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Increased Risk of Revision With Hamstring Tendon Grafts Compared With Patellar Tendon Grafts After Anterior Cruciate Ligament Reconstruction

A Study of 12,643 Patients From the Norwegian Cruciate Ligament Registry, 2004-2012

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Background: The graft choice for anterior cruciate ligament reconstruction (ACLR) is controversial. Hamstring tendon (HT) autografts and patellar tendon (PT) autografts are the most common grafts used and have shown similar subjective and objective outcomes.

Purpose: To compare the revision rate between HT and PT autografts used in ACLR in Norway and to estimate the influence of patient age and sex.

Study Design: Cohort study; Level of evidence, 2.

Methods: The study included all patients who underwent primary ACLR without concomitant ligament injuries registered in the Norwegian Knee Ligament Registry from 2004 through 2012. The cohort was stratified by age group (15-19, 20-29, and ≥30 years) and autograft type (HT or PT). Revision rates at 1, 2, and 5 years were calculated using the Kaplan-Meier analysis, and hazard ratios (HRs) for revision were calculated using multivariate Cox regression models.

Results: With a mean follow-up of 4.0 years, 12,643 primary ACLRs were identified, with 3428 PT and 9215 HT grafts, among which 69 revisions with PT grafts and 362 revisions with HT grafts were performed. The overall 5-year revision rate was 4.2%. A higher revision rate was recorded for HT versus PT grafts at all follow-up times. When adjusted for sex, age, and type of graft, the HR for revision was 2.3 (95% CI, 1.8-3.0) for HT grafts compared with PT grafts. The HR for revision in the youngest age group was 4.0 (95% CI, 3.1-5.2) compared with the oldest age group. Sex had no effect on the revision rate.

Conclusion: Patients with HT grafts had twice the risk of revision compared with patients with PT grafts. Younger age was the most important risk factor for revision, and no effect was seen for sex. Further studies should be conducted to identify the cause of the increased revision rate found for HT grafts.

Keywords: ACL; reconstruction; revision; graft; patellar tendon; hamstring tendon

Anterior cruciate ligament reconstruction (ACLR) is one of the most common operations performed by orthopaedic surgeons. In the United States, the incidence of ACLR has been found to be 36.9 per 100,000 citizens per year,[14] and similar incidences have been found in Norway,[17] Denmark,[32] and Sweden.[18]

The choice of graft depends on multiple factors such as concomitant ligament injuries, donor site morbidity, age, and surgeon's preference.[8,25] The most common grafts used in Scandinavia for ACLR are hamstring tendon (HT) autografts and patellar tendon (PT) autografts.[18] Despite the extent of research on the topic, there is so far no consensus on which of the two is the superior graft.

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The authors of several systematic reviews,[10,16,37,48] a case series,[7] and a prospective randomized study[15] did not find any difference in graft ruptures/survival between PT and HT grafts. Freedman and colleagues[11] found that PT grafts had a lower failure rate compared with HT grafts. Similarly, Barrett et al[5] found a higher clinical failure rate in patients younger than 25 years with HT grafts, and a newly published register study identified the risk of early revision to be 1.82 times higher when using HT grafts compared with PT grafts.[34] However, an increased risk of contralateral ACL (CACL) ruptures has been found when using PT grafts.[7,41]

There has recently been a trend favoring the use of HT grafts instead of PT grafts in the United States.[9] A similar trend has been seen in Sweden, where 96.1% of ACLRs were performed with HT grafts in 2010.[2]

The Norwegian Knee Ligament Registry (NKLR) was established in June 2004 and collects prospective information on all reported cases of cruciate ligament reconstructions and revisions in Norway.[17] Based on data from the NKLR, we aimed to compare the risk of revision between HT and PT grafts after a primary ACLR, adjusting for age and sex.

MATERIALS AND METHODS

The NKLR is owned by the Norwegian Orthopedic Association and is run by the Norwegian Arthroplasty Register (NAR). The registry is exclusively funded by the government. Surgery details are gathered based on registration forms completed by the surgeons directly after the operations. Every person in Norway has a unique personal identification number, which is registered in the form, making it possible to link each revision to the index operation. All surgeries on cruciate ligaments and all later knee surgeries performed on these knees are to be reported to the registry. Clinical follow-ups with the Knee injury and Osteoarthritis Outcome Score[44] at 2, 5, and 10 years postoperatively are to be reported through postal questionnaires or by a web-based solution, but these data were not included in the present study. The completeness of registration to the NKLR for ACLR and revision ACLR was found to be 86% during the years 2008 and 2009 according to a study comparing data from the NKLR versus the Norwegian Patient Register and the electronic patient charts for public and private hospitals, respectively.[53]

As of December 31, 2012, a total of 14,302 patients who underwent primary ACLR were registered in the NKLR. The following patients were excluded: patients with grafts other than PT or HT autografts (n = 98), primary injuries other than ACL ruptures (n = 140), concomitant ligament injuries (n = 1135), and patients younger than 15 years (n = 286) (Figure 1). Consequently, 12,643 patients were included, 9215 with HT grafts and 3428 with PT grafts.

Body mass index (BMI) was calculated for patients in whom both height and weight were registered (n = 5539). Based on previous studies having shown that younger age is an important risk factor for revision,[5,21,26,47] the cohort was stratified into 3 age groups: 15-19 years, 20-29 years, and ≥30 years. This rendered comparable group sizes for the analyses. Subanalyses on risk for CACL reconstruction (CACLR) were performed.

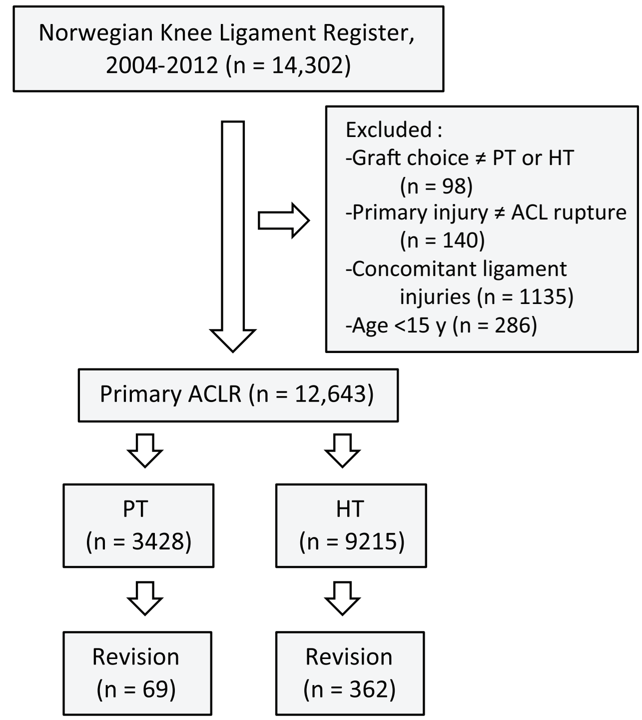

Figure 1. Flow diagram illustrating the cohort with included patients. ACLR, anterior cruciate ligament reconstruction; HT, hamstring tendon autograft; PT, patellar tendon autograft.

Statistical Analysis

Statistical analyses were performed using SPSS software version 21 (SPSS Inc, Chicago, Illinois). All tests were 2-sided with a .05 significance level. To test for group differences, we used the χ^2 test for categorical variables and the independent Student *t* test or Mann-Whitney *U* test for continuous variables. To test the yearly changes in graft choice we used the χ^2 linear-by-linear association test. Crude revision rates at specific time points were calculated using Kaplan-Meier survival tables, and potential confounding factors were adjusted for in multivariate Cox regression analyses with revision as the end point. Patients were followed until death (n = 31), emigration (n = 171), or end of the study (December 31, 2012).

RESULTS

Baseline epidemiological and patient characteristics are presented in Table 1. There were small but statistically significant differences between the 2 graft types in terms of age at surgery, distribution of graft types within age groups, sex, surgery time, and mean follow-up, and a slightly increased difference in patients with less than 2 years of follow-up. The type of graft used in the different

TABLE 1
Baseline Epidemiological and Patient Characteristics[a]

Factor[b]	PT (n = 3428)	HT (n = 9215)	*P* Value
Age at surgery, y	29.0 ± 10.1	28.3 ± 10.2	**<.001**[d]
Age group, n (%)			
15-19 y	936 (25.0)	2783 (75.0)	**.002**[e]
20-29 y	1070 (26.6)	2873 (73.4)	
≥30 y	1422 (28.5)	3559 (71.5)	
Male patients, %	58.9	56.8	**.033**[e]
Height (n = 5586), cm	174.9 ± 9.0	174.7 ± 9.0	.558[e]
Weight (n = 5566), kg	77.8 ± 14.6	76.9 ± 23.2	.220[e]
BMI (n = 5539), kg/m^2	25.3 ± 3.7	25.1 ± 7.5	.371[e]
Outpatient surgery, %	50.9	50.7	.916[e]
Previous surgery in index knee, %	22.7	21.3	.181[e]
Meniscal injury,[c] n (%)	1687 (49.2)	4657 (50.5)	.185[d]
ICRS grade 3-4 (n = 11,770), n (%)	249 (7.3)	639 (7.0)	.486[d]
Surgery time, min	75.5 ± 32.7	77.1 ± 30.5	**.006**[e]
Follow-up, y	4.7 ± 2.6	3.7 ± 2.4	**<.001**[e]
Patients with <2 years' follow-up, n (%)	684 (20)	2727 (29.6)	**<.001**[d]
Time to surgery from injury (n = 12,015), y	1.9 ± 3.8	1.8 ± 3.5	.073[e]
Median	0.65	0.66	.111[f]

[a]Values are expressed as mean ± standard deviation unless otherwise indicated. Significant *P* values are in bold. BMI, body mass index; HT, hamstring tendon autograft; ICRS, International Cartilage Repair Society; PT, patellar tendon autograft.
[b]Sample number next to the factor indicates the number of patients with registered factors in the data set if not complete.
[c]Reported injury to 1 or both menisci.
[d]χ^2 test.
[e]Student *t* test.
[f]Mann-Whitney *U* test.

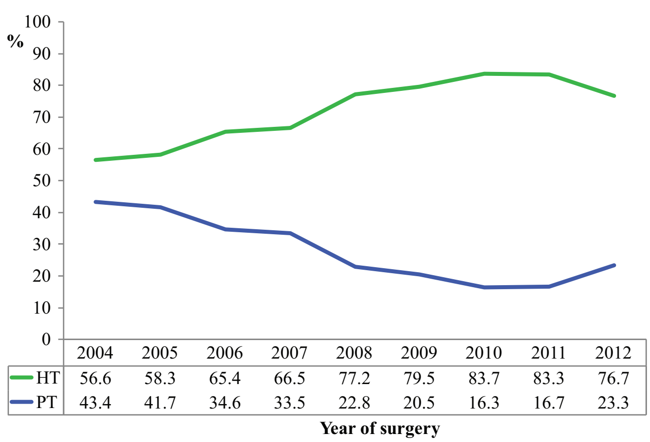

Figure 2. Time trend for graft choice for primary anterior cruciate ligament reconstruction in the Norwegian Knee Ligament Registry.

age groups was relatively constant, but there was 13% more PT grafts in patients aged ≥30 years compared with patients aged 15-19 years for the whole period ($P <$ .001). The mean follow-up for the whole cohort was 4.0 ± 2.5 years. There were no statistically significant differences in height, weight, BMI, percentage performed as outpatient surgery, previous surgery of the index knee, concomitant meniscal or International Cartilage Repair Society grade 3 to 4 cartilage injuries, and time to surgery from injury between the 2 graft groups.

There were 431 revisions (362 with HT grafts and 69 with PT grafts) identified in the data set (Figure 1). The use of the 2 grafts from 2004 to 2012 is illustrated in Figure 2. Initially, there was an increase in the use of HT grafts, with a peak in 2010 (84%). In the last 2 years of the study period, however, there was a decline to 77% and a parallel increased use of PT grafts. The yearly change in use of the two grafts was statistically significant ($P <$ .001).

The cumulative revision analysis stratified by graft type is presented in Figure 3. Crude revision rates for the examined factors are presented in Table 2. The 5-year revision rate was 4.2% (95% confidence interval [CI], 3.8-4.7) for the whole cohort, 7.8% (95% CI, 6.8-8.9) for the youngest age group, and 1.8% (95% CI, 1.4-2.2) for the oldest age group. Within 5 years, 5.1% in the HT group and 2.1% in the PT group had been revised. In all age groups, the revision rate was lower in patients with PT grafts compared with HT grafts. The largest difference was found in the youngest age group, with a 5-year revision rate of 9.5% (95% CI, 8.1-10.8) for HT grafts and 3.5% (95% CI, 2.1-4.8) for PT grafts. The 5-year revision rate for the oldest age group was 2.1% (95% CI, 1.5-2.7) for HT grafts and 1.2% (95% CI, 0.6-1.8) for PT grafts.

Adjusted for age and sex, the hazard ratio (HR) for revision was 2.3 (95% CI, 1.8-3.0) (Table 3) in the HT group compared with the PT group. The HR for revision in the youngest age group was 4.0 (95% CI, 3.1-5.2) compared with the oldest age group. Sex had no statistically significant effect on revision. In a subanalysis adjusted for age

TABLE 2
Crude Revision Rates for the Examined Variables[a]

Factor and Category	n	Revision Rate (95% CI), % 1 y	2 y	5 y
Overall	12,643	0.8 (0.7-1.0)	2.2 (1.9-2.5)	4.2 (3.8-4.7)
Sex				
Male	7252	0.8 (0.6-1.0)	2.1 (1.7-2.4)	4.0 (3.4-4.5)
Female	5391	0.9 (0.6-1.2)	2.4 (2.0-2.9)	4.6 (4.0-5.3)
Graft type				
HT	9215	1.1 (0.8-1.3)	2.8 (2.4-3.2)	5.1 (4.6-5.7)
PT	3428	0.3 (0.1-0.5)	0.7 (0.4-1.0)	2.1 (1.6-2.7)
Age at surgery, y				
15-19	3719	1.5 (1.1-1.9)	4.3 (3.6-5.0)	7.8 (6.8-8.9)
20-29	3943	0.9 (0.6-1.2)	1.9 (1.4-2.3)	4.0 (3.3-4.7)
≥30	4981	0.3 (0.1-0.5)	0.9 (0.6-1.2)	1.8 (1.4-2.2)
Age group and graft type				
15-19 y and HT	2783	1.9 (1.3-2.4)	5.4 (4.5-6.3)	9.5 (8.1-10.8)
15-19 y and PT	936	0.4 (0.0-0.8)	1.2 (0.4-1.9)	3.5 (2.1-4.8)
20-29 y and HT	2873	1.2 (0.7-1.6)	2.4 (1.8-3.0)	4.7 (3.7-5.7)
20-29 y and PT	1070	0.3 (0.0-0.7)	0.6 (0.1-1.1)	2.3 (1.3-3.4)
≥30 y and HT	3559	0.3 (0.1-0.5)	1.1 (0.7-1.4)	2.1 (1.5-2.7)
≥30 y and PT	1422	0.2 (0.0-0.5)	0.6 (0.1-1.0)	1.2 (0.6-1.8)

[a]HT, hamstring tendon autograft; PT, patellar tendon autograft.

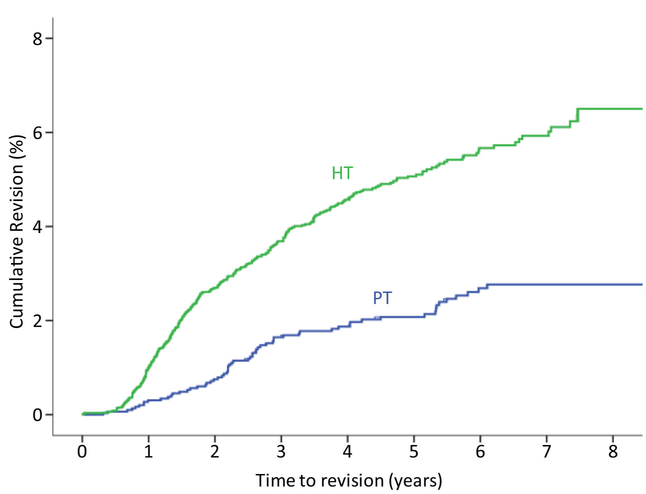

Figure 3. Overall revision analysis stratified by graft type.

TABLE 3
Multivariate Cox Regression of Significant Risk Factors for Revision[a]

Risk Factor and Category	Hazard Ratio	95% CI	*P* Value
Age at surgery, y			
15-19	4.0	3.1-5.2	**<.001**
20-29	2.0	1.5-2.7	**<.001**
≥30	Reference		
Sex			
Male	1.1	0.9-1.4	.248
Female	Reference		
Graft type			
HT	2.3	1.8-3.0	**<.001**
PT	Reference		

[a]Significant *P* values are presented in bold. HT, hamstring tendon autograft; PT, patellar tendon autograft.

and sex of the primary ACLRs registered in 2004 to 2008 (n = 6342), the HR for revision was 2.1 (95% CI, 1.6-2.8; $P < .001$) in the HT group (n = 4165; mean follow-up, 5.8 ± 1.6 years) compared with the PT group (n = 2177; mean follow-up, 6.3 ± 1.7 years).

The subanalysis adjusted for age, sex, and graft type on the risk of CACLR showed no effect of graft type and sex. Similarly to revision, the youngest age group had an increased risk of CACLR compared with the oldest age group (HR, 4.9; 95% CI, 3.5-6.9; $P < .001$).

When analyzing only cases with a registered BMI (n = 5539), adjusting for age, sex, and graft type, the HR for revision of 1.7 (95% CI, 1.1-2.6; $P = .012$) was found for patients with a BMI of <25 kg/m^2 (n = 3129) compared with those with a BMI of >25 kg/m^2 (n = 2410). No significant result was found for CACLR between the 2 BMI groups.

DISCUSSION

The main finding of this study was an increased risk of revision after the use of HT grafts compared with PT grafts, in particular for the youngest patients. Patients with an HT graft had more than twice the risk of revision compared with those treated with a PT graft, which is similar to the results reported by Maletis et al[34] using data from the Kaiser Permanente registry. They found a 1.8 times higher risk of early revision for HT grafts compared with PT grafts, with a mean follow-up of 1.5 years. We can only speculate what caused this increased risk of revision in the HT group. It is possible that there are subgroups or combinations of fixation methods that have an increased risk of revision or simply that the HT graft is weaker than the PT graft.[37] A Cochrane systematic review[37] concluded that reconstructions with PT grafts are more likely to result in statically stable knees, which could lead to fewer reruptures, hence leading to our finding of a lower revision rate for PT grafts. Maletis et al[35] found an increased risk of infections after the use of HT grafts without identifying the cause. Not all infections will lead to our revision end point, which was removal of the graft, but there might have been more revisions in the HT group than in the PT group caused by infections. However, we do not believe that this could explain the major differences found between the grafts. More new graft fixation devices have been introduced for HT than for PT in the past few years, and it is possible that learning curves with new devices/procedures have led to more technical failures and a consequently higher risk of revision for HT. The graft fixation devices used have changed during the study period, however the results were similar when analyzing patients who underwent surgery from 2004 to 2008, indicating that no major time-dependent factor influenced our findings.

We found overall 2- and 5-year revision rates of 2.2% and 4.2%, respectively, closely resembling those previously found in studies with a similar design from the Danish[32] (2-year revision rate, 2.9%) and Swedish[2] (5-year revision rate, 4.1%) ACL registries. A case-control study by Hettrich et al,[21] including 980 patients prospectively followed, reported a revision rate after ACLR of 7.7%. This is slightly higher than in our study, which could be explained by the longer follow-up and a low median age, which both would lead to more reruptures according to our findings.

In line with our results, a younger age has previously been found to be a risk factor for revision.[5,21,26,47] In addition to the assumed increased activity in the youngest patients, the effect could also be influenced by factors such as compliance in terms of rehabilitation and early return to pivoting sports. Lower revision rates were seen in the older age groups. We believe that one reason for this may be that older patients are more apt to accept a relatively inferior result (eg, in terms of reduced stability) because of lower activity levels.[36]

An increased risk of primary ACL injuries in women has been found in several earlier studies.[19,42,45,50] We found no effect of sex with respect to the risk of revision. It is possible that altered anatomy, biomechanics, and neuromuscular control[39,40] after ACLR overrule the effect of sex for native ACL injuries.

The trend of the increasing use of HT grafts in recent years was prominent in our data, even though there was a slight decrease in the last 2 years of the study period. Why the youngest patient group more frequently received HTs compared with the oldest age group is difficult to explain. Some patients in this group might be skeletally immature, and treatment for these patients is debated.[38] However, good outcomes have been reported with HT grafts,[28,43] and concerns of growth disturbances when using a patellar bone block or hardware across the physis have been discussed.[27,52] This could influence the graft choice in favor of the HT. There might be a general tendency that "new and promising" methods and grafts are used in the youngest patients. Thus, it may be possible that HTs were chosen more often in the youngest patient group because of the increase in their popularity until 2010. The Swedish ACL registry had a total dominance of HT grafts up to 2010.[2] Data from a survey presented by Duquin et al[9] similarly showed a trend favoring the use of HT grafts in the United States. Several randomized studies have shown similar clinical outcomes and patient satisfaction between the 2 grafts,[||] although some found that PT grafts rendered higher donor site morbidity and anterior knee pain compared with HT grafts.[2,11,51] These complications may have contributed to the observed increasing use of HT grafts.[2,8,41] During the last years, several femoral cortical fixation devices have been introduced for HT grafts, and it is possible that commercial campaigns promoting these products may, to some degree, have influenced surgeons' graft preference.

Surprisingly, patients with a BMI of <25 kg/m^2 had a higher risk of revision compared with patients with a BMI of >25 kg/m^2. A possible explanation is that there is a correlation between increased activity levels and lower BMI and consequently a higher risk of revision.[6]

We did not find a similar increased risk of CACL ruptures when using PT grafts as Pinczewski et al[41] and Bourke et al[7] did. Similar to our results, previous studies have shown that young age increased the risk of CACL ruptures.[23,47,49]

The mean time from injury to surgery was just below 2 years, but the median value was around 0.65 years for both groups. This indicates that there were patients in the cohort with an extensive time from injury to surgery. We do not know the reason for this, but it could be that their primary health care was not effective enough to detect or refer ACL injuries, or simply that some patients had not developed instability symptoms until later. There have also been recent studies advocating nonoperative treatment with an optional delayed reconstruction,[12,13] which could have influenced the treatment in recent years.

Strengths and Weaknesses

The high number of patients included in this study made it possible to detect differences between variables in spite of the relatively low rates of revision. Consequently, the major strengths of our study are the large cohort size and the extensive period of follow-up. We are not aware of other published studies with a similar sample size and follow-up comparing the risk of revision for the 2 graft types. With the high validity and reliability of information recorded by the NAR,[3] we believe our findings to be of high validity. In addition, because of its multicenter design, the results closely resemble those in a real-life setting and would therefore be applicable to a general population.

There are some limitations of the present study. First, with no randomized design we cannot exclude possible selection biases. For instance, some subgroups of patients

[||] References 1, 4, 15, 20, 22, 24, 29-31, 33, 46.

may more frequently have received one of the graft types. Data describing the surgeon's experience and rehabilitation protocol used is not reported to the registry and may have influenced the risk of revision. However, with the data available, we believe we have adjusted for the most important factors influencing the risk of revision.

We had no data on patients potentially lost to follow-up (revision ACLRs of the index knee not reported to the NKLR). We assume, based on the previously mentioned article addressing data completeness,[53] that around 14% of the revision ACLRs in our cohort were not reported. However, we have no reason to believe that loss to follow-up would be influenced by graft type or age group. Optimally, there should have been a 50/50 distribution and similar mean follow-up time between the two graft types. The use of HT was throughout the study period higher than the use of PT, and yearly changes in graft choice rendered different mean follow-up times between the graft types. However, differences in follow-up times for the grafts are taken into account in the survival analyses. Furthermore, in the subanalysis including patients operated from 2004 to 2008, the follow-up time was more similar between the graft types and the results were very similar to the overall results.

Due to the limited report rate of data available to calculate BMI (44% of the total cohort), results from analyses on this subgroup might be subject to a reporting bias.

It is debatable if our revision end point gives a representative overview of general graft failure after ACLR, as clinical and subjective failures are not registered. The proportion of revisions among the failed ACLRs, however, is not likely to be different between the graft types but might differ between the age groups, as previously mentioned. The cohort was not homogeneous with respect to surgical techniques and types of fixation, and this could also have affected the risk of revision.

CONCLUSION

Patients with HT grafts had more than twice the risk of revision in terms of graft removal compared with those having PT grafts. Younger age and a BMI of <25 kg/m^2 were also associated with an increased risk of revision but did not explain the difference in the revision rate between the grafts. In the majority of patients, an HT graft was used, particularly in the youngest age group with the highest risk of revision. The effect of fixation methods for the graft types should be addressed, and large-scale functional results would be of major interest.

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