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original article

Double-bundle anterior cruciate ligament reconstruction in patients aged 60 years and older

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ABSTRACT

Background: This study aimed to examine the clinical outcomes of double-bundle (DB) anterior cruciate ligament (ACL) reconstruction in patients aged ≥60 years.
Methods: Anatomical DB-ACL reconstruction using hamstring tendon autografts was performed in 13 patients aged ≥60 years at our institution between June 2012 and May 2018. The patients included seven men and six women, and the mean age at surgery was 65.0 years (range, 60–73 years). The mean time from injury to surgery was 80.5 months (range, 1–480 months), and the mean follow-up time was 26.2 months (range, 24–42 months). All patients were assessed based on physical examination findings, clinical scores, Kellgren–Lawrence grades preoperatively and at the final postoperative follow-up, intraoperative meniscal or chondral lesions, and perioperative complications. Status of returning to sports for all patients was assessed at the final follow-up.
Results: The mean side-to-side differences by arthrometer improved from 4.3 mm (range, 2–8 mm) to 0.9 mm (range, 0–2 mm), and the positive pivot-shift test decreased from 100% to 8%. The mean extensor muscle strength was 93.3% (range, 74–116%) postoperatively. The mean Lysholm score improved from 71.1 (range, 27-85) to 95.2 (range, 89-100). Ten of the 13 patients (77%) returned to their pre-injury level of sports performance, and one patient (8%) returned to sports with less intensity. Intraoperatively, meniscal tears were observed in 10 patients (77%), and chondral lesions >grade 2 were observed in 11 (85%). One patient developed perioperative complications. At the final follow-up, the Kellgren–Lawrence grade worsened in only one patient. No re-injury or infection was observed, and revision surgery was not required for any patients.
Conclusions: Anatomical DB-ACL reconstruction could provide satisfactory clinical outcomes and knee function restoration in patients aged ≥60 years.
Level of evidence: A retrospective study, case series (IV).

1. Introduction

The incidence of anterior cruciate ligament (ACL) injuries has increased in the recent years owing to the increased participation of middle-aged and older people in sports activities. In the past, ACL reconstruction was considered the treatment of choice for young athletic patients with functional instability,[1] whereas patients aged ≥40 years with ACL injury were treated non-operatively (e.g., through physical therapy and reduction in sports activity level).[2–4] However, some studies reported the difficulty of returning to sports and high re-injury rate after non-operative treatment of ACL injury in older patients.[1,5] ACL reconstructions were not routinely performed in older patients because of surgeon's concerns regarding adverse events, such as postoperative stiffness, thromboembolism, and osteoarthritic change, that are associated with the patient's older age. However, in the recent decades, several studies have reported successful clinical results after ACL reconstructions for patients aged ≥40 years, including middle-aged

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List of abbreviations

ACL	anterior cruciate ligament
AM	anteromedial
BTB	bone-tendon-bone
DB	double-bundle
K-L	Kellgren–Lawrence
NA	not available
N/A	not applicable
OA	osteoarthritis
PL	posterolateral
ROM	range of motion
SB	single-bundle

athletes.[6–14] Nonetheless, reports on clinical results of ACL reconstruction in patients aged ≥60 years are limited.[11,15]

The anatomical double-bundle (DB) ACL reconstruction can reproduce the dynamics of a native ACL and help the patient acquire better rotational control than conventional single-bundle (SB) ACL reconstruction.[16–19] Although several case series have reported satisfactory results of SB-ACL reconstruction for older patients, to our best knowledge, no study has reported clinical outcomes of anatomical DB-ACL reconstruction for patients aged ≥60 years.[12,20]

This study aimed to evaluate clinical and radiological outcomes of anatomical DB-ACL reconstruction in patients aged ≥60 years with a minimum 2-year follow-up. We hypothesised that DB-ACL reconstruction in patients aged ≥60 years would provide successful clinical results.

2. Materials and methods

2.1. Patients

All patients who underwent ACL reconstruction between June 2012 and May 2018 at our institution were retrospectively evaluated. The inclusion criteria were patients aged ≥60 years who underwent primary DB-ACL reconstruction for continued functional instability of the knee or giving way in daily living or sports activities despite conservative treatment. The conservative treatment consisted of nonsteroidal anti-inflammatory medication, activity modification, physical therapy, and bracing. The exclusion criteria were other than DB-ACL reconstruction, revision ACL reconstruction, multi-ligament knee injuries, and previous surgery on the affected limb. During the same period, 86 patients over the age of 60 with ACL injuries came to our institution. Among the 19 patients (22%) who underwent primary ACL reconstruction, six patients were excluded. one patient underwent SB-ACL reconstruction, two patients underwent ACL reconstruction using bone-tendon-bone autograft, two patients underwent multi-ligament reconstruction, one patient underwent subsequent high tibial osteotomy. The remaining 13 patients were included in the subsequent analysis. Patient demographic data were collected from medical records. The Lysholm Knee Score, status of sports recovery, and objective data, including knee range of motion (ROM), pivot-shift test (positive defined as 1+ or greater), instrumented knee laxity measurement (KT-1000 arthrometer; Medmetric, San Diego, USA), and isokinetic muscle strength were evaluated preoperatively and at the final postoperative follow-up. Isokinetic muscle strength was measured using a Biodex isokinetic dynamometer (Biodex Corporation, New York, USA). The mean peak torque at a speed of 60°/s was calculated and compared with that on the non-operated side and described as the percentage of muscle strength of the operated knee. Osteoarthritis (OA)-related change of the affected knee was graded according to the Kellgren-Lawrence radiologic classification. Intraoperative chondral lesions or meniscal tears were retrospectively evaluated. The chondral lesion in each compartment was graded according to the International Cartilage Repair Society cartilage injury classification, and lesions ≥grade 2 were defined as chondral lesion positive. This study was approved by the institutional review board of our hospital and was performed in compliance with the Helsinki Declaration. Each patient provided written consent for study participation before enrolment.

2.2. Surgical procedure

All patients underwent anatomical DB-ACL reconstruction with a hamstring tendon autograft using the inside-out or outside-in tunnel technique. The semitendinosus tendon was harvested through a 2- to 3-cm longitudinal skin incision parallel to the pes anserinus. The harvested semitendinosus tendon was split into two halves to create two double-looped grafts. The loop side was connected to the ENDOBUTTON CL (Smith and Nephew, London, UK), and the other side was connected to the Leeds–Keio artificial ligament.[16]

The remnant of the lateral femoral attachment was dissected until the resident's ridge[21] was confirmed. To create two femoral tunnels for the anteromedial (AM) and posterolateral (PL) bundles in the lateral condyle, a guide wire was first drilled at the centre of the femoral attachment of the AM or PL bundle through the far AM portal for the inside-out technique or a lateral incision was made with the outside-in anatomic ACL guide system (Smith and Nephew) for the outside-in technique. On the tibial side, the AM bundle was placed just posterior to the anterior ridge (Parsons knob)[22] and the PL bundle was placed just anterior to the intertubercular fossa[23] using the ACUFEX Director ACL Tip Aimer (Smith and Nephew). The tibial remnant was preserved as much as possible. After the PL and AM grafts passed through the bone tunnels, graft fixation was achieved by the ENDOBUTTON CL on the femoral side, and the staples were placed on the tibial side with 0–10° knee flexion with a tension of 20 N to the PL graft and 30 N to the AM graft. In cases of concomitant meniscal tears, meniscal repair was performed in repairable cases and partial meniscectomy was performed in irreparable cases.

2.3. Rehabilitation protocol

Postoperative rehabilitation protocol similar to that for younger patients was followed for all patients. All patients performed active quadriceps exercises and started passive motion exercises using a continuous passive motion machine from the second postoperative day. At 2 weeks after surgery, patients were allowed full weight-bearing walking with a hinged brace. A knee brace was worn for 3 months. Jogging was allowed at 3 months with a gradual return to previous sports activities, including competitive sports, between 8 and 12 months after surgery. Knee extensor and flexor muscle strength were measured at 4, 6, 9, and 12 months and were used as a reference for returning to sports activity.

2.4. Statistical analysis

Differences between preoperative and postoperative results were compared using the paired *t*-test, Mann–Whitney *U* test, or Fisher's exact test. All differences were considered statistically significant at $P < 0.05$. All data were analysed using SPSS ver. 26 (IBM SPSS Statistics 19.0; IBM Corp., Armonk, NY, USA).

3. Results

Patient demographics and preoperative clinical data are summarised in Table 1. Seven men and six women were included in the study. The mean age at surgery was 65.0 years (range, 60–73 years), and the mean follow-up time was 26.2 months (range, 24–42 months). The mean time from injury to surgery was 80.5 months (range, 1–480 months). The main mechanisms of injury were skiing (n = 7), fall (n = 2), tennis (n = 2), football (n = 1), and volleyball (n = 1).

Table 1
Patient characteristics.

Patient	Age, years	Sex	Mechanism of Injury	Injury to Surgery, months	Follow-up, months	Side-to-Side Difference, mm	Lysholm Score
1	66	Female	Skiing	7	24	6	81
2	64	Male	Skiing	480	29	NA	57
3	64	Male	Volleyball	168	24	5	77
4	64	Male	Skiing	2	24	6	76
5	60	Female	Tennis	2	28	8	85
6	70	Female	Skiing	4	26	5	66
7	60	Male	Fall	3	24	2	27
8	61	Female	Fall	168	42	3	82
9	64	Female	Skiing	1	24	2	85
10	66	Male	Football	168	24	2	61
11	66	Female	Skiing	3	24	4	85
12	73	Male	Skiing	2	24	2	77
13	67	Male	Tennis	39	24	7	65

NA, not available.

All patients achieved normal or nearly normal ROM, and no patients had a limited ROM of >5° as compared with the ROM of the contralateral knee. The pivot-shift test was negative in 12 patients (92%) and mildly positive in one at the final follow-up. The mean side-to-side difference on maximum manual arthrometric testing improved from 4.3 mm (range, 2–8 mm) preoperatively to 0.9 mm (range, 0–2 mm) postoperatively. The mean percentage of extensor and flexor strength of the operated knee was 93.3% (range, 74–116%) postoperatively and 89.6% (range, 72–106%) at the final follow-up.

The mean Lysholm score significantly improved from 71.1 (range, 27-85) preoperatively to 95.2 (range, 89-100) at the final follow-up. Ten of the 13 patients (77%) returned to their pre-injury level of sports performance, whereas one patient (8%) returned to sports with less intensity. Radiographic OA grades were exacerbated in only one patient at the final follow-up (Table 2).

Table 3 shows type of meniscal tear and chondral lesions, Among 10 patients (77%) with meniscal lesions, five underwent partial meniscectomy and three underwent meniscal repair with all-inside technique. Eleven patients (85%) had more than International Cartilage Repair Society grade 2 cartilage lesions intraoperatively, including isolated patellofemoral in one patient (8%), isolated medial compartment in one patient (8%), isolated lateral compartment in one patient (8%), and multicompartmental in 8 patients (62%). Only one patient (7%) had a perioperative complication (i.e., a transient ischaemic attack) 2 days postoperatively. However, the patient recovered within 2 weeks of onset, and the complication did not affect the rehabilitation. No re-injury or infection was observed, and no revision surgery was required for any patients.

Table 2
Functional and clinical outcomes.

Score	Preoperative	Postoperative	*P* value
Side-to-Side Difference, mm	4.3 (2-8)	0.9 (0-2)	<0.001
Pivot-Shift Test Positive	13 (100%)	1 (8%)	<0.001
0	0 (0%)	12 (92%)	
1+	8 (62%)	1 (8%)	
2+	4 (31%)	0 (0%)	
3+	1 (8%)	0 (0%)	
Lysholm Score	71.1 (27-85)	95.2 (89-100)	<0.001
Return to Sports		10 (77%)	
Return to Sports (less intensity)		1 (8%)	
Extensor Muscle Strength, %		93.3 (74-116)	
Flexor Muscle Strength, %		89.6 (72-106)	
OA Grade, K-L Grade			0.98
Grade 0	4 (31%)	3 (23%)	
Grade 1	5 (39%)	6 (46%)	
Grade 2	3 (23%)	3 (23%)	
Grade 3	1 (8%)	1 (8%)	
Grade 4	0 (0%)	0 (0%)	

K-L, Kellgren-Lawrence; OA, osteoarthritis.

Table 3
Intraoperative meniscal or chondral lesions.

Lesion	Number (%)
Meniscal tears	10 (77%)
Medial meniscus	7 (54%)
Lateral meniscus	4 (31%)
Both	1 (8%)
Tear type	
Longitudinal	4 (36%)
Horizontal	1 (9%)
Oblique	2 (18%)
Bucket-handle	1 (9%)
Complex	3 (27%)
Repair technique	
All-inside	3 (100%)
Chondral lesions	11 (85%)
Isolated patellofemoral	1 (8%)
Isolated medial compartment	1 (8%)
Isolated lateral compartment	1 (8%)
Multicompartmental	8 (62%)

4. Discussion

Our study demonstrated significant improvement in clinical scores and functional outcomes, including ROM, anteroposterior knee stability, muscle strength, and good rate of returning to sports after DB-ACL reconstruction in patients aged ≥60 years. Historically, older patients with ACL rupture have been treated conservatively or recommended to modify their physical activities.[4,5,24–26] Ciccotti et al. reported that 83% of the patients had satisfactory results with conservative treatment for ACL rupture, whereas patients aged 40–60 years who wished to return to sports had significant re-injury rates and unsatisfactory results.[4]

There are several recent reports of successful clinical outcomes after ACL reconstruction in middle-aged or older patients that are comparable to the results of ACL reconstruction in younger patients.[27–29] Table 4 summarised the findings of previous relevant studies. The patients in most studies were ≥40 years of age, including two studies with patients aged ≥60 years.[15,11] Both studies assessed the outcomes of SB reconstruction and concluded that older and active patients with ACL ruptured knees need not be excluded from surgical treatment.

To our best knowledge, no study has reported clinical outcomes of arthroscopic DB-ACL reconstruction in patients aged ≥60 years. DB-ACL reconstruction using the hamstring tendon can anatomically mimic the fibre arrangement of the AM and PL bundles of the ACL and has been shown to provide better rotational stability than SB-ACL reconstruction.[17–19] Some studies compared clinical outcomes between SB and DB and concluded that there were no significant differences between the two procedures.[30–32] Ventura et al.[12] compared clinical outcomes between patients aged over 50 years who underwent SB- and DB-ACL reconstruction and concluded that there was no significant

Table 4
Summary of previous studies of patients aged 50 years and older.

Author	Year	No. of Patients	Mean Age, years	Follow-up, months	Graft Type[a]	Lysholm Score	Side-to-Side Difference, mm	Reinjury, %	Return to Sport (less intensity), %
Arbuthnot et al.[38]	2010	14	60	114	Various; Autograft BTB or Hamstring SB	79	1.5	7	N/A
Ventura et al.[12]	2012	50	54	41	Hamstring SB or DB	90	2.7	0	N/A
Wolfson et al.[14]	2014	32	58	60	Various; Allograft BTB or Hamstring SB	87	1.2	3	N/A
Figueroa et al.[7]	2014	50	52	53	Various; Allograft Achilles Tendon or Hamstring SB	94	N/A	4	88
Toanen et al.[11]	2017	12	61	50	Hamstring SB	N/A	1.9	0	50 (83)
Iorio et al.[8]	2018	36	54	64	Hamstring SB	94	1.6	0	56 (100)
Ovigue et al.[10]	2020	75	54	28	Hamstring SB	90	N/A	8	51 (86)
Weng et al.[13]	2020	67	57	30	Hamstring SB	86	N/A	0	54 (81)
Our study	2021	13	65	26	Hamstring DB	95	0.9	0	77 (85)

[a] BTB, bone-tendon-bone; DB, double-bundle; N/A, not applicable; SB, single-bundle.

difference between two groups. However, recent studies have shown the superiority of DB-ACL reconstruction over SB-ACL reconstruction in terms of long-term clinical outcome or chondroprotectivity.[33,34] Our results demonstrated a 92% rate of postoperative negative pivot-shift and a 77% rate of return to pre-injury sports level in patients aged ≥60 years. These results are comparable to those of previous studies on SB-ACL reconstruction in patients aged ≥40 years.

Middle-aged and older patients with ACL reconstruction have shown good muscle recovery in many reports. Blyth et al.[35] evaluated the isokinetic muscle strength after ACL reconstruction in patients aged ≥50 years at the mid-term (i.e., at the mean postoperative time point of 46 months) and reported that the mean torque ratio recovered to 94% on extension and 102% on flexion. Kim et al.[27] concluded that postoperative muscle strength was similar between young patients and those aged ≥50 years. Our results are consistent with findings from these studies, suggesting that muscle recovery in highly active geriatric patients might be similar to that in younger patients. In this study, most patients tended to be highly motivated to return to sports, which might be related to their successful rehabilitation.

All patients had participated in competitive or recreational sports activities preoperatively, and 85% of the patients had returned to sports by the final follow-up. This result is similar to those reported in previous studies of middle-aged patients (60–86%).[9,36] Regarding the type of sports, Schumacher et al. reported that skiers had a significantly higher improvement in the Knee Injury and Osteoarthritis Outcome Score after SB-ACL reconstruction than non-skiers.[37] Ovigue et al. reported that 51% of all patients aged ≥50 years had returned to their pre-injury sports level at 24 months postoperatively, with a higher rate in the skiing group (72.3%).[10] In our study, seven of the 13 patients were skiers, and six of them returned to sports. This high recovery rate in skiers might be reflected in the 85% overall rate of return to sports in our study.

Several studies reported secondary OA progression after ACL reconstruction, even in younger patients. Furthermore, OA progression after ACL reconstruction in older patients may lead to poor clinical outcomes and patient dissatisfaction.[6,35,38] Costa et al.[39] reported disappointing rates of OA progression on radiographs from 1.9% preoperatively to 15% at 32–64 months postoperatively in patients aged 50 years. In our study, mild OA progression, grade 0 to 1, was observed in only one patient at a mean follow-up of 26.2 months. Intraoperatively, 85% of the patients had >grade 2 articular cartilage lesions and 77% had meniscal tears. The high incidence of cartilage lesions and meniscal tears had no significant impact on OA change at the mean 2-year follow-up. However, longer follow-up is necessary to confirm OA progression after ACL reconstruction in older patients.

Regarding postoperative complications, a previous study in patients aged >40 years reported incidence rates of 0.3% and 0.2% for deep venous thrombosis and pulmonary embolism, respectively, which were similar to the rates observed in younger patients.[6] In our study, one patient experienced a transient ischaemic attack unrelated to the surgery on postoperative day 2. No perioperative complications, including infection, deep venous thrombosis, postoperative contracture, or intraoperative fracture, were observed. Some surgeons might be hesitant about performing surgical treatment for older patients because of the increased risk of complications due to their advanced age. In fact, the development of transient ischaemic attack in one study participant is a classic example of this risk. However, Tan et al. reported no significant differences in the risk of complications between younger patients and those aged >50 years in a total of 287 case studies.[29]

There were some limitations to this study. First, the small number of patients and the lack of control cases, such as SB-ACL reconstruction, weakened our conclusion. Considering surgical invasiveness and possible increased complication rates with older age, there may be an opinion that SB-ACL reconstruction may be more reasonable. Second, the follow-up period might be too short to evaluate OA progression. Third, since all patients were Asian, the study results may not be generalisable to other populations. Fourth, evaluation by other clinical scoring, such as the Tegner score or the International Knee Documentation Committee scale, should be considered. Finally, as older people tend to not undergo staple removal, secondary arthroscopic evaluation of chondral lesions or meniscal repair of tears was performed.

5. Conclusions

The number of older patients participating in sports activities is increasing and many studies have reported successful clinical outcomes after SB-ACL reconstruction in patients aged ≥40 years. Our study demonstrated good to excellent clinical outcomes after double-bundle ACL reconstruction in patients aged ≥60 years. Therefore, anatomical DB-ACL reconstruction may be a successful treatment for ACL dysfunction in these patients who enjoy sports activity, even among those with mild OA.

Ethics statement

Reference number is "#202104".

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Declaration of competing interest

The authors have no conflicts of interest directly relevant to the content of this article.

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