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Superior return to sports rate after patellar tendon autograft over patellar tendon allograft in revision anterior cruciate ligament reconstruction

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Abstract
Purpose After revision anterior cruciate ligament reconstruction (ACLR), the rate of return to the pre-injury type of sport (RTS type) is low and graft choice might be an important factor. The aim of this study was to determine whether there is a difference in outcome after revision ACLR using a patellar tendon allograft compared to an ipsilateral patellar tendon autograft. It was hypothesized that the rate of RTS type using an ipsilateral patellar tendon autograft will be superior to using patellar tendon allograft.
Methods The design is a retrospective cohort study. Inclusion criteria were patients who underwent revision ACLR with a minimum follow-up of 1 year after revision using a patellar allograft or ipsilateral autograft. Primary study parameter was rate of RTS type. Secondary study parameters were RTS level, subscores of the KOOS, the $IKDC_{subjective}$, the Tegner score and reasons for no RTS.
Results Eighty-two patients participated in this study (36 allografts and 46 autografts). In patients with a minimum follow-up of 1 year, rate of RTS type was 51.4% for the patellar tendon allograft and 62.8% for the patellar tendon autograft group (n.s.). In patients with a minimum follow-up rate of 2 years, rate of RTS type was 43.3 versus 75.0%, respectively ($p = 0.027$). No differences in secondary study parameters were found. In patients with a minimum follow-up of 1 year, rate of RTS type was significantly higher ($p = 0.025$) for patients without anxiety compared to patients who were anxious to perform certain movements.
Conclusion After a minimum follow-up of 2 years, rate of RTS type is in favour of using an ipsilateral patellar tendon autograft when compared to using a patellar tendon allograft in patients undergoing revision ACLR; after a minimum follow-up of 1 year, no significant difference was found. In revision ACLR, the results of this study might influence graft choice in favour of autologous graft when the use of an allograft or autograft patellar tendon is considered.
Level of evidence III.

Keywords ACL · Revision · Autograft · Allograft · Sports resumption · Anxiety

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Introduction

In primary anterior cruciate ligament reconstruction (ACLR), graft choice might be of influence in rate of return to pre-injury type (RTS type) and level (RTS level) of sport, subjective outcome and residual laxity [8, 20, 23]. After revision ACLR, rate of RTS type and RTS level is slightly

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lower than after primary ACLR [1, 16]. Options in graft choice for revision ACLR may include ipsilateral or contralateral hamstring, patellar or quadriceps autograft tendon, depending on the graft used for primary ACLR. For allograft use, more options are available. However, for revision ACLR, optimal graft choice is still controversial [9, 12]. Wright et al. [24] reported that of 12,000 patients in their cohort, graft choice for revision ACLR was 49% allograft, 48% autograft and 3% combined allograft and autograft. Patellar tendon—either allograft or autograft—was used most often.

The use of a patellar allograft tendon might have advantages over a patellar autograft tendon, such as smaller incision, shorter operating time, less postoperative pain [3, 14] and the possibility of using larger bone blocks at the end of the graft. Disadvantages of using a patellar allograft tendon include a small chance of bacterial infectious disease or virus transmission [2, 7, 15], higher costs, increased failure rates in more active individuals due to graft weakening from sterilization processes [22], age of the graft as donor grafts are frequently from older donors, a mismatch between size of the donor graft and patient's knee and availability [14]. By contrast, disadvantages of using a patellar autograft tendon might include anterior knee pain [21], donor site morbidity, quadriceps weakness [5, 21] and therefore a lower knee extensor moment [17].

The present study adds to the current literature the analysis of differences in rate of RTS type and RTS level between a patellar allograft tendon and a patellar autograft tendon in revision ACLR. We hypothesized that rate of RTS type and RTS level after revision ACLR using an ipsilateral patellar tendon autograft are superior to revision ACLR using patellar allograft tendon.

Materials and methods

A retrospective cohort study was conducted at the Orthopaedic Department of Martini Hospital in Groningen and Centre for Orthopaedic Surgery OCON in Hengelo, the Netherlands.

In the period between 2005 and 2015, 115 patients who underwent revision ACLR with a patellar tendon allograft or ipsilateral patellar tendon autograft with a minimum follow-up of 1 year after revision ACLR were eligible for this study (mean 44.7 months; minimum 12, maximum 108.9). Four surgeons performed the ACLRs. Exclusion criteria were patients with a history of second revision ACLR, contralateral ACLR and revision ACLR with a graft other than a patellar tendon allograft or ipsilateral autograft. Seventy-eight patients (67.8%) were included for analyses on rate of RTS type and RTS level. Eighty-two patients (71.3%) were included for analyses on functional results (KOOS, $IKDC_{subjective}$, Tegner scores). A subgroup analysis was conducted in patients with a minimum follow-up of 2 years. Fifty-five patients (47.8%) were eligible for this analysis. A flowchart of inclusion is presented in Fig. 1. Baseline characteristics at the time of revision ACLR are presented in Tables 1 and 2.

The primary outcome measure was rate of RTS type. Secondary outcome measures were rate of RTS level, the Dutch version of the Knee injury and Osteoarthritis Outcome Score (KOOS) [4], the International Knee Documentation Committee subjective form ($IKDC_{subjectve}$) [6], the Tegner score [19] and the reasons for not returning to sport. Rate of RTS level was divided into three categories based on the open questions; 1: patients who returned to sports on a lower than pre-injury level; 2: patients who returned to sport on their pre-injury level; 3: patients who returned to sport on a higher than their pre-injury level.

The Medical Ethical Committee of Martini Hospital approved the study design, procedures and protocol (METC number: 2014-87). All patients were informed about the study procedure and interest by letter or by e-mail.

Procedure

All patients included in the study were asked to fill in a questionnaire. This questionnaire was sent together with an accompanying letter explaining the interest and purpose of this study by mail or by e-mail using an online questionnaire. The questionnaire contained the Dutch version of the KOOS [4], the $IKDC_{subjective}$ [6], the Tegner score [19] and homemade open questions as presented in Table 3.

Statistical analysis

The data were processed using SPSS Version 20 (IBM SPSS Statistics for Mac. Armonk, NY: IBM Corp.). A Chi-square test was used to compare the distribution of rate of RTS type between patients with a minimum follow-up of 1 and 2 years who underwent revision ACLR using a patellar tendon allograft or ipsilateral patellar tendon autograft. Fischer's exact test was used to compare rate of RTS level in patients with a minimum follow-up of 1 and 2 years who underwent revision ACLR using a patellar tendon allograft or ipsilateral patellar tendon autograft, as the criteria were not met for a Chi-square test.

The independent sample *t* test was used to compare the subscores $KOOS_{sport}$, $KOOS_{symptoms}$, $KOOS_{qol}$ of the KOOS and $IKDC_{subjective}$ score between those patients with a minimum follow-up of 1 and 2 years who underwent revision ACLR using a patellar tendon allograft or ipsilateral patellar tendon autograft. As the score of the $KOOS_{ADL}$ (kurtosis = 4.3) and the $KOOS_{pain}$ (kurtosis = 2.0) were not normally distributed and the Tegner score is an ordinal level,

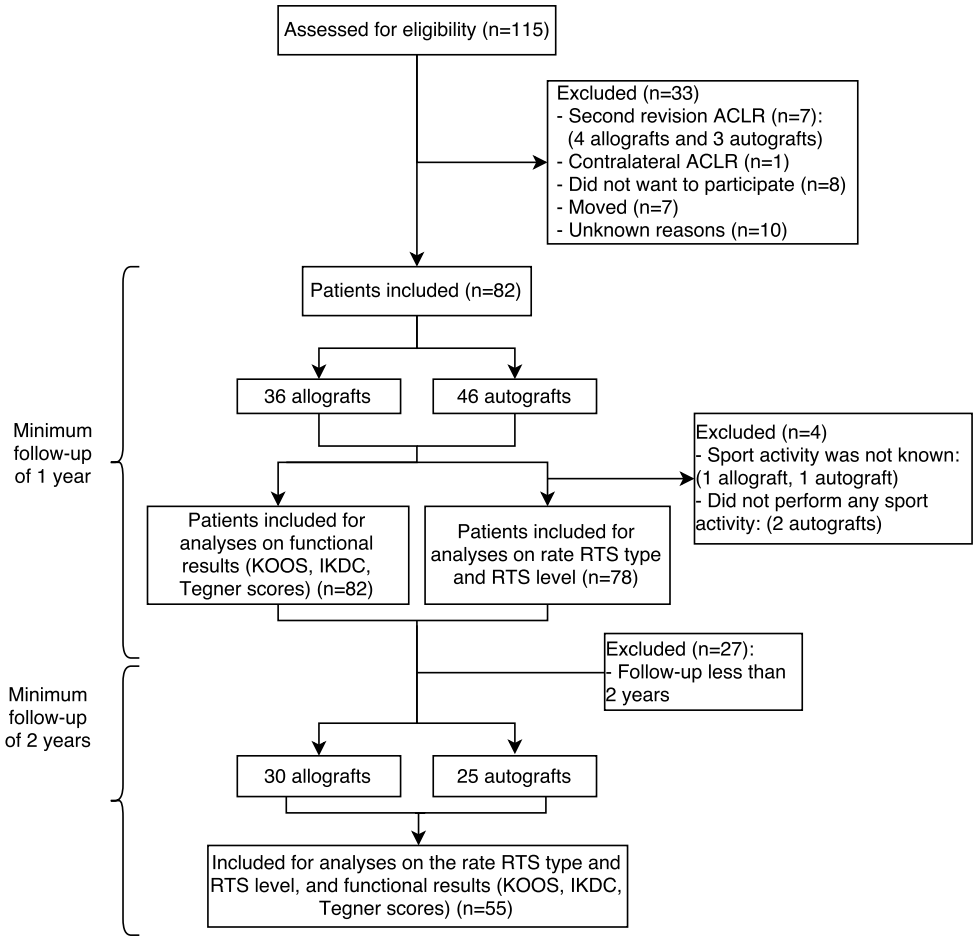

Fig. 1 Flow chart of the included patients

the Mann–Whitney *U* test was used to compare these scores among patients who underwent revision ACLR using a patellar tendon allograft or ipsilateral patellar tendon autograft.

In addition, a Chi-square analysis was used to compare rate of RTS type and anxiety to perform certain movements between patients with a minimum follow-up of 1 and 2 years.

An alpha level of $p \leq 0.05$ was considered to be significant. No sample size calculation was performed before conducting the study, as all patients who met the inclusion criteria were included in this study. A post hoc power calculation revealed a power of 84.1% for analysis regarding RTS type of patients at least 2 years postoperative and a power of 17.7% for analysis regarding RTS type of patients at least 1 year postoperative.

Results

Baseline characteristics

No significant differences were found in demographic characteristics (Table 1) or in meniscal and cartilage injury (Table 2). No significant differences were found for these parameters between patients who did not fill in the questionnaire and the patients who did fill in the questionnaire (Tables 2, 3).

Before primary ACL injury ten patients performed their sport at recreational level, 51 patients at regional competition level, 14 at national competition level and three patients performed sport their sport at international competition level. No significant differences were found between the groups for rate of RTS type and RTS level after primary ACL injury.

Rate of RTS type after revision ACLR

In patients with a minimum follow-up of 1 year, no significant difference was found between the groups (mean 56.0%, allograft 51.4%, autograft 62.8%; Table 4). However, in patients with a minimum follow-up of 2 years, rate of RTS type did reach a significant difference ($p = 0.031$) in favour of the patellar tendon autograft group (mean 57.4%, allograft 43.3%, autograft 75%; Table 5).

Table 1 Baseline characteristics of the participants: allograft versus autograft

	Allograft	Autograft	*p* value (allograft vs. autograft)	Lost to follow-up	*p* value (included vs. lost)
Number of patients	36	46		33	
Women/men	14/22	16/30	n.s.	11/22	n.s.
Age at revision ACLR [mean (SD)]	26.7 (10.3)	25.9 (6.6)	n.s.	25.9 (8.4)	n.s.
Left/right	15/21	18/28	n.s.	13/20	n.s.
Months between primary ACLR and revision ACLR [mean (SD)]	45.3 (53.5)	32.3 (26.4)	n.s.	40.8 (34.7)	n.s.
Primary graft used					
Hamstring autograft	25	43		28	
Hamstring allograft	1	1		0	
Hamstring contralateral	1	0		0	
Patellar autograft	8	0		2	
Patellar allograft	0	0		2	
Tuberositas tibialis graft	0	1		0	
Leeds-Keilo implant	1	0		0	
Not known	0	0		1	
Level of sport before primary injury			n.s.		
Did not do sports	1	1		–	
Recreational	3	7		–	
Competition regional	24	27		–	
Competition national	5	9		–	
Competition international	3	0		–	
Not known	0	2		–	

n.s. not significant

Table 2 Baseline characteristics for accompanying meniscal and/or cartilage injury at the moment of revision: allograft versus autograft

	Allograft	Autograft	Lost to follow-up
Cartilage injury			
Medial	18	22	16
Lateral	9	15	9
Patellar	11	13	4
Meniscal injury medial			
No	14	25	13
Yes	5	7	3
Yes, subtotal meniscectomy	2	1	1
Yes, partial meniscectomy	15	11	13
Yes, meniscal repair	0	2	3
Meniscal injury lateral			
No	24	33	19
Yes	5	5	2
Yes, subtotal meniscectomy	0	0	1
Yes, partial meniscectomy	7	6	9
Yes, meniscal repair	0	2	2

Rate of RTS level after revision ACLR

In those patients who did return to their pre-injury type of sports, no significant difference was found in rate of RTS level after revision ACLR using a patellar tendon allograft or patellar tendon autograft with a minimum follow-up of 1 year (Table 4) or 2 years (Table 5).

$IKDC_{subjective}$, KOOS and Tegner scores

No significant differences were found in $KOOS_{symptoms}$, $KOOS_{pain}$, $KOOS_{ADL}$, $KOOS_{sport}$, $KOOS_{qol}$, $IKDC_{subjective}$ or Tegner scores with a minimum follow-up of 1 year (Table 4) or 2 years (Table 5).

Reasons for not returning to pre-injury type of sports

For reasons for no RTS and anxiety about performing certain movements, see Table 6. A significant difference ($p = 0.025$) was found after a minimum follow-up of 1 year in rate of RTS type between patients who were anxious

Table 3 Open questions included in the questionnaire (in Dutch)

What kind of sport(s) did you perform before your knee injury?
At what level did you perform these sport(s)?
Did you perform the same sport(s) again after your first ACLR?
If so, at what level did you perform your sport(s)?
Did you perform the same sport(s) again after revision ACLR?
If so, at which level did you perform your sport(s)?
If you did not return to the same sport(s), what was the reason?
Does your knee injury affect you in such a way that you are anxious to perform certain actions?
What kind of work or study did you do before you injured your ACL?
Did you change your work or study because of your knee injury?

Table 4 Return to pre-injury type of sport (RTS type) rate, return to pre-injury level of sports (RTS level) rate, KOOS, Tegner and $IKDC_{subjective}$ score: Allograft versus Autograft in patients with a minimum follow-up of 1 year after surgery

	Allograft	Autograft	*p* value (2-tailed)
RTS type rate (percentage)	51.4	62.8	n.s.
RTS level rate (percentage lower/same/higher)	41.2/52.9/5.9	63/37/0	n.s.
$KOOS_{symptoms}$ [mean (SD)]	55.5 (12.5)	59.2 (10.5)	n.s.
$KOOS_{pain}$ [mean (SD)]	76.5 (22.8)	83.4 (15.5)	n.s.
$KOOS_{ADL}$ [mean (SD)]	85.1 (20.1)	90.1 (13.5)	n.s.
$KOOS_{sport}$ [mean (SD)]	51.3 (29.8)	56.7 (28.6)	n.s.
$KOOS_{qol}$ [mean (SD)]	43.4 (15.2)	46.3 (13.2)	n.s.
Tegner score [median (range)]	4 (10)	4.5 (8)	n.s.
$IKDC_{subjective}$ [mean (SD)]	62.0 (10.2)	64.5 (9.8)	n.s.

n.s. not significant

Table 5 Return to pre-injury type of sport (RTS type) rate, return to pre-injury level of sport (RTS level) rate, KOOS, Tegner, and $IKDC_{subjective}$ score: Allograft versus Autograft in patients with a minimum follow-up of 2 years after surgery

	Allograft	Autograft	*p* value (2-tailed)
RTS type rate (percentage yes/no) or	43.3	75	0.027*
RTS level (percentage lower/same/higher)	46.2/46.2/7.7	66.7/33.3/0	n.s.
$KOOS_{symptoms}$ [mean (SD)]	55.2 (12.8)	57.6 (10.1)	n.s.
$KOOS_{pain}$ [mean (SD)]	76.8 (21.0)	83.8 (16.0)	n.s.
$KOOS_{ADL}$ [mean (SD)]	86.6 (15.9)	90.5 (12.6)	n.s.
$KOOS_{sport}$ [mean (SD)]	49.2 (25.9)	58.2 (27.3)	n.s.
$KOOS_{qol}$ [mean (SD)]	43.3 (14.8)	44.8 (14.4)	n.s.
Tegner score [median (range)]	4 (8)	4 (10)	n.s.
$IKDC_{subjective}$ [mean (SD)]	61.6 (8.9)	64.3 (10.0)	n.s.

n.s. not significant

* significant

(rate RTS type: 49%) and patients who were not anxious about performing certain movements (rate RTS type: 82%). No significant difference in rate of RTS type between patients who were anxious and patients who were not anxious about performing certain movements was found after a minimum follow-up of 2 years.

Discussion

The most important finding of the present study was that, in patients undergoing revision ACLR, after a minimum follow-up of 2 years there was a significant difference in rate of RTS type in favour of using an ipsilateral patellar tendon autograft over a patellar tendon allograft, even though after a minimum follow-up of 1 year no difference was found.

Ardern et al. [1] reported that two-thirds of patients after a primary ACLR have not returned to sport 1 year after surgery. This might explain the difference between rate of RTS type after a minimum follow-up of 1 versus 2 years, the shorter follow-up period may be too short and a follow-up of 2 years is more representative for this outcome measure. In contrast to the present study, Legnani et al. [10] reported

Table 6 Reasons for no RTS and anxiety

Reasons for no RTS	Number of participants	Anxiety about performing certain movements (69.6%)	Number of participants
Risk of re-injury	29	Tossing and turning	23
Knee pain	22	Kicking a ball	5
Knee swelling	3	Running	11
Knee instability	21	Jumping	22
Discouraged by physiotherapist or orthopaedic surgeon	6	Stair-climbing	1
		Squatting	3
		Sudden movements	7
		Kneeling	5
		Unstable movements	2
		New activities	1
		Sport-related activities	20

Table 7 Studies comparing the use of an allograft and autograft tendon for revision ACLR

Study	Graft type	Outcome scores: graft favoured
Wright et al. [23]	Not reported	$IKDC_{subjective}$ and KOOS: autograft
		Marx scale: combined allograft and autograft
		Re-rupture rate: autograft
Lind et al. [11]	Either hamstring or patellar tendon autograft or allograft	Re-rupture: autograft
Mayr et al. [13]	Patellar tendon	Anterior tibia translation, manual examination for stability, $IKDC_{subjective}$: autograft = allograft
		Extension deficits: allograft
		Lateral gonarthritis and femoral tunnel widening and pain during walking downhill: autograft
Steadman et al. [18]	Patellar tendon	Lysholm score, Tegner activity scale, and patient satisfaction with outcome: allograft = autograft
		Re-rupture rate: autograft
Legnani et al. [10]	Patellar or Achilles tendon	Quicker RTS time: autograft
		$IKDC_{subjective}$, KOOS: allograft = autograft
		RTS level: allograft = autograft
		Anterior tibia translation: allograft = autograft

that patients reconstructed with a contralateral autograft tendon returned to sport more quickly after revision ACLR than patients reconstructed with an allograft patellar or Achilles tendon. However, the autograft was harvested from the contralateral knee and in the allograft group patellar as well as Achilles tendon, grafts were used.

Furthermore, Reinhardt et al. [16] reported a higher rate of RTS level (52%) for patients with a minimum follow-up of 2 years when compared to the present study (24%). This difference might be explained by the older age of the studied population (the present study: 16–57; Reinhardt et al.: <18 years).

Few previous studies have compared use of an allograft and autograft for revision ACLR (see Table 7). Most outcome measures ($IKDC_{subjective}$ [22, 23], KOOS [23], re-rupture rate [11, 18, 23], incidence of lateral compartment knee osteoarthritis [13], femoral tunnel widening [13] and pain during walking downhill [13]) favoured using an autograft tendon. Some outcome measures (anterior translation [13], manual examination for stability [13], $IKDC_{subjective}$ [13], Lysholm score [18], Tegner activity scale [18] and patient satisfaction with outcome [18]) were similar in their use of an autograft and allograft tendon. Mayr et al. [13] reported greater extension deficits in patients who underwent revision ACLR with an autograft compared to a patellar tendon allograft. No significant differences in patient reported outcome measures were found in the present study.

A significant difference was found in rate of RTS type between patients who reported that they were anxious

to perform certain movements and those that were not. A future study could investigate whether psychological treatment to reduce the anxiety may improve rate of RTS type.

Besides the retrospective nature of the present study, some other limitations need to be addressed. One such limitation is that no objective instrumented assessment was used to measure knee function. A future study could determine whether there is a difference in clinical instrumented tests between using a patellar tendon allograft or a patellar tendon autograft for revision ACLR. In addition, patients who declined to fill in the questionnaire ($n = 8$) or did not fill in the questionnaire for unknown reasons ($n = 10$) might have introduced a non-response bias. However, no significant differences were found in age at revision ACLR, sex, months between primary ACLR and revision ACLR, cartilage damage, or meniscal damage between responders and non-responders. Moreover, in the present study, patients participated at different levels of sports (recreational, regional, national or international) before their ACL injury. A lower pre-injury level might be easier to return to than a higher pre-injury level. As most patients in the present study participated in their pre-injured sports on a regional level, no analyses were conducted to determine this difference in rate of RTS. Future studies could identify if this. Preferably, a RCT is needed to confirm the results of the present study.

The clinical relevance of the present study is that, in revision ACLR, the results might influence the choice in favour of autologous graft when the use of an allograft or autograft patellar tendon is considered.

Conclusion

The results have shown that after a minimum follow-up of 2 years, rate of RTS type can be seen in favour of using an ipsilateral patellar tendon autograft over a patellar tendon allograft in patients undergoing revision ACLR; after a minimum follow-up of 1 year, no significant difference was found.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Funding No external source of funding was used.

Ethical approval The Medical Ethical Committee of Martini Hospital approved the study design, procedures and protocol (METC No. 2014-87).

Informed consent For this type of study formal consent is not required.

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