictor of rotational instability in patients with ACL rupture [10]. In our study, a statistically significant difference was found when comparing LPTS values between groups ($p = 0.04$), with higher values in the second group of patients (with ACL graft rupture). The influence of MPTS on the likelihood of graft rupture was not identified. This suggests that the influence of LPTS on graft rupture may be due to greater anterior-posterior displacement of the lateral compartment, creating an additional rotational component that increases the load on the ACL graft.

Study limitations

Our study has limitations related to the complexity of comparing the obtained data with other works due to the large number of techniques for measuring the posterior tibial slope.

CONCLUSION

ACL graft rupture has a multifactorial nature, and one of the possible predictors is an increased posterior tibial slope. In our study, the influence of lateral posterior tibial slope on the risk of ACL

graft rupture ($p < 0.05$) with an indirect mechanism of injury was identified.

Given the contradictory data in the literature regarding the relationship between ACL graft injury and posterior tibial slope, further research with a focus on large samples and standardized measurement methods is needed.

DISCLAIMERS

Author contribution

All authors made equal contributions to the study and the publication.

All authors have read and approved the final version of the manuscript of the article. All authors agree to bear responsibility for all aspects of the study to ensure proper consideration and resolution of all possible issues related to the correctness and reliability of any part of the work.

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Ethics approval. Not applicable.

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