ORIGINAL STUDY

acta orthopaedica belgica, 2023, 89, 429-433

doi.org/10.52628/89.3.11518

Relationship between graft failure following anterior cruciate ligament reconstruction and hamstring autograft diameter

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With the increase in the number of individuals participating in sports, anterior cruciate ligament (ACL) injuries are also increasing gradually and the number of patients requiring surgical treatment is increasing in parallel. The primary aim of this study was to investigate the relationship between the need for revision surgery and graft diameter following primary ACL reconstruction (ACLR) using hamstring autografts. The secondary aim of the study was to clarify relationships between anthropometric characteristics and graft diameter. Patients who underwent ACLR with hamstring autografts were included in this retrospective study. The age, body mass index, height, and weight of all patients were recorded preoperatively and the diameters of the grafts were recorded during surgery. The relationship between revision rate and graft diameter and the relationships between anthropometric measurements and graft diameter were investigated for these patients at least one year after surgery.

This study included 58 people with graft diameters of ≤7 mm and 261 people with graft diameters of >7 mm. A statistically significant difference was found between the graft diameters of the group that needed revision surgery and the group that did not ($p<0.001$). A positive relationship was also found between the patient's height and graft diameter ($r=0.168$). In this study, it was found that the risk of ACL revision surgery increased by 5.5 times among patients with graft diameters of ≤7 mm. The positive relationship between the patient's height and graft diameter can make a significant difference in terms of the need for revision surgery.

Key words: Anterior cruciate ligament, hamstring autograft, reconstruction, graft failure, diameter.

INTRODUCTION

With the increase in the number of young individuals participating in sports, the incidence of anterior cruciate ligament (ACL) rupture is also increasing rapidly[1]. It is estimated that 85/100,000 of adolescents and young adults aged 10-40 years, for whom the incidence of ACL rupture is high, undergo surgical operations after experiencing ACL rupture[1]. After reconstruction, re-ruptures may occur, mainly for reasons related to new trauma, the chosen surgical techniques, and biological factors, and revision surgery may be needed[2]. In parallel with the increases in the numbers of individuals participating in sports and the numbers of patients admitted to hospitals due to ACL injuries, the numbers of patients in need of revision surgery are also gradually increasing[1]. Since revision surgeries do not give results as acceptable as those of primary surgeries, thoroughly examining the factors that cause graft failure and reducing the rates of failures caused by alterable factors is of great importance[3].

Although patellar tendon grafts are considered the gold standard in ACL reconstruction (ACLR) due to their ability to achieve bone-bone fixation in both tunnels and lower re-rupture rates compared to other tendons, the incidence of anterior knee pain in patients who have undergone ACLR with this method reaches up to 30%[4]. Hamstring autografts have become popular as a result of searches for different graft sources. The most important advantages of hamstring autografts are low donor site morbidity and ideal graft length and stiffness for reconstruction[5]. However, while the risk of postoperative anterior knee pain is reduced by using hamstring tendon grafts, some complications may occur due to graft durability being low, late osseointegration, and the thickness of the graft varying from patient to patient[5].

Previous animal studies revealed an inverse relationship between the cross-sectional area of the graft and the anterior-posterior translation of the tibia relative to the femur[6,7]. Studies have also shown that the ideal hamstring autograft diameter should be between 7 and 10 mm in order to reduce graft failure[8,9]. In another study, it was shown that using grafts with a thickness of 7-8 mm reduced the risk of revision surgery and improved patient-reported postoperative outcome measures[10]. The aim of the present study is to examine the relationship between hamstring autograft diameter and the need for revision surgery. The hypothesis of the study is that the need for revision surgery increases when autograft diameters are ≤7 mm. We also assumed that there would be correlations between hamstring autograft diameter and patient height and weight.

MATERIALS AND METHODS

This research was approved by the local ethics committee (decision number 73, dated 21.04.2022). Anthropometric data of patients who suffered isolated ACL injury and underwent reconstruction surgery with hamstring autografts between 2016 and 2020 were retrospectively reviewed, including graft diameter, age, gender, height, weight, body mass index (BMI), and time elapsed between surgery and follow-up, and patients who needed revision surgery were identified. The data had been recorded during operations performed by two experienced orthopedics and traumatology specialists (MU, DAÖ). ACLR was performed with the arthroscopic-assisted technique. Femoral tunnels were drilled using the medial portal technique. The femoral tunnel was consistently drilled to be the same diameter as the prepared graft. Femoral fixation was achieved with a cortical button in all cases. The tibial tunnel was consistently drilled to be the same diameter as the prepared graft and fixation was achieved with an interference screw supported with either a staple or a screw and washer.

Hamstring tendons (the semitendinosus and gracilis) were extracted through an oblique incision of 3 cm in length made 2 cm medially to the tibial tubercle. After separating the tendons from the surrounding adhesions, they were extracted with a tendon stripper. The muscle tissue around the tendons was removed and then the graft was prepared with consistent use of the 2ST-2Gr (semitendinosus, gracilis) folding technique. Grafts were prepared with a graft sizing block and ranged from 4.5 mm to 12.5 mm in increments of 0.5 mm (Figure I).

The gender, age, height, and weight of the patients were recorded during the preparation for the operation.

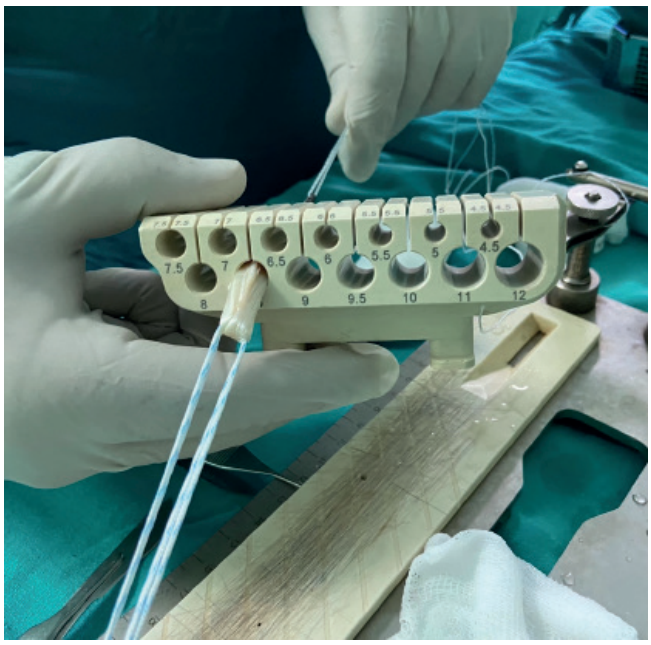

Figure I. The graft size was measured with a standard sizing block ranging from 4.5 mm to 12.5 mm in 0.5 mm increments. (GRAFTMASTER III Slotted Sizing Block, Smith & Nephew).

Patients whose graft sizes were recorded during their operations were contacted and called in for follow-up starting from 2021. During these follow-up appointments, patients who had needed revision surgery and those who had not were identified and divided into two groups.

The decision to perform revision surgery was made according to patients' complaints of instability (unreliability of the knee in pivot movements, knee rotation, or a sense of hollowness) and results of instability evaluations using Lachman and pivot-shift tests. Anteroposterior radiographs were taken with patients in standing and extended positions and lateral radiographs were taken with 30° knee flexion. The integrity of the grafts was evaluated by magnetic resonance imaging (MRI), which was performed for patients with complaints of instability and positive anterior drawer tests, Lachman tests, and pivot-shift tests. Revision surgery was planned for patients who had positive examination findings and were also found to have graft failure by MRI.

Patients who underwent surgery less than 12 months previously, patients with multiple ligament injuries, patients with previous ligament injuries, and patients who had grafts other than hamstring autografts were excluded from the study.

The conformity to normal distribution of the numerical variables evaluated in this study was confirmed with the Shapiro-Wilk test. Numerical variables were described with median and interquartile range

Table I. — Demographic and clinical characteristics of the groups

	Graft diameter		p
	≤7 mm (n=58)	>7mm (n=261)	
Age (Median, IQR)	28.5 (12)	26 (9)	0.154*
Sex (n, %)			
Male	53 (91.4)	249 (95.4)	0.218**
Female	5 (8.6)	12 (4.6)	
BMI	25.8 (3.5)	25.4 (4.2)	0.636
Follow-up (months)	62.5 (20.3)	60 (27)	0.447
BMI: Body mass index *Mann-Whitney U test **chi square test.			

Table II. — Demographic and clinical characteristics of patients who needed revision surgery and those who did not

	Revision		p
	Not needed (n=290)	Needed (n=29)	
Age (Median, IQR)	27 (10)	26 (10.5)	0.518
Sex (n, %)			
Male	274 (94.5)	28 (96.6)	0.637
Female	16 (5.5)	1 (3.4)	
BMI	25.4 (4.2)	25.9 (4)	0.352
Follow-up (months)	60 (25.3)	64 (23)	0.780
Graft diameter (n, %)			
≤7 mm	42 (14.5)	16 (55.2)	<0.001*
>7 mm	248 (85.5)	13 (44.8)	
BMI: Body mass index, * chi square test.			

(IQR) values and categorical variables were described with frequency and percentage values. Independent medians were compared with the Mann-Whitney U test. Relationships between two categorical variables were evaluated with the chi-square test. Analysis was performed with 95% confidence intervals and $p<0.05$ was accepted as significant.

RESULTS

Fifty-eight patients with graft diameters of ≤7 mm and 261 patients with graft diameters of >7 mm were included in the study. There was no statistically significant difference between the groups in terms of mean age, gender distribution, BMI, or time elapsed between surgery and follow-up ($p>0.05$) (Table I).

While there was no statistically significant difference between patients who needed revision surgery (n=29) and patients who did not (n=290) in terms of age, gender distribution, BMI, or time elapsed between surgery and follow-up, a statistically significant difference was found between the two groups in terms of graft diameter ($p<0.001$) (Table II).

Table III. — Evaluation of the relationship between graft diameter and risk of revision surgery

	PPV	NPV	Risk (95% CI)
Graft diameter≤7 mm	27.6%	95.0%	5.5 (2.8-10.9)
PPV: positive predictive value, NPV: negative predictive value, CI: confidence interval.			

Table IV. — Evaluation of the relationship between anthropometric characteristics and graft diameter

	Graft Diameter	
	r	p
Age	-,062	,261
Height	,168**	,002
Weight	,058	,297
BMI	-,030	,594
**: p<0.01, BMI: Body mass index.		

It was found that the risk of revision surgery was 5.5 times higher when the graft diameter was ≤7 mm (Table III).

When the relationships between graft diameter and age, height, weight, and BMI were examined, a weak positive correlation (r=0.168) between graft diameter and height ($p<0.01$) was observed. However, there was no significant relationship between the other variables and graft diameter (Table IV).

DISCUSSION

ACLR is a surgical procedure that is widely and routinely performed in orthopedics and usually has good results[11]. The relationship between graft diameter and ACLR failure has been shown in biomechanical studies[12-14]. This study has similarly shown that the need for revision surgery increases when the graft diameter is ≤7 mm. A relationship between graft diameter and patient height has also been demonstrated.

In a study conducted by Magnussen et al., it was shown that surgeries performed with hamstring autografts with diameters of ≤8 mm increased the risk of revision surgery[12]. In the study of Inderhaug et al., who evaluated the data of 4029 patients registered in the Norwegian Knee Ligament Registry, it was observed that graft size and BMI were not independent risk factors for revision surgery for the 150 patients who needed revision surgery 2.5 years after the primary surgery[15]. In a study conducted by Thorkell et al. evaluating 18,425 patients retrospectively, it was found that patients with hamstring tendon grafts larger

than 8 mm had a lower risk of revision surgery than patients with smaller graft diameters[16]. Additionally, they observed that patients who had hamstring autografts with diameters of 9 or 10 mm had a lower risk of revision surgery compared to patients who had patellar tendon grafts[15]. In the study conducted by Murgier et al., which included 992 patients and in which graft failure was seen at a rate of 5.2% during a mean follow-up period of 38 months, no relationship between graft diameter and revision surgery was found[17]. In the review conducted by Conte et al., it was found that the risk of revision surgery decreased when graft diameter was >8 mm. The authors noted that it may be difficult to obtain grafts of larger than 8 mm for patients of shorter heights and female patients, and they suggested that methods to increase the graft diameter or patellar tendon grafts be used in such cases[18]. In a study conducted by Kang et al. with 2243 knee evaluations and a 2-year follow-up period, the obtained cut-off value of 7 mm for hamstring tendon autografts supported the aforementioned conclusions[9]. According to Alomar et al., who conducted a meta-analysis that included the data of 19,799 cases, cases with graft diameters of ≥7 had lower risk of ACLR failure than those with graft diameters of <7 mm[8]. According to Alomar et al., that meta-analysis yielded valuable results in terms of study content as it evaluated the results of 5 level II, 8 level III, and 3 level IV large case series. In a study conducted by Bedi et al., it was emphasized that increasing graft diameter is not important for stability or, at the very least, anatomical reconstruction is more important than graft diameter for time-zero stability[19]. In their study, Boniello et al. found a relationship between graft diameter and maximum tensile force, as force of 4000 N was only reached with grafts having diameters of ≥8 mm. These authors also showed that the risk of revision surgery increased when the diameter of the graft decreased[10]. When evaluating time-zero stability, it should be kept in mind that graft strength will gradually decrease during the ligamentization process. It is thought that graft diameter affects the success of surgery, similarly to many other factors such as the pre/postoperative rehabilitation processes of the patient, whether anatomical reconstruction was performed, the type of injury, and the angle of the tibial slope[2,10].

Alkalaf et al. found that patients who underwent ACLR with autograft diameters of less than 8 mm were 7.2 times more likely to require revision surgery and this risk was independent of age[4]. In another study, it was found that the risk of revision surgery was 0.82 times lower with every increase of 0.5 mm in graft diameter in the range of 7 to 9 mm[20]. In the present study, it was found that when graft diameter was ≤7 mm, the risk of revision surgery increased by 5.5 times.

There is interest among researchers in finding methods to preoperatively estimate graft diameter, which cannot be controlled by the surgeon and which has been found to be related to reconstruction success in previous studies, as well as in the present study[21]. In a review evaluating the relationship between anthropometric data and graft diameter, the authors reported that the anthropometric characteristic possessing the strongest association with larger graft diameter was the height of the patient[18]. In a study conducted by Mariscalco et al., who evaluated the second-year postoperative follow-up results of 263 patients, the group of patients with graft size of >8 mm had higher average age and BMI compared to other groups[22]. In the study conducted by Thomas et al., which included 132 patients, no correlation was found between BMI and graft diameter, but a correlation was found between patient height and graft diameter ($r=0.38$, $p<0.01$)[23]. Through regression analysis, they confirmed that height was the most important statistical predictor of graft diameter ($F=20.1$, $p<0.01$). In the study conducted by Treme et al., which included 50 patients, correlations were found between graft length and both height and leg length. In the same study, correlations were also found between graft diameter and weight and thigh circumference[24]. On the other hand, Tuman et al. found a relationship between graft diameter and height and age for female patients but did not otherwise find any relationships between graft diameter and height, age, BMI, or weight[25]. Similarly, no relationship was found between BMI and graft diameter in the present study. It may be more logical to interpret graft diameter in light of lean body mass assessments instead of looking for a relationship between BMI and graft diameter[25]. Future studies of these assessments are required. In some of the mentioned previous studies, anthropometric measurements were made by the authors, while in others, patient-reported measurements were used[21,22,25]. The variance of relationships between graft diameter and anthropometric measurements may have been caused by differences between self-reported measurements and author measurements. Patient populations living in different geographical regions may be another reason for differences in results. The most prominent anthropometric characteristic in relation to graft diameter in the aforementioned studies was observed to be height. Similarly, a weak positive correlation was found between height and graft diameter in the present study. Since it may play a role in decision-making processes regarding graft selection, it is important to be able to correctly estimate the size

of the graft before surgery. Some fixation methods and devices such as absorbable cross-pins may not be fit for use with smaller grafts[25]. Additionally, methods to be applied in the event of an insufficient graft (for example, preparing grafts using triple or quadruple tendons of appropriate length to increase the size of small grafts) should be discussed with the patient before surgery[10]. For these reasons, further studies on variables that can predict graft diameter before surgery are required.

While this study was retrospective, all data were obtained from a prospectively designed database. One of the limitations of the study is the number of patients in need of revision surgery being low. Due to the multifactorial nature of ACL injuries, not evaluating other factors such as tibial slope, intercondylar notch spacing, tunnel position, preoperative and postoperative rehabilitation conditions, and patient compliance is another limitation of this study.

CONCLUSION

As a result of this study, it was determined that the need for revision surgery increased 5.5 times when graft diameter was ≤7 mm in ACLR. For this reason, we think that with the development of triple or quadruple folding techniques, adjusting the graft diameter to be >7 mm will play an important role in eliminating the need for multiple surgeries.

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