Original Clinical Article

JOURNAL OF CHILDREN'S ORTHOPAEDICS

Journal of Children's Orthopaedics
2022, Vol. 16(2) 147–151

DOI: 10.1177/18632521221084180
journals.sagepub.com/home/cho

Does harvesting of the semitendinosus tendon really spare the gracilis in pediatric anterior cruciate ligament reconstruction?

Maxime Testory[1], Etienne Cavaignac[2], Julie Vial[3], Jérôme Sales de Gauzy[1], and Franck Accadbled[1]

Abstract

Purpose: The use of isolated semitendinosus tendon for Anterior Cruciate Ligament Reconstruction bears several advantages and is popular worldwide. It assumes that the gracilis tendon is spared. The aim of the study was to measure the surface area of the gracilis tendon in children who had undergone arthroscopic reconstruction of the anterior cruciate ligament using a semitendinosus tendon graft. Our hypothesis was that the gracilis tendon may be unintentionally and iatrogenically sectioned due to the anatomical proximity and the small size of the patients.

Methods: Fifty patients who had undergone a magnetic resonance imaging preoperatively and postoperatively at 1 year from the surgery and who had been operated between January 2017 and March 2019 were included in this prospective series. The surface area of the gracilis tendon was measured on fat-saturated T2-weighted axial views at the widest point of the medial epicondyle of the femur. Age, sex, body weight, and height were documented.

Results: One hundred magnetic resonance imaging of 50 knees were reviewed, from 34 boys (68%) and 16 girls (32%). The mean age was 14.5 years (10–18). The gracilis was visualized in all cases at 1 year postoperatively. The average tendinous surface area of the gracilis before the surgical procedure was 7.13 mm^2 versus 8.73 mm^2 at 1 year, representing an increase of 1.6 mm^2 ($p = 0.0003$).

Conclusions: This study demonstrated that harvesting of the semitendinosus for the purpose of Anterior Cruciate Ligament Reconstruction was a safe technique that preserves the gracilis.

Level of evidence: III.

Keywords: Magnetic resonance imaging, pediatric sports medicine, hamstrings, anterior cruciate ligament reconstruction, treatment, semitendinosus tendon

Introduction

Reconstruction of the anterior cruciate ligament (ACL) has seen numerous past and present developments. It is one of the main procedures performed in elective orthopedic surgery. The use of the semitendinosus (ST) as a single tendon graft is growing,[1] therefore sparing the gracilis.

The gracilis is a biarticular muscle, which originates on the inner third of the inferior edge of the ischiopubic ramus (ischial tuberosity) and, after traveling diagonally downward and outward, inserts distally on the medial side of the proximal tibia (pes anserinus), a common insertion for the ST.[2] This anatomical proximity may generate iatrogenic injuries during harvesting of the ST, especially in small size adolescents. Curtis et al.[3] described its anatomy in the medial region of the knee. Its function involves adduction of the hip joint, flexion–internal rotation of the knee, and a role in controlling excessive external rotation of the tibia, thereby

[1]Department of Orthopaedic Surgery, Hôpital des Enfants, CHU de Toulouse, Toulouse, France
[2]Department of Orthopaedic Surgery, Hôpital Pierre Paul Riquet, CHU de Toulouse, Toulouse, France
[3]Department of Radiology, Hôpital des Enfants, CHU de Toulouse, Toulouse, France

Date received: 21 October 2021; accepted: 10 February 2022

Corresponding Author:
Franck Accadbled, Orthopédie Traumatologie, Hôpital des Enfants, 330 avenue de Grande Bretagne, TSA 70034, 31059 Toulouse cedex 9, France.
Email: faccadbled@gmail.com

serving as a protective factor for the graft in case of ACL reconstruction. Furthermore, these pes anserinus tendons significantly contribute to the stability of the knee, and namely in internal rotation.[4,5] It therefore seems useful to preserve this muscle group, hence the isolated use of the ST rather than the ST/gracilis combination, especially since some studies show that using a single tendon does not adversely affect the results of ACL reconstruction.[6]

The aim of this study was to answer a simple question that remains without clear answers in the literature: does isolated harvesting of an ST tendon graft really preserve the gracilis? Our hypothesis was that gracilis tendon may be injured.

Materials and methods

A prospective, consecutive, single-center cohort of 50 patients who had undergone ACL reconstruction from October 2017 to April 2019 using isolated ST graft was analyzed. This entire cohort had received a preoperative magnetic resonance imaging (MRI) and postoperative MRI 1 year after the procedure.

Patients

There were 17 girls (34%) and 33 boys (66%), with a mean age of 14.5 years (minimum: 12/maximum: 17). The mean weight was 54.4 kg (minimum: 36 kg/maximum: 90 kg), the mean height was 161 cm (minimum: 140 cm/maximum: 174 cm). The mean Tanner stage was 2.8 (minimum: 2/maximum: 4). All but one patients were skeletally immature at the time of surgery, according to knee radiographs.

Surgical technique

Harvesting was carried out through a 2-cm oblique incision to the anteromedial aspect of the tibia. The fascia was incised, the gracilis tendon, more proximal than the ST, was identified then retracted using a dissector. The ST tendon was in turn identified and hooked out then harvested using an open stripper (Mitek DePuy Synthes, Raynham, MA, USA).[7] Pes insertion was not repaired at completion of the procedure. The procedures were carried out by two senior fellowship-trained pediatric orthopedic surgeons, each performing about 50 Anterior Cruciate Ligament Reconstruction (ACLR) in skeletally immature individuals yearly. They used the transphyseal arthroscopic technique according to Accadbled.[8]

Acquisition of MRI images

All the MRI images were acquired using a 1.5-T MR system (Toshiba Vantage Titan, Japan). The knee was in extension throughout the entire acquisition.

The standard protocol for each patient consisted of acquisition of the following sequences in the three anatomical planes (coronal/sagittal/axial):

- Fat-saturated T2-weighted.
- T1-weighted.

Two orthopedic surgeons conducted a double reading of each pre- and postoperative MRI, without consultation concerning the obtained results. Each reader thus performed 100 MRI readings, and then a new reading was done 1 week later. No measurement recordings had been done on the console to avoid influencing the second reading.

This reading had a dual purpose:

- First, to address the primary endpoint of the study, namely, is the gracilis preserved on the MRI 1 year postoperatively?
- Second, if the answer to the previous question was affirmative, the reader then proceeded to measure the cross section of the gracilis at a predetermined slice level, which we are going describe. The measurement was done twice, on each preoperative and postoperative MRI, with the objective of determining the intra- and inter-observer variation of this measurement.

Level of measurement

Based on the literature, many authors agree on the fact that the most reliable location is the widest portion of the medial epicondyle of the femur, as illustrated by the MRI slice in Figure 1.[9] In this regard, on a fat-saturated T2-weighted MRI sequence, we can easily visualize the gracilis tendon, which is found laterally from the ST.

Measurement method

We used a dedicated MRI radiology console in the Department of Radiology (syngo.via). This console allowed us to measure a surface area in mm^2 units using a freehand region of interest (ROI) on a fat-saturated T2-weighted axial slice when it had been validated that the gracilis was present postoperatively (Figure 2). This measurement method (MRI sequence, slice, and ROI selection) was validated by a senior fellowship-trained radiologist specialized in musculoskeletal imaging.

Statistics

Statistical analyses were performed using R software (Version 1.1.456—© 2009–2018 RStudio, Inc.). Univariate

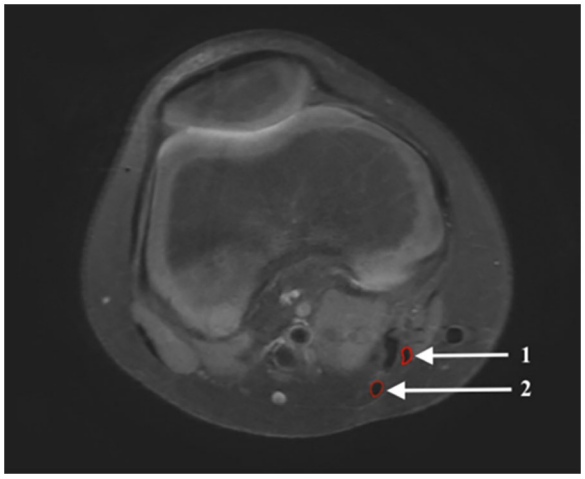

Figure 1. Right knee. Fat-saturated T2 MRI slice illustration: (1) gracilis (2) semitendinosus.

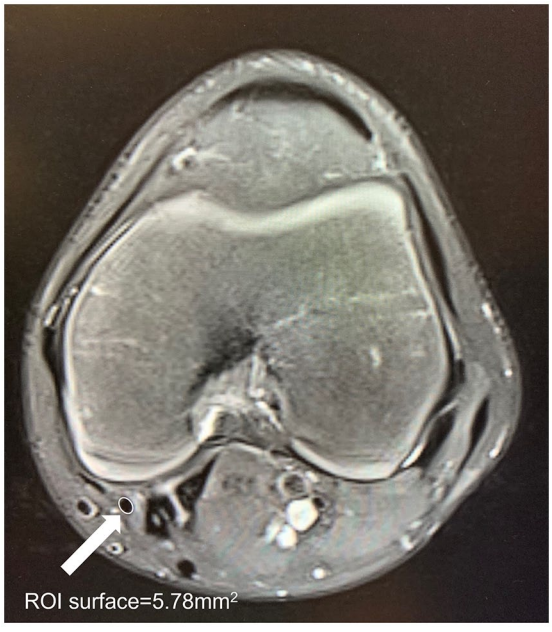

Figure 2. Left knee. Fat-saturated T2, axial MRI slice, gracilis tendon identified medially from the semitendinosus (arrow), measured by the freehand ROI tool. Window indicating the measurement in mm^2, performed with Siemens syngo.via MRI reading software.

descriptive analyses were done to describe our sample. Cronbach's alpha was used for intra-observer reliability. Tests to determine the intra-class correlation were done to evaluate inter-observer reliability. Linear regression analysis was used to analyze the relationship between the surface area of the gracilis and age, gender, weight, height, and body mass index (BMI).

Results

There was no statistically significant influence of age ($p=0.2$), gender ($p=0.3$), height ($p=0.3$), weight ($p=0.3$), or BMI ($p=0.4$) on preoperative gracilis tendon surface area. The gracilis was present in 100% of the postoperative MRIs. The ST tendon was harvested each time, with no visible iatrogenic injury to the gracilis. We also observed a mean increase of 1.5 mm^2 of the gracilis surface area. There was excellent intra- and inter-observer reliability (Tables 1 and 2). Diameter of the tendon grafts once prepared in a 4-strand fashion ranged from 7 to 9 mm. There were no complications, no re-ruptures, and no patients were lost to follow up at the time of the second MRI, 12 months after ACLR.

Discussion

The gracilis tendon was present in all postoperative MRIs and did not show any form of previous injury. This study first showed that the harvesting technique of the ST tendon was reliable and did not endanger the gracilis tendon, in spite of their close anatomical proximity and the pediatric population. Indeed, the relatively small size of the pes anserinus in children and the frequent need to extend the harvest of the ST tendon to its periosteal attachment to obtain a longer graft represent specific risks of damaging the gracilis tendon. The MRI reading technique (MRI sequence, slice, and ROI selection), validated by a radiologist specializing in pediatric musculoskeletal imaging, was reliable and reproducible.

The evolution of the gracilis tendon at 1 year showed a tendency to increase its surface area. This increase may suggest compensation of the gracilis following the loss of the ST. Both muscles are indeed knee flexors, and we can interpret this increase as the gracilis taking over a function that is usually ensured by both these muscles. A study conducted by Konrath et al.[10] found a similar result with the biceps femoris 2 years after the combined harvest of the ST and the gracilis for ACLR. During the procedure, they observed a volumetric increase in the biceps femoris, which in this case was interpreted as a compensatory phenomenon. This concept, however, contrasts with different studies on muscle strength recovery in patients following hamstring allografts. Rogowski et al.[5] showed no difference in the muscle recovery of patients who received a graft using the ST or a ST/gracilis combination. The follow-up was only 6 months, however, and this raises the question as to whether the follow-up was too short to assess muscle recovery.[5] Our cohort was comprised of children and adolescents with a mean age of 14.5 years and mostly male, thus with a still significant

Table 1. Reader A and B results.

	Gracilis present postoperative MRI	Preoperative gracilis section (mm^2, average)	Postoperative gracilis section (mm^2, average)	Preoperative/ postoperative difference (mm^2, average)	p-value
Reader A, first measurement	100%	7.13	8.63	1.50	0.0003
Reader A, second measurement	100%	7.01	8.57	1.53	0.0001
Reader B, first measurement	100%	7.03	8.57	1.50	0.0001
Reader B, second measurement	100%	7.005	8.54	1.53	0.0001

MRI: magnetic resonance imaging.

Table 2. Inter-observer reliability.

	Intra-class correlation	95% CI—lower limit	95% CI—upper limit
First reading preoperative MRI	0.85	0.76	0.91
Second reading preoperative MRI	0.98	0.97	0.99
First reading postoperative MRI	0.989	0.980	0.994
Second reading postoperative MRI	0.995	0.992	0.997

CI: confidence interval; MRI: magnetic resonance imaging.

growth potential. Although this absolutely does not influence the result of our primary endpoint, it may, however, have repercussions on our secondary endpoint due to growth. Several studies have also shown a relationship between height, weight, and BMI for the cross-sectional surface area of these tendons.[11] Other authors have focused on this potential link, their aim being to predict the diameter of the graft at the time of surgery via the preoperative MRI in order to have an additional argument for the choice of graft since a too small diameter would increase the risk of graft rupture.[6]

Although these studies show a connection between the anthropometric data and the diameter of the hamstring tendon, it can be safely assumed that with a 1-year interval between the two MRIs, the evolution of these data potentially influenced this increase due to growth. Functional preservation of the gracilis is favorable because of its role in controlling excessive external rotation of the tibia, thereby being a protective factor of the graft. Its preservation also enables it to be used in case of revision surgery, but also in various other ligament reconstruction procedures such as medial patellofemoral ligament,[12] lateral collateral ligament of the ankle,[13] anterolateral ligament of the knee,[14] or acromioclavicular ligament.[15]

The first limitation of this study stems from the fact that we base the results on two senior surgeons, experienced in pediatric ligament surgery and specifically in this surgical technique and this harvesting method. It can therefore be emphasized that the gracilis is certainly preserved but that this study does not take into consideration a learning curve. Indeed, in this context, it can be easily conceived that errors in tendon harvesting are more frequent but also that the learning curve of the technique can result in iatrogenic injury of the gracilis, which can then go unnoticed. Another limitation of this study is that our observations were purely based on imaging without clinical data. Although the primary objective of this study did not require a clinical comparison to be confirmed, the secondary endpoint opens a prospect for new studies. Indeed, we think it would be interesting to establish a link between this increased caliber and muscle strength, which would thus determine whether the gracilis is truly adapting to the absence of the ST. Another element that this observation could provide in terms of clinical application is protection of the graft from the risk of re-rupture through stress on the valgus, especially in girls. The distal limit of the MRI from the knee, sometimes located above the level of the pes anserinus, which is a technical acquisition pitfall of imaging, in association with a measurement made above the joint space, would prevent a guarantee that there is no gracilis injury at its tibial insertion since the MRI does not allow us to access there. MRI analysis was not truly blinded as the intercondylar notch was visible and a reader would have been able to identify if ACL was present or not and notice potential traumatic changes on preoperative images. Finally, no control group was available to evaluate potential gracilis regrowth after tendon harvest.

Conclusion

This study demonstrated that harvesting of the ST for the purpose of ACL reconstruction preserved the gracilis. We also observed a trend to hypertrophy of the gracilis after harvesting, which opens prospects for further studies.

Author contributions

M. Testory, MD (contribution: data collection, manuscript preparation). E. Cavaignac, MD (contribution: study design and manuscript revision). J. Vial, MD (contribution: data analysis). J. Sales de Gauzy, MD (contribution: supervised research). F.Accadbled, MD, PhD (contribution: study design and manuscript revision).

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical approval

This research involved strictly human participants. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Institutional Review Board approval no. is # 03-1216.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Informed consent

Written informed consent was obtained in each case from both the patient and the parents.

ORCID iD

Franck Accadbled https://orcid.org/0000-0001-5366-3885

References

1. Accadbled F, Gracia G, Laumonerie P, et al. Paediatric anterior cruciate ligament tears: management and growth disturbances. A survey of EPOS and POSNA membership. *J Child Orthop* 2019; 13: 522–528.
2. Khan IA, Bordoni B, Varacallo M. *Anatomy, bony pelvis and lower limb, thigh gracilis muscle*. Treasure Island, FL: StatPearls, 2021.
3. Curtis BR, Huang BK, Pathria MN, et al. Pes anserinus: anatomy and pathology of native and harvested tendons. *Am J Roentgenol* 2019; 213(5): 1107–1116.
4. Zamarra G, Fisher MB, Woo SL, et al. Biomechanical evaluation of using one hamstrings tendon for ACL reconstruction: a human cadaveric study. *Knee Surg Sports Traumatol Arthrosc* 2010; 18(1): 11–19.
5. Rogowski I, Vigne G, Blache Y, et al. Does the graft used for ACL reconstruction affect the knee muscular strength ratio at six months postoperatively? *Int J Sports Phys Ther* 2019; 14(4): 546–553.
6. Rafael Calvo R, Maximiliano Espinosa I, David Figueroa P, et al. Prediction of semitendinosus-gracilis graft diameter in children and adolescents using anthropometric measures. *Knee Surg Sports Traumatol Arthrosc* 2016; 24(3): 702–706.
7. Lanternier H, de Cussac JB, Collet T. Short medial approach harvesting of hamstring tendons. *Orthop Traumatol Surg Res* 2016; 102(2): 269–272.
8. Accadbled F, Thevenin Lemoine C, Barbier D. Transphyseal ACL reconstruction in children, 2015, https://www.vumedi.com/video/transphyseal-acl-reconstruction-in-children/
9. Bickel BA, Fowler TT, Mowbray JG, et al. Preoperative magnetic resonance imaging cross-sectional area for the measurement of hamstring autograft diameter for reconstruction of the adolescent anterior cruciate ligament. *Arthroscopy* 2008; 24(12): 1336–1341.
10. Konrath JM, Vertullo CJ, Kennedy BA, et al. Morphologic characteristics and strength of the hamstring muscles remain altered at 2 years after use of a hamstring tendon graft in anterior cruciate ligament reconstruction. *Am J Sports Med* 2016; 44(10): 2589–2598.
11. Toor AS, Limpisvasti O, Ihn HE, et al. The significant effect of the medial hamstrings on dynamic knee stability. *Knee Surg Sports Traumatol Arthrosc* 2019; 27(8): 2608–2616.
12. Schottle PB, Romero J, Schmeling A, et al. Technical note: anatomical reconstruction of the medial patellofemoral ligament using a free gracilis autograft. *Arch Orthop Trauma Surg* 2008; 128(5): 479–484.
13. Michels F, Cordier G, Burssens A, et al. Endoscopic reconstruction of CFL and the ATFL with a gracilis graft: a cadaveric study. *Knee Surg Sports Traumatol Arthrosc* 2016; 24(4): 1007–1014.
14. Cavaignac E, Castoldi M, Marot V, et al. Minimally invasive ultrasound-guided anterolateral ligament reconstruction with autologous 2-strand gracilis graft. *Arthrosc Tech* 2019; 8(7): e685–e689.
15. Scheibel M, Ifesanya A, Pauly S, et al. Arthroscopically assisted coracoclavicular ligament reconstruction for chronic acromioclavicular joint instability. *Arch Orthop Trauma Surg* 2008; 128: 1327–1333.