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A Comparison of Results in Older, Middle-aged, and Younger Patients after Primary Anterior Cruciate Ligament Reconstruction: Minimum 10-Year Follow-up

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Background: Anterior cruciate ligament (ACL) reconstruction is commonly performed to prevent decreased knee function and restore stability in middle-aged and even older patients. However, few studies have compared the long-term clinical outcomes of ACL reconstruction between older, younger, and middle-aged patients. The purpose of this study was to compare the long-term clinical outcomes of ACL reconstruction in older patients with those in younger and middle-aged patients.

Methods: A total of 352 patients who underwent primary ACL reconstruction between January 2003 and March 2008 were retrospectively reviewed and classified into three groups (group A: 246 [age, 20–29 years], group B: 72 [age, 40–49 years], group C: 34 [age, 50–65 years]). The mean follow-up period was 14.2 ± 1.6 years. Clinical outcomes were evaluated and compared between groups.

Results: The differences in the range of motion, clinical scores, and stability tests were not statistically significant among the three groups. The difference in the graft failure rate among the three groups was significant (group A: 16 [6.5%], group B: 7 [9.7%], group C: 6 [17.6%]; $p = 0.040$). In particular, when compared between the two groups, there was a significant difference between group A and group C ($p = 0.036$). The 10-year survival rates were 93.5%, 90.3%, and 82.4% for groups A, B, and C, respectively ($p = 0.048$).

Conclusions: Although graft failure rates were higher in older patients than younger and middle-aged patients, clinical outcomes of ACL reconstruction in older patients were comparable to those of younger and middle-aged patients in terms of the range of motion, clinical scores, and stability tests at a minimum follow-up of 10 years.

Keywords: *Anterior cruciate ligament, Anterior cruciate ligament reconstruction, Age, Knee, Survival rate*

Anterior cruciate ligament (ACL) reconstruction in young and active patients has shown favorable outcomes.[1] In recent years, ACL injuries have become more frequent in middle-aged patients, who are increasingly participating in physically demanding sports.[2] In addition, ACL reconstruction has been more commonly performed to prevent decreased knee function and restore stability in middle-aged and even in older patients.[3,4]

However, there is controversy regarding whether ACL reconstruction is necessary for older patients. Shelbourne and Stube[5] reported that ACL reconstruction in patients with chronic instability and degenerative changes

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provides long-term stability and symptom relief. Moreover, individuals over 40 years are extremely reluctant to accept potential knee instability during pivoting activities, so they prefer ACL surgery despite the risk of surgical complications.[4] Individuals aged ≥ 40 years continue to participate in intensive pivoting activities, which require a functional ACL.[3] Weng et al.[6] reported patients aged 50 years or older achieved significant improvements in clinical and functional outcomes after ACL reconstruction. On the other hand, there are concerns about a higher postoperative rate of stiffness, arthrofibrosis, infection, or thromboembolic disease after ACL reconstruction in the older patients. In addition, preexisting cartilage lesions could increase the risk of progressive articular degeneration.[7]

Several studies have reported the outcomes of ACL reconstruction only in middle-aged patients;[8-15] only a few studies have compared results according to age.[3,16-19] However, young age was ambiguously defined in these studies (20–24, 16–39, and 18–40 years), and there was no distinction between middle-aged and older groups (40–51, 40–52, and 40–55 years) with no comparison for groups aged > 55 years. Furthermore, these studies have limitations of having a short-term follow-up of 12 to 24 months.

Therefore, the purpose of this study was to compare the long-term clinical outcomes of ACL reconstruction between older, younger, and middle-aged patients. Our hypothesis was that the clinical outcomes of ACL reconstruction in older patients were comparable to those in younger and middle-aged patients.

METHODS

A total of 610 patients who underwent primary ACL reconstruction between January 2003 and March 2008 were retrospectively reviewed. Ethical approval for the study was obtained from the Institutional Review Board of Kyung Hee University Hospital (No. KHUH 2022-06-020), and the requirement for informed consent was waived. Patients with ACL reconstruction who were followed up for a minimum of 10 years were included. Exclusion criteria were as follows: (1) multiple ligament injury, (2) concomitant cartilage injury requiring operative treatment, (3) contralateral ACL injury, (4) moderate to severe osteoarthritis (Kellgren-Lawrence grade ≥ 3), (5) patients aged < 20 years and 30–39 years who did not clearly belong to the younger or middle-aged groups were excluded to clearly distinguish between the younger and middle-aged groups. Finally, 352 patients (296 men and 56 women) were enrolled in this study.

The patients were divided into three groups according to the age range (group A: 20–29 years, group B: 40–49 years, group C: 50–65 years). Patients aged ≥ 50 years were classified into the older group because age-related apoptosis in the skeletal muscle increases in individuals aged > 50 years[20] (Fig. 1).

Surgical Technique and Rehabilitation

ACL reconstructions were performed by a single surgeon (KHY) in all patients using the same technique. A tibial tunnel was made in the tibial ACL footprint at a 55° angle to the tibial shaft, approximately the same size as an 8–9 mm graft. Remnant fibers were preserved as much as possible. Then, the femoral tunnel was made according to the osseous landmarks and arthroscopic findings of the ACL footprint and remnant fiber position in the anteromedial bundle, posterolateral bundle, or center position in the ACL footprint using the transtibial technique with remnant preservation. A soft-tissue graft (autologous ham-

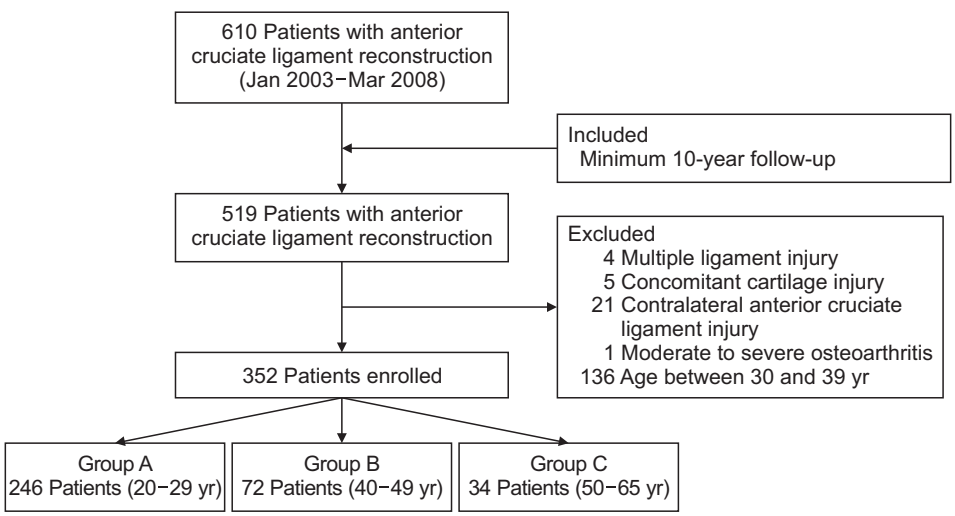

Fig. 1. Flowchart of patient enrollment.

string tendon and tibialis anterior allograft tendon) was used in ACL reconstruction. The tendon graft was fixed on the femoral side with two bioabsorbable cross pins (RIGIDFIX Cross Pin System; DePuy Mitek, Raynham, MA, USA). Staples were used for graft fixation on the tibial side and biodegradable interference screws (BioRCI-HA; Smith and Nephew, Andover, MA, USA) were fitted to the tunnel's diameter. The rehabilitation protocol was similar for all patients except those who underwent meniscus repair. The rehabilitation protocol included range-of-motion exercises of the knee immediately after surgery, as well as progressive weight-bearing as tolerated. From 6 weeks postoperatively, the patients were allowed to perform a gait without a brace. Jogging and swimming started in the third month, and full sporting activities were allowed 9 months postoperatively. In those patients who required a meniscus repair, the rehabilitation program was modified to exclude weight-bearing activities and 90° of knee flexion for the first 5 to 6 weeks.

Clinical and Stability Evaluation

The range of motion was measured with a goniometer preoperatively and during the last follow-up. Knee function was evaluated preoperatively and at the last follow-up using the clinical scores such as Lysholm score, Tegner activity score, and International Knee Documentation Committee (IKDC) subjective score. Physical examinations under anesthesia were performed preoperatively and postoperative assessments were performed at the last follow-up. The knee joint stability was evaluated using the anterior drawer test, Lachman test, pivot-shift test, and side-to-side difference in the anterior tibial translation on Telos stress radiographs (Telos, Weiterstadt, Germany) (Fig. 2).

Graft Failure

Definition of graft failure was the need for additional surgery (revision ACL reconstruction, anterolateral ligament reconstruction, high tibial osteotomy, or arthroplasty) and a complete tear of the ACL graft seen on magnetic resonance imaging.[21]

Statistical Analysis

All statistical analyses in this study were performed with IBM SPSS ver. 22.0 (IBM Corp.). To compare preoperative and last follow-up data within each group, Wilcoxon signed-rank tests, linear by linear association test, and Fisher's exact test were used. Preoperative demographic data among the three groups were compared using Kruskal-Wallis tests. When normality test was performed using Kolmogorov-Smirnov, pre- and postoperative range of motion, IKDC subjective score, and Lysholm score showed normality, but Tegner activity score did not show normality. For the IKDC subjective and Lysholm score, a one-way analysis of variance test was used. For the Tegner score, the Kruskal-Wallis test was used. Comparisons of other categorical variables, including anterior drawer test, Lachman test, pivot-shift test, and side-to-side difference in anterior tibial translation on Telos stress radiographs, were performed using the Fisher exact test. Kaplan-Meier method was used for survivorship analysis, with graft failure as the endpoint; 95% confidence intervals (CIs) were presented. The p-values of < 0.05 were considered significant. Twenty-five patients in each group were needed to detect a between-group difference in IKDC subjective scores larger than the minimal clinically important change of 11.5 points[22] with an estimated standard deviation of 12[23] with an alpha level of 0.017 and 80% power.

Two independent clinical fellows (SHH and HSL) performed all radiographic measurements to minimize observational bias. For interobserver and intraobserver reliability, the intraclass correlation coefficient (ICC) was assessed by the two observers who independently and blindly performed the measurements. The ICC for intraobserver and interobserver reliability was > 0.8.

RESULTS

According to age, 246 patients were assigned to group A, 72 patients to group B, and 34 patients to group C. The

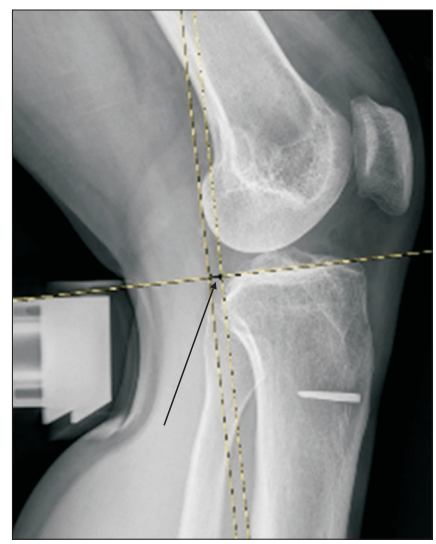

Fig. 2. Measurement of anterior tibial translation on a stress radiograph. Black arrow indicates anterior tibial translation.

overall mean follow-up period and age were 14.2 ± 1.6 years and 31.1 ± 11.6 years (range, 20–65 years), respectively. The patient demographic characteristics are summarized in Table 1. Preoperative demographic data were not significantly different among the three groups.

Range of Motion and Clinical Scores

All patients achieved satisfactory range of motion, and no significant differences ($p > 0.05$) were observed among the three groups preoperatively and during the last follow-up (Table 2). The Lysholm, Tegner activity, and IKDC subjective scores all improved during the last follow-up in the three groups. However, no significant differences were observed between them (Table 3).

Knee Joint Stability

The results of the anterior drawer test ($p = 0.014$), Lachman test ($p = 0.011$), and pivot-shift test ($p = 0.018$) and the side-to-side difference in anterior tibial translation on Telos stress radiographs significantly improved during the last follow-up compared with the preoperative values in overall patients ($p = 0.035$). When the three groups were compared preoperatively and during the last follow-up, no significant differences were observed ($p > 0.05$) (Table 4).

Graft Failure

There were 16 failures in group A (6.5%), 7 in group B (9.7%), and 6 in group C (17.6%). The difference in the graft failure rate among the three groups was significant ($p = 0.040$). In particular, when compared between the two groups, the failure rate of group C was significantly higher than that of group A (group A vs. group B, $p = 0.600$; group B vs. group C, $p = 0.193$; group C vs. group A, $p = 0.036$). Regardless of the type of graft, graft failure

Table 1. Patient Demographics

Variable	Group A (n = 246)	Group B (n = 72)	Group C (n = 34)	*p*-value
Age (yr)	23.9 ± 2.8	44.7 ± 2.5	54.2 ± 4.1	-
Male sex	208 (84.6)	60 (83.3)	28 (82.4)	0.412
Body mass index (kg/m^2)	23.8 ± 3.0	24.2 ± 2.4	23.0 ± 5.3	0.566
Follow-up (yr)	14.4 ± 1.5	14.0 ± 1.5	13.4 ± 1.6	0.641
Time from injury to surgery (mo)	4.3 ± 2.2	5.1 ± 3.1	5.5 ± 3.6	0.236
Associated meniscal injury	180 (73.3)	55 (76.4)	25 (73.5)	0.321
None	66 (26.7)	17 (23.6)	9 (26.5)	
Medial meniscus	73 (29.7)	16 (22.2)	10 (29.4)	
Lateral meniscus	60 (24.4)	19 (26.4)	7 (20.6)	
Medial and lateral	47 (19.2)	20 (27.8)	8 (23.5)	
AutoHA	180 (73.2)	54 (75.0)	21 (61.8)	0.326

Values are presented as mean ± standard deviation or number (%).
AutoHA: autologous hamstring tendon graft.

Table 2. Results of Range of Motion Preoperatively and during the Last Follow-up

Variable	Group A (n = 246)	Group B (n = 72)	Group C (n = 34)	*p*-value
Range of motion (°)				
Preoperative	132.5 ± 15.1	131.6 ± 17.9	134.0 ± 13.2	0.841
Last follow-up	134.1 ± 13.5	132.8 ± 17.3	135.7 ± 12.3	0.810
p-value	0.584	0.602	0.571	

Values are presented as mean ± standard deviation.

Table 3. Results of Clinical Scores Preoperatively and during the Last Follow-up

Variable	Group A (n = 246)	Group B (n = 72)	Group C (n = 34)	*p*-value
Lysholm score				
Preoperative	34.1	36.5	31.3	0.387
Last follow-up	84.8	83.1	79.8	0.859
p-value	0.021	0.024	0.035	
Tegner activity score				0.719
Preoperative	1.4	1.3	1.2	0.414
Last follow-up	5.4	5.2	4.9	
p-value	0.032	0.045	0.023	
IKDC subjective score				0.751
Preoperative	33.5	35.5	32.1	0.812
Last follow-up	84.5	83.0	79.5	
p-value	0.041	0.023	0.026	

Values are presented as mean.
IKDC: International Knee Documentation Committee.

Table 4. Results of Stability Tests Preoperatively and during the Last Follow-up

Variable	Group A (n = 246)	Group B (n = 72)	Group C (n = 34)	*p*-value
Anterior drawer test (0 : 1+ : 2+ : 3+)				
Preoperative	0 : 0 : 76 : 170	0 : 4 : 26 : 42	0 : 4 : 10 : 20	0.130
Last follow-up	122 : 93 : 24 : 7	35 : 29 : 7 : 1	14 : 17 : 2 : 1	0.443
p-value	0.001	0.013	0.031	
Lachman test (0 : 1+ : 2+ : 3+)				
Preoperative	0 : 0 : 60 : 186	0 : 3 : 23 : 46	0 : 2 : 10 : 22	0.087
Last follow-up	111 : 109 : 18 : 8	32 : 30 : 10 : 0	13 : 16 : 4 : 1	0.266
p-value	0.001	0.012	0.028	
Pivot shift test (0 : 1+ : 2+ : 3+)				
Preoperative	0 : 0 : 103 : 143	0 : 2 : 32 : 38	0 : 4 : 13 : 17	0.180
Last follow-up	83 : 129 : 24 : 10	26 : 34 : 12 : 0	10 : 17 : 5 : 2	0.294
p-value	0.001	0.009	0.048	
STSD (< 2 : 3–5 : 6–10 : > 10 mm)				
Preoperative	0 : 0 : 66 : 180	0 : 4 : 27 : 41	0 : 4 : 9 : 21	0.072
Last follow-up	112 : 103 : 24 : 7	29 : 31 : 12 : 0	12 : 18 : 3 : 1	0.209
p-value	0.011	0.035	0.038	

Values are presented as number of patients.
STSD: side-to-side difference.

Table 5. Characteristics of ACL Graft Failure

Characteristic	Group A (n = 246)	Group B (n = 72)	Group C (n = 34)	*p*-value
Total	16 (6.5)	7 (9.7)	6 (17.6)	0.040
Additional surgery	13	6	5	
Complete tear on MRI	3	1	1	
Mean time to failure (mo)	46.2 ± 8.5	51.2 ± 10.8	54.0 ± 9.6	0.382
AutoHA	5 (2.8)	2 (3.7)	2 (9.2)	0.285
Allograft	11 (16.6)	5 (27.8)	4 (30.8)	0.370
p-value*	< 0.001	< 0.001	0.001	

Values are presented as number (%) or mean ± standard deviation.
ACL: anterior cruciate ligament, MRI: magnetic resonance imaging, AutoHA: autologous hamstring tendon graft.
*The *p*-values are based on statistical analysis between AutoHA and allograft in each group.

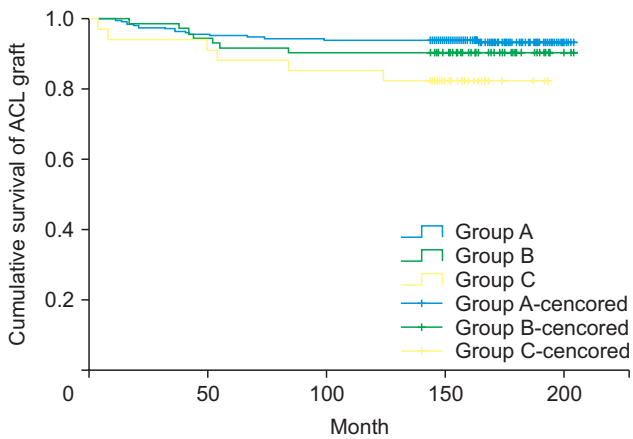

Fig. 3. Kaplan-Meier survival estimates of anterior cruciate ligament (ACL) graft failure at the 10-year follow-up were 93.5%, 90.3%, and 82.4%. The log-rank test (Mantel-Cox, 95% confidence interval) showed significant difference among the groups ($p = 0.048$).

increased in the older group, but it was not statistically significant. Autograft was more favorable than allograft in terms of the graft failure rate regardless of age (Table 5).

Survivorship

Kaplan-Meier survival estimates, with ACL reconstruction failure as the endpoint, are shown in Fig. 3. In groups A, B, and C, the survival rates at 10-year follow-up were 93.5% (95% CI, 89.3%–96.9%), 90.3% (95% CI, 85.7%–94.5%), and 82.4% (95% CI, 78.5%–85.2%), respectively. Significant difference was shown in the log-rank test (Mantel-Cox, 95% CI) among the three groups ($p = 0.048$).

DISCUSSION

The most important finding of this study is that clinical outcomes of ACL reconstruction in older patients were comparable to those of younger and middle-aged patients in terms of the range of motion, clinical scores, and stability. Although graft failure rates were higher in older patients than those in younger and middle-aged patients, older patients showed significant improvement in clinical scores and stability tests postoperatively, and no significant differences were found compared to younger and middle-aged patients. The 10-year survival rates were 93.5%, 90.3%, and 82.4% for groups A, B, and C, respectively. Possible explanation for the high failure rate in the older patients is that it is attributed to biologic factors such as increased apoptosis of skeletal muscle in the study reported by Park et al.[20] In addition, Park et al.[24] also reported a study showing that the volume and strength of the knee flexor muscle decrease with age. So, graft failure can be influenced by weakening of the strength of grafts due to weakening of the hamstring muscles with age.

Many previous studies have demonstrated that ACL reconstruction results in middle-aged patients are comparable with those in younger patients.[8,16,17,19,25,26] Barber et al.[3,16] classified two groups according to age (16–39 vs. 40–52 years, minimum 12 months of follow-up; 18–39 vs. 40–55 years, minimum 24 months of follow-up). They concluded that the age of 40 years was not an obstacle to successful ACL reconstruction. Brandsson et al.[17] compared the clinical results of the middle-aged (40–55 years) and younger groups (20–24 years, with the minimum of 22 months). They reported that the results of subjective and objective function in middle-aged patients were

similar to those in younger patients, and the complication rate was comparable. Sylvia et al.[26] reported patients aged 40 years and older who underwent ACL reconstruction achieved IKDC patient acceptable symptom state scores. Therefore, in middle-aged patients, age does not appear to be a disqualifying factor. On the other hand, good results have been reported in terms of stability and improvement in overall knee function after ACL reconstruction in older patients over 50 years of age.[8,11,13] These were consistent with the results that older patients showed comparable clinical scores with those of younger and middle-aged patients in the present study. According to Costa et al.,[18] the failure rate of primary ACL reconstruction in older patients (over 50 years) was 2.7% (range, 0%–14.3%), which included only cases requiring revision ACL surgery. In the present study, the failure rate was high in all groups (6.5%, 9.7%, and 17.6%), which is thought to be because the definition of failure was broad.

However, the standard classification of age as young, middle-aged, and old remains to be established. In previous studies, the age range for the younger group was either very narrow or very broad (20–24, 16–39, and 18–40 years).[3,16,17] In some studies, the middle-aged group comprised people aged > 40 years, while others classified the middle-aged patients as those aged > 50 years.[8-15] Moreover, there was no distinction between middle-aged and older groups (40–51, 40–52, and 40–55 years). Therefore, whether patients aged 30–39 years should be included in the younger or middle-aged group remains unclear. In this study, patients were classified as younger, middle-aged, and older people according to the age range of 20–29 years (group A), 40–49 years (group B), and 50–65 years (group C), respectively. Patients aged 30–39 years were excluded to clearly distinguish between the younger and middle-aged groups. Additionally, patients aged ≥ 50 years were classified into the older group, because age-related apoptosis in the skeletal muscle increases in individuals aged > 50 years and the volume and strength of the knee flexor muscle decrease with age.[20,24]

A reason for hesitation in undergoing ACL reconstruction in older patients is the possibility of complications.[8] Reported rates of graft failure range from 2.9% to 11%.[27-29] The failure rate of 8.2% in our study seems to be on par with that reported in the literature. No patient required total knee arthroplasty during the follow-up period, but 1 patient in the older group required high tibial osteotomy.

The older patients showed functional improvements postoperatively, but the results were not as good as those of the younger patients. There was also a statistically significant failure rate in the older group. As life expectancy and sports participation increase, ACL reconstruction is required to restore previous activity levels and improve the quality of life in older patients.

This study has several limitations. First, it was a non-randomized retrospective study and potential selection bias could not be avoided. Second, the sample sizes were different among the three groups. Considering the reluctance to surgery in older patients, however, it is inevitable that the number of patients in the elderly is small. Third, the position of femoral tunnel, which can influence the results, was not evaluated. However, the strength of this study is that the patients were classified into three groups according to age and the clinical outcomes were compared among them. Additionally, this study had a long-term follow-up period and the 10-year survival rates of the younger, middle-aged, and older groups were evaluated.

Although graft failure rates were higher in older patients than younger and middle-aged patients, clinical outcomes of ACL reconstruction in older patients were comparable to those of younger and middle-aged patients in terms of the range of motion, clinical scores, and stability tests at the minimum follow-up of 10 years. Given these results, ACL reconstruction in older patients can be considered despite its higher failure rates.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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