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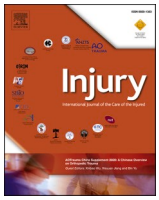

Anterior cruciate ligament reconstruction in the elderly: 5-Year follow-up study

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ABSTRACT

Background: Older adults remain active for longer and continue sports and activities that require rotation on one leg later in life. The rate of anterior cruciate ligament (ACL) tears is therefore increasing in those over 40 years old, with an associated increase in the rate of surgical reconstruction (ACLR), but there is limited literature on its effectiveness. Our aim was to compare the outcomes of elderly patients who have undergone ACLR with those of a younger group of patients.

Materials and Methods: Patients who underwent ACLR with bone-patella tendon-bone grafting (BPTB) at a level I trauma center between 2015 and 2017 were included in the study with a 5-year follow-up. Patients were divided into 4 groups: below 40 years, 40–49 years, 50–59 years and over 60 years. The graft function was evaluated by the International Knee Documentation Committee (IKDC) Objective Score, the anteroposterior (AP) displacement was measured by arthrometer (KT-1000; MEDMetric) and the Lysholm scale was used for subjective evaluation.

Results: 195 patients were included in the final analysis. The IKDC score showed significantly poorer scores in the 50–59 years and over 60 years group than in the younger groups, however in 83 % and 66 % of cases reached normal or nearly normal grades, respectively. A significant difference was found in the knee AP displacement (measured in mm) between the below 40 years group and 50–59 years as well as over 60 years old groups; however, the number of graft failure (laxity >5 mm) and elongation (>3 mm) did not increased in these senior groups. The patient-reported Lysholm scores in the 40–49 years, 50–59 years and 60 years groups was lower than in the below 40 years group, but the average score was “good”.

Conclusions: The long-term results of ACL reconstruction in older athletes are comparable to those of younger patients, both in terms of knee function and patient satisfaction. Furthermore, there is no difference in outcomes for older patients over the age of 40 compared to those in their 50 s or even 60 s. There is still insufficient published evidence to define an upper age limit for ACL reconstruction in older athletes.

Introduction

In the developed countries of today’s aging world, more than 75 % of people are expected to live to be at least 75 years old [1]. Along with this unprecedentedly long life expectancy, the number of physically active older adults is increasing [2]. Due to this trend, anterior cruciate ligament (ACL) tears affect the older generation more frequently than before. Regardless of their age, ACL injuries in older athletes have the same negative impact on quality of life as they do in younger athletes.

During the early stages of surgical care in the 1990s, anterior cruciate ligament (ACL) injuries seen in people over 40 years of age were generally treated non-operatively or functionally, and ACL reconstruction (ACLR) was traditionally reserved for young athletes [3,4]. However, the development in surgical techniques, anesthesiology, and rehabilitation has allowed the progressive extension of surgical indications to older age groups [5]. The gradual accumulation of recent data suggests older athletes benefit from ACLR as well, as opposed to the classically known treatment strategy [6–8]. There are even cases of an

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84-year-old patient who received an ACLR [9]. Plancher et al. actually found that 95 % of patients over 40 years of age had stable knee joints during their follow-ups [10]. Although several studies have demonstrated favorable outcomes of ACLR in middle-aged and older patients ranging from 40 to 60 years of age, scientific information on the elderly population is hardly available [11,12]. There are few reports of ACL reconstruction in patients over 60 years old. Moreover, in our review of the literature on ACLR in patients older than 60 years, we did not find any studies of long-term outcomes of ACLR. Despite these promising reports, some authors have suggested that surgery be withheld from older patients because of concerns of higher rates of arthrofibrosis and decreased range of motion; however, no clinical studies have supported that hypothesis [13].

Due to the scarceness of data on ligament-deficient patients aged 65 and older, surgical indications continue to be a matter of controversy. In our study, we aimed to compare the clinical outcomes of senior patients over 60 with younger age groups. To the best of our knowledge, only a few case presentations and studies with low patient numbers have focused on people over 60 years of age undergoing ACLR surgery, particularly with bone-patellar tendon-bone (BPTB) technique [14]. We hypothesized that senior patients could have the same benefit from the ACLR procedure. For this purpose, we aimed to add our data to the scientific information available on the elderly, comparing the clinical outcomes of a series of senior patients over 60 years of age and older with younger individuals who underwent ACLR surgery with patellar grafts in our level I trauma center.

Methods

Ethics approval

The study was conducted in accordance with the Declaration of Helsinki. Our research has been approved by the local medical ethics committee at the University of Szeged (Regional and Institutional Review Board of Human Investigations, Chairperson: Prof. Tibor Wittmann) under reference number 10/2021-SZTE REKB.

Study design and inclusion criteria

Adult patients (age, ≥18 years) who underwent single-bundle BPTB graft ACLR surgery between 01 January 2015 and 31 December 2017 at the University of Szeged were evaluated at the 5–year follow–up (study ended at 31 December 2022) using patient–reported outcome measures and physical and radiological examination. Athletes and patients who performed only recreational sports or were physically active were equally involved. Patients were allocated into four study groups based on their age at the time of surgery. According to this, the following groups were formed: age <40 years; 40–49 years; 50–59 years; ≥60 years.

Exclusion criteria

Patients under 18 years of age were excluded from the study. We also excluded allograft and non-BPTB autograft reconstructions to ensure that the graft type did not influence the analysis. Also patients who have undergone surgery on other body parts such as the contralateral knee or the hip joint or those presenting with 3rd degree OA identified with arthroscopic examination or those with grade III or higher OA on plain X rays according to the Kellgren-Lawrence classification were excluded. In addition, fractures, open intra-articular injuries, knee dislocations or knee injuries with complete ruptures of the medial and lateral collateral ligaments (MCL, LCL) were excluded. Patients with incomplete examination data at follow-up in objective scores were also excluded.

Surgery and rehabilitation

The patellar graft was harvested from the central part of the tendon, and the positioning of the tunnel was anatomical in each case. All patients underwent preoperative rehabilitation according to the same principles. In cases of concomitant injuries, preoperative protocols were adjusted accordingly. Meniscus injuries entailed an arthroscopic resection or reinsertion, and 6–16 weeks recovery prior to ACLR surgery. Patients with concomitant medial collateral ligament (MCL) tears received functional braces and 6–12 weeks recovery period before ACLR. Postoperatively, conventional (12-month-long) and accelerated (6-month-long) rehabilitation schedules were used for patients. Both programs were divided into six phases, which used the traffic light concept at the end of each rehabilitation stage. Rehabilitation time following ACLR can be greatly affected by concomitant knee injuries, so we did not include the outcomes of patients with other knee injuries to the final analysis when comparing the effectiveness of rehabilitation protocols. [15].

Statistical analysis

Statistical analysis was conducted utilizing SigmaPlot 13.0 statistical software (Jandel Corporation, San Rafael, CA, USA). Descriptive statistics, including frequencies, proportions, means, standard deviations (SDs), and interquartile ranges (IQRs), were utilized to outline the characteristics and outcomes of the study sample. Categorical variable differences were assessed using either the Chi-square test or Fisher's exact test, contingent on the number of groups. Continuous variables were analyzed employing either a one-way ANOVA or a two-way ANOVA, depending on the number of groups, with normal distribution assessed using the Shapiro-Wilk test. Statistical significance was considered at $p < 0.05$.

Outcomes

Data including sex, age, Body Mass Index (BMI), comorbidities and concomitant injuries at the time of surgery, length of pre- and post-operative rehabilitation schedules were extracted from the electronic database (e-medSolutions).

Elongations and failures

Failure was defined as the need for revisions (repeated ipsilateral ACLR), non-operated reruptured ACL, KT-1000 arthrometer laxity >5 mm, and high-grade (3+) Lachman or pivot-shift test. Elongation was defined as increased graft length causing a difference in anteroposterior laxity of more than 3 mm. [16–18].

Instrumented ap knee laxity

Arthrometer testing (KT-1000; MEDMetric) was used to measure the anterior displacement of the tibia with respect to the femur under 134 N of applied anterior force and was performed in duplicate on each leg. The results were reported as a side-to-side difference (SSD) between limbs (mean of the surgical knee minus the mean of the contralateral knee).

IKDC objective score (A-D)

The IKDC Objective Score was calculated 5 years after surgery. The IKDC grading is based on physical examination and evaluates symptoms, range of motion (ROM), and knee laxity. The worst rating for the subgroups defined the overall final rating, from the normal, nearly normal, abnormal and severely abnormal. [19].

Lysholm score

The Lysholm scale is a form containing eight questions; limping, the use of crutches, the feeling of clicking and blocking in the knee, joint instability, pain, the presence of an effusion, the ability to walk the stairs

and to make squats. In the patient-reported Lysholm scale the higher scores indicate a better outcome with fewer symptoms or disability. The total score is the sum of each item and may range from 0 t(worst result) to 100 (best result) [20].

Results

Patient population

A total of 412 patients received ACLR surgery by the same orthopaedic-trauma surgeon in our institution between 2015 and 2018. Ultimately, 195 participants met our inclusion criteria. The flowchart for patient enrollment is presented in Fig. 1.

Patient characteristics

The mean age of the participants was 34 ± 15 years, and only 25.6 % of the patients were female.

4.1 % of the patients had a BMI over 25; 5.5 % suffered from hypertension; and 1.4 % from non-insulin dependent diabetes. No patients displayed Generalised ligament laxity, while moderate hypermobility (Beighton score 4) was detected in 5.5 % of the participants. The accelerated rehabilitation protocol was applied only below 40 years, in 39 % of this group of patients. In the elderly groups, conventional rehabilitation was applied (Table 1.)

Surgery and rehabilitation

Meniscal ruptures were observed in 16 % of all cases, in which partial meniscectomy was performed. The incidence of mild (Kellgren-Lawrence I and II) articular cartilage injury was seen in 32 % of all patients (those with severe cartilage damage were excluded), the accompanying injury of the medial and lateral collateral ligaments occurred in 14,9 % of all cases. The average time between injury and surgery was 15 weeks (4–42 weeks). Among the most common sports that led to injuries, football, tennis, athletics, and other leisure activities were the most common (Table 2).

185 patients had reached their previous activity level one year after surgery. 8 patients had quit competitive sport and 2 patients permanently remained lower below their previous activity level, but in both cases an underlying cardiac problem was noted. Accelerated rehabilitation displayed significant association with graft elongation; the association between rehabilitation time and graft failure and quitting competitive sport did not reach significance at the 0.05 level (Table 3).

The instrumented anteroposterior (AP) knee laxity was expressed as the SSD. According to our protocol, measurements were made at regular intervals (6 weeks, 6 months and 12 months follow-up) during the rehabilitation process of the patients and then measured again during the present study at the 5-year follow-up medical examination (Fig. 2). In the present study, a significant difference was found between the below 40 years and 50–59 years groups ($p = 0.018$) as well as between the below 40 years and over 60 years groups ($p = 0.025$). A significant difference could also be observed within the below 40 years group at the 5 year follow up ($p = 0.018$ vs 6 weeks, $p = 0.003$ vs 6 months and $p = 0.009$ vs 12 months). At 5 years after reconstruction, patients in all age groups had mean SSD knee laxity of 1 mm with Interquartile range (IQR) of 1–2 in less than 40 years, 1- 2.75 in 40–49 years, 0.75–2 in 50- 59 years and 1 - 3 in over 60 year age groups 83 % of patients in 40–49 year group had 88 % normal / near normal outcome while same was 71 % in 50–59 year age group and 66 % in above 60 age group.

The function of the knee was evaluated with the IKDC Objective Score. (Table 4). 88 % of the <40 years group had normal or nearly normal knee function with a complete physical examination. 83 % of patients in 40–49 year group had 88 % normal / near normal outcome while same was 71 % in 50–59 year age group and 66 % in above 60 age group.A significant difference could be observed in the abnormal and severely abnormal groups in IKDC Objective Scores among different age groups (Table 4)

The assignment of the majority of patients' outcome in this study was "excellent" for 95 to 100 point, with a 96.1 mean score in the <40 years group. In the senior groups, the patients' outcome was assigned to "excellent" or "good", and only one patient among the above 60 years patients displayed "fair" score. The difference among groups in the Lysholm score was not statistically significant (Table 5).

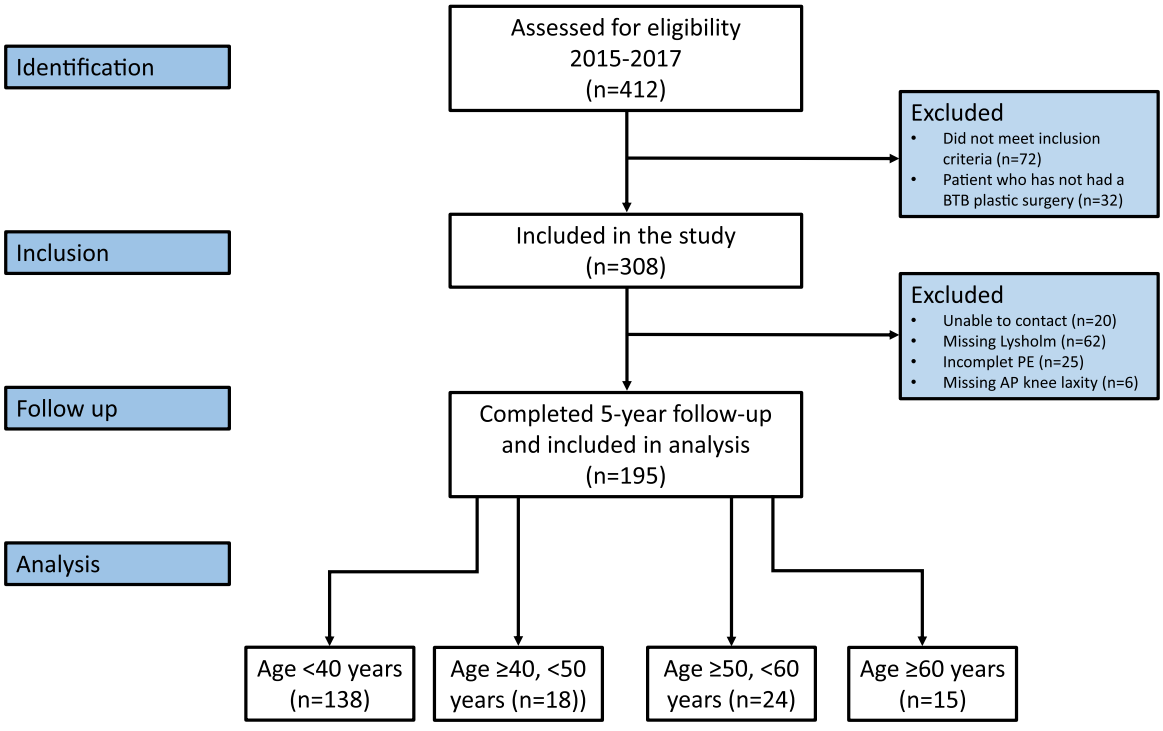

Fig. 1. Study flowchart with inclusions and exclusions.

Table 1
Patient characteristics and clinical outcomes.

Demographics	All patients (n = 195)	Age <40 years (n = 138)	Age ≥40, <50 years (n = 18)	Age ≥50, <60 years (n = 24)	Age ≥60 years (n = 15)	P value
Age						<0.001 *
Age *(y) mean ± SD*	34 ± 15	25 ± 4	45 ± 2	53 ± 2	67 ± 4	
Age *(y) median [IQR]*	26 [24–44]	25 [22–26]	45 [43–46]	53 [51–54]	67 [66–69]	
Sex						0.068
Female *n (%)*	50 (25.6)	28 (20.3)	7 (38.9)	9 (37.5)	6 (40.0)	
Male *n (%)*	145 (74.4)	110 (79.7)	11 (61.1)	15 (62.5)	9 (60.0)	
Comorbidities						0.765
BMI >30 *n (%)*	12 (6.2)	6 (4.4)	2 (11.1)	3 (12.5)	1 (6.7)	
Chronic disease *n (%)*	41 (21.0)	9 (6.5)	8 (44.4)	12 (50.0)	12 (80.0)	
Hypertension *n (%)*	36 (18.5)	8 (5.8)	7 (38.9)	11 (45.8)	10 (66.7)	
NIDDM *n (%)*	5 (2.6)	1 (0.7)	1 (5.6)	0 (0.0)	3 (20.0)	
Hypothyroidism *n (%)*	3 (1.5)	0 (0.0)	1 (5.6)	1 (4.2)	1 (6.7)	
CAD *n (%)*	1 (0.5)	0 (0.0)	0 (0.0)	1 (4.2)	1 (6.7)	
Parkinson's disease *n (%)*	1 (0.5)	0 (0.0)	0 (0.0)	1 (4.2)	0 (0.0)	
Bipolar disorder *n (%)*	1 (0.5)	0 (0.0)	0 (0.0)	1 (4.2)	0 (0.0)	
Glaucoma *n (%)*	1 (0.5)	0 (0.0)	0 (0.0)	0 (0.0)	1 (6.7)	
Gout *n (%)*	1 (0.5)	1 (0.7)	1 (1.1)	0 (0.0)	0 (0.0)	
Rehabilitation						<0.001 *
6 months *n (%)*	54 (27.7)	54 (39.1)	0 (0.0)	0 (0.0)	0 (0.0)	
10–12 months *n (%)*	141 (72.3)	84 (60.9)	18 (100.0)	24 (100.0)	15 (100.0)	

BMI = Body Mass Index, NIDDM = Non–insulin-dependent diabetes mellitus, CAD = Coronary artery disease,.
* $P < 0.05$ (Chi-square) are considered as significant.

Discussion

As the average age continuously increases, the number of active senior athletes who play sports has increased as well. Regardless of their age, ACL injuries in older athletes have the same negative impact on quality of life as they do in younger athletes. Due to the limitation of cruciate ligament replacement techniques, ACL injuries in older patients were classically treated nonoperatively; however, gradual accumulation of recent data suggests older athletes benefit from ACLR as well, as opposed to the classically known treatment strategy [8,21,22].

Through constantly increasing data, we cannot further ignore the fact that age plays a smaller role than previously hypothesized. We evaluated compliant "Senior" athletic patients without orthopaedic comorbidities (severe arthrosis, arthritis etc.), where the chances of "full" recovery after ACLR are plausible, even when compared with the younger athletes. In general, comorbidities, level of physical activity, and biological age of the knee are considered as determining factors instead of chronological age [23,24]. Nevertheless, a careful approach is needed when it comes to deciding on ligament-stabilizing surgery for the elderly.

Older patients with good compliance and motivation benefit the most from ACLR, and patients should be examined for severe arthrosis in the affected joint. In the present study, we enrolled patients only with or without moderate (Kellgren-Lawrence I-II) arthrosis; Several different authors emphasize that one of the keys to achieving surgical results is determined by the status of the preoperative joint [10,24]. Severe arthrosis seemed to be an exacerbatory factor after ACLR.In patients with moderate osteoarthritis or with medial unicompartmental arthrosis it was found that ACLR provided good subjective results and stability at a mean of 10 years postoperatively [25]. In most studies, ACLR was contraindicated in patients with arthrosis of grade III or higher arthrosis in the Kellgren-Lawrence score [26–28].

Older patients are more difficult to rehabilitate as they need more time to regain muscle strength and coordination [29], but it is precisely for them that an accelerated rehabilitation programme would be more desirable to facilitate their return to daily activity and family life. In the present study, we applied the accelerated rehabilitation protocol only to patients under 40 years of age to avoid complications as the recovery is slower in older patients [30]. We have compared the result of the two subgroups, in patients with conventional and accelerated rehabilitation protocols, and we found significant correlation with the graft elongation and the application of accelerated rehabilitation protocol. Therefore, we would still not recommend the accelerated protocol for older patients whose ACL have a worse biological propensity to heal than those of younger patients [31]. Slower tissue repair and regeneration due to various factors (e.g. lower cell turnover, decreased collagen production [32–34],we would advocate a careful approach avoiding accelerated rehabilitation

In the present study, graft failure did not occur at all in the over-40 groups, which may be due to the low number of elements in those groups or because the older people were more cautious about their physical activity in the postoperative period. The findings of this study align with previous research [35,36] and a multicenter cohort study, indicating that with every 10-year decrease in age, there is a 2.3-fold increase in the likelihood of graft rupture, as reported by the authors [37]. Similarly, the investigation of the AP laxity revealed no significant correlation with the age between study groups.

In our study, the IKDC score in the older groups tended to be lower, with a significant decrease in the 50–59 years and over 60 years old groups. This is in accordance with a recent systematic review, which compared the results of patients over and under of 50 years, and revealed that the younger groups had a significant higher IKDC score than the over 50 group at the end of follow-up [38].Of note, the majority of patients in the 50–59 years and over 60 years groups reached normal or nearly normal grades for their knee function, only 29 % and 43 % displayed poorer outcome, respectively. Brandsson et al., compared two groups; patients under the age of 24 and over 40 who had undergone ACLR and neither the Lysholm scale nor the IKDC showed significant discrepancy [39]. In our study, the subjective scoring and the Lysholm grade of senior groups can be considered completely satisfactory, especially in the 5-year-long follow-up of patients.

In cases of older candidates for ACLR, similar aspects require consideration as by youth, albeit with heightened emphasis on several indicating- and risk factors. When establishing indication for surgery, lifestyle, level of physical activity and long-term goals need meticulous evaluation. Comorbidities also have to be assessed carefully, with particular attention to the ones that may impact the healing capacity of tendons (e.g. diabetes, obesity, hypothyroidism, peripheral vascular

Table 2
Sport activities and concomitant injuries.

	All patients (*n* = 195)	Age <40 years (*n* = 138)	Age ≥40, <50 years (*n* = 18)	Age ≥50, <60 years (*n* = 24)	Age ≥60 years (*n* = 15)	*P* value
Practiced sport						
Football *n (%)*	102 (52.3)	77 (55.8)	7 (38.8)	13 (54.2)	5 (33.3)	
Handball *n (%)*	6 (3.1)	6 (4.4)	0 (0.0)	0 (0.0)	0 (0.0)	
Basketball *n (%)*	13 (6.6)	12 (8.7)	1 (5.6)	0 (0.0)	0 (0.0)	
Volleyball *n (%)*	7 (3.6)	5 (3.6)	1 (5.6)	1 (4.2)	0 (0.0)	
Tennis *n (%)*	17 (8.7)	8 (5.8)	2 (11.1)	3 (12.5)	4 (26.7)	
Athletics *n (%)*	14 (7.2)	9 (6.5)	3 (16.6)	2 (8.3)	0 (0.0)	
Skiing *n (%)*	7 (3.6)	5 (3.6)	1 (5.6)	1 (4.2)	0 (0.0)	
Martial arts *n (%)*	7 (3.6)	6 (4.4)	1 (5.6)	0 (0.0)	0 (0.0)	
Other martial arts *n (%)*	22 (11.3)	10 (7.2)	2 (11.1)	4 (16.6)	6 (40.0)	
Concomitant injuries						
Meniscus lesion *n (%)*	31 (15.9)	18 (13.0)	7 (38.9)	4 (16.7)	2 (13.3)	0.041*
Cartilage injury (Kellgren-Lawrence I-II)	60 (30.8)	47 (34.1)	5 (27.8)	5 (20.8)	4 (26.6)	0.371
MCL injury *n (%)*	21 (10.8)	14 (10.1)	4 (22.2)	2 (8.3)	1 (6.7)	0.404
LCL injury n (%)	8 (4.1)	4 (2.9)	4 (22.2)	0 (0.0)	0 (0.0)	>0.001 *

Most of the study participants (52.3 %) were football players. Meniscus lesions and associated MCL and LCL injuries were diagnosed with magnetic resonance imaging (MRI). Incomplete and superficial fissures were not considered as meniscus injuries due to the lack of a notable influence on the long-term outcome. MCL=Medial Collateral Ligament, LCL=Medial Collateral Ligament.
* $P < 0.05$ (Chi-square) are considered as significant.

disease, osteoarthrosis [40–42]). Ultimately, the determination of therapy should be a joint decision between the doctor and the patient, respecting medical factors warranting exclusion such as severe osteoarthrosis.

Conclusion

Several studies have shown that reconstructive surgery for acute ACL tears between the ages of 40–59 years is still worthwhile because the results in daily activity and function will be better than with conservative therapy [23,24,38]. In the present study, we further confirm the benefit of surgical reconstruction of ACL tears, whereby ACLR over 40, 50 and 60 years of age can achieve the same long-term functional outcomes and patient satisfaction as in younger athletes. However, the quality of currently available data is still limited and further well-designed studies are needed with an increased number of cases to determine long-term efficacy and to better inform our patients with regard to expected outcomes.

Classification

Retrospective cohort.

Table 3
Associations between the timing of return to play (RTP) and graft elongation, reoperation, and quitting sport career.

Patient groups	No graft failure	Graft failure	**Total**
Age <40 years	129	9	138
Age ≥40, <50 years	18	0	18
Age ≥50, <60 years	24	0	24
Age ≥60 years	15	0	15
Total	186	9	195
Fisher's exact test		***P-value***	
	0.273		
Patient groups	No reoperation	Reoperation due to graft failure	**Total**
Conventional, 12-month-long rehabilitation	91	1	92
Accelerated, 6-month-long rehabilitation	49	5	54
Total	140	6	146
Fisher's exact test		***P-value***	
	*0.028**		
Patient groups	Continues competitive sport	Quit competitive sport	**Total**
Conventional, 12-month-long rehabilitation	91	1	92
Accelerated, 6-month-long rehabilitation	50	4	54
Total	141	5	146
Fisher's exact test		***P-value***	
	0.596		

* $P < 0.05$ (Fisher's exact test) are considered as significant.

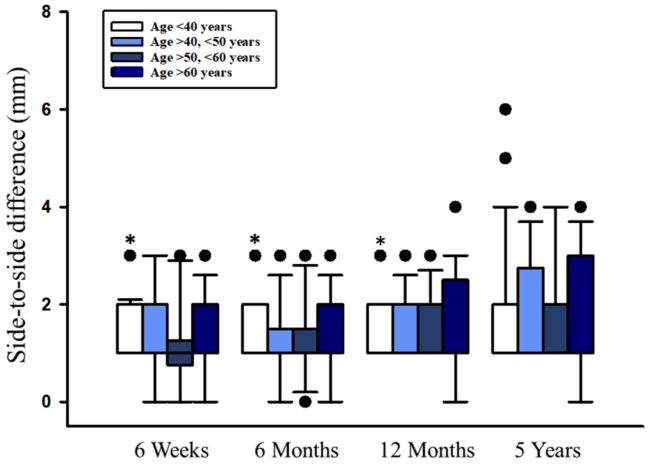

Fig. 2. Changes in the side-to-side difference between limbs from 6 weeks to 5 years postoperatively. Data are presented as IQR ± SD. The circle in the figure represent the outliers. Present data was analysed using a Two-Way ANOVA (Bonferroni post-hoc test). *$P < 0.05$ vs 5 years are considered as significant.

Table 4
IKDC Objective Score Outcomes at 5 years after reconstruction.

Overall grade	**Age <40 years**	**Age ≥40, <50 years**	**Age ≥50, <60 years**	**Age ≥60 years**	***P* value**
Normal *n (%)*	54 (39)	9 (50)	11 (46)	5 (33)	**0.709**
Nearly normal *n (%)*	68 (49)	6 (33)	6 (25)	5 (33)	**0.086**
Abnormal *n (%)*	11(8)	2 (11)	5 (21)	4 (30)	**0.010** *
Severely abnormal *n (%)*	5 (4)	1 (5)	2 (8)	1 (7)	**0.001** *

* $P < 0.05$ (Chi-square) are considered as significant.

Table 5
Comparison between groups for Lysholm Score at 5 years after reconstruction.

TABLE 5 Comparison Between Groups for Lysholm Score

Lysholm	N	Mean	SD	95 % Confidence Interval for Mean	
				Lower Bound	Upper Bound
Age <40 years	138	96,89	4455	96,14	97,64
Age ≥40, <50 years	18	97,00	3106	95,46	98,54
Age ≥50, <60 years	24	96,79	2570	95,71	97,88
Age ≥60 years	15	96,40	3089	94,69	98,11
All patients	195	96,85	4044	96,28	97,42
One-Way ANOVA	**Sum of Squares**	**df**	**Mean Square**	**F**	***P* value**
Between groups	3759	3	1253	0,076	0,973

Present data was analysed using One-Way ANOVA. No significant differences were detected between groups ($P = 0.086$).

Ethical consideration

All patients gave their written consent to enter the current study.

CRediT authorship contribution statement

Takayuki Kurokawa: Conceptualization, Data curation, Writing – original draft, Writing – review & editing. **Károly Csete:** Data curation, Formal analysis, Methodology, Validation, Writing – original draft. **Péter Jávor:** Data curation, Formal analysis, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Lilla Sándor:** Data curation, Formal analysis, Visualization, Writing – review & editing. **Bálint Baráth:** Conceptualization, Data curation, Formal analysis, Methodology, Validation, Writing – review & editing. **Helga Holovic:** Formal analysis, Investigation, Visualization. **László Török:** Data curation, Methodology, Supervision, Writing – review & editing. **Petra Hartmann:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing.

Declaration of competing interest

None declared.

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