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Abstract

Background: Risk factors have been reported for osteoarthritis (OA) after anterior cruciate ligament (ACL) reconstruction, but previous studies did not include a control group, and may have included OA that would have naturally developed even in the absence of ACL injury. This study investigated risk factors compared with the patient's own contralateral knee.

Methods: Three hundred forty-nine patients who had undergone ACL reconstruction at least 15 years previously were invited to visit the hospital. After exclusion criteria were applied, 40 patients were included in the study, including 16 with progressive OA and 24 without OA. Progressive OA was defined as OA that was more advanced on the affected side than on the contralateral side. The variables evaluated included age at the time of surgery, time from injury to surgery, sex, graft material, cartilage damage, and meniscectomy.

Results: No significant differences between groups were seen in terms of age, time from injury to surgery, sex, graft material, or cartilage damage. Meniscectomy was ultimately performed significantly more frequently in the OA group (88%) than in the non-OA group (38%; $p<0.01$).

Conclusions: Meniscectomy was found to constitute a risk factor for the progression of OA after ACL reconstruction.

Introduction

The incidence of meniscus injury naturally increases after anterior cruciate ligament (ACL) rupture. An increased risk of osteoarthritis (OA) has also been reported.[1,2] There is broad consensus that ACL reconstruction should be performed to allow continued participation in sports. Whether ACL reconstruction decreases the risk of OA, however, remains controversial.[1]

Some reports have shown that ACL reconstruction, similar to conservative treatment, did not prevent OA progression.[3,4] However, cases in which a torn ACL was left in a dysfunctional state had a high probability of progressing to OA.[5] Knees with deficient ACLs were more likely to progress to OA compared with normal ACLs, but ACL reconstruction might not have prevented this even if it had been performed. Body mass index, sex, stability, concomitant meniscal injury, cartilage damage, and postoperative activity have been reported as risk factors for the progression of OA after ACL reconstruction.[6-9]

The studies reporting those factors were not controlled, however, and may have included risk factors for OA that developed naturally even in the absence of ACL injury. This study investigated risk
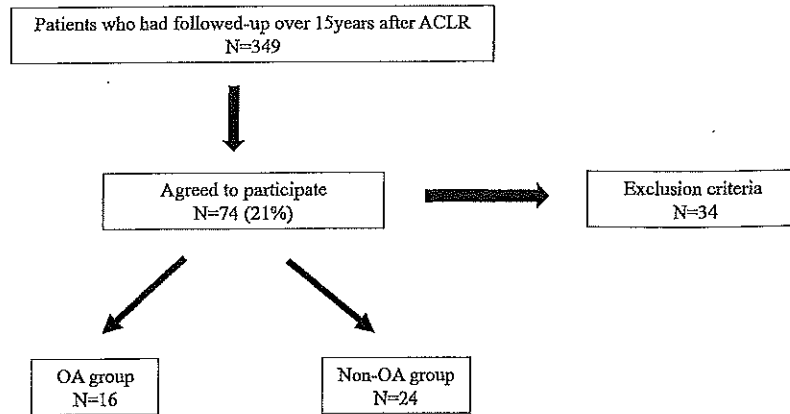
Fig. 1 Flowchart demonstrating the selection of patients for study inclusion.
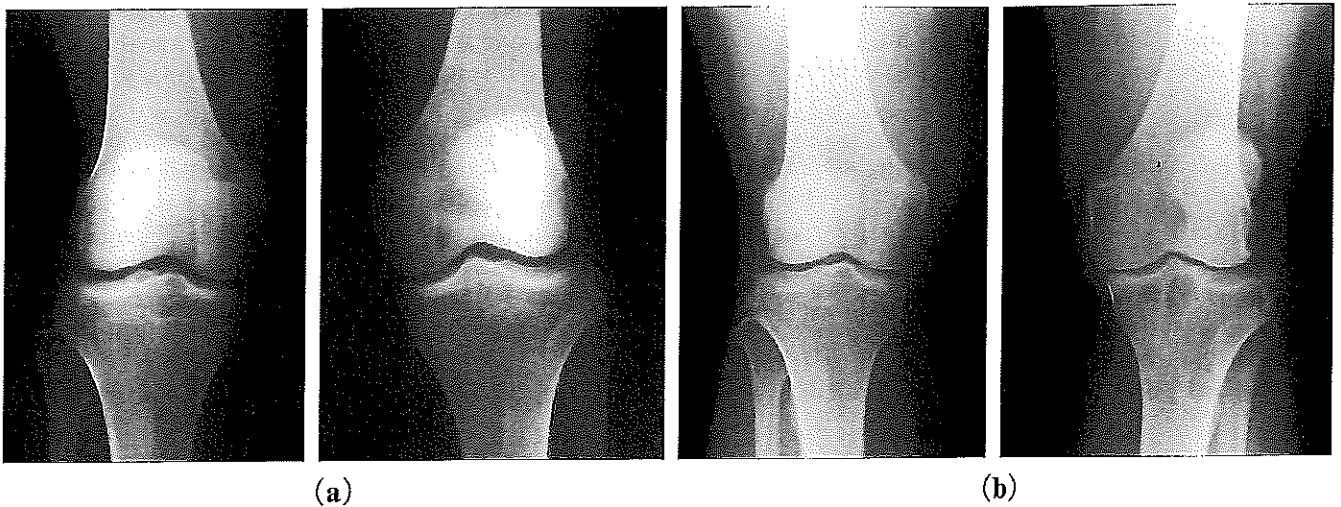ACLR: anterior cruciate ligament reconstruction, OA: osteoarthritis

(a) **(b)**

Fig. 2 Radiographs taken (a) prior to surgery and (b) 15 years after surgery
The left knee 15 years after surgery showed progression of osteoarthritis. However, there was no sign of osteoarthritis in the unoperated right knee.

factors in the postoperative knee compared with the patient's contralateral knee. We investigated risk factors for the progression of OA in patients who had undergone ACL reconstruction at least 15 years prior.

Hypothesis

Meniscectomy is the greatest risk factor for OA progression after ACL reconstruction.

Materials and Methods

Patients who had undergone ACL reconstruction by knee specialists in a single institution between 1993 and 1997 were sent mailed invitations to attend the hospital. Those with an injury to the contralateral side, those in whom the ACL had reruptured, and those with several injured ligaments requiring surgery were excluded. The remaining patients with progressive OA were then categorized as the OA group, and those without OA as the non-OA group. Direct mail was sent to 349 patients, of whom 74 (21%) agreed to

participate. After the exclusion criteria were applied, 40 patients were included in the study (OA group, n = 16; non-OA group, n = 24) (Fig. 1).

ACL reconstruction was performed using the bone-patellar tendon-bone (BTB) method between April 1993 and September 1996, and the quadrupled semitendinosus and gracilis (STG) tendon method between September 1996 and December 1997. For all patients, the tibia tunnel was formed central to the tibial attachment of the ACL and the femur tunnel was at 10-11 o'clock (right knee) using the transtibial technique. Partial resection of all concomitant meniscal injuries was performed.

In this study, progression of OA was defined as OA of the operated knee that was more advanced at the final evaluation than at the preoperative weight-bearing frontal plain X-rays, as determined by the Kellgren-Lawrence grade and compared with the contralateral side (Fig. 2). If OA was equally advanced on the contralateral side as on the operated side, then the operation was not considered to be at fault, and the

patient was not classified as having progressive OA.

The variables evaluated included age at the time of surgery, time from injury to surgery (waiting time), sex, graft material, cartilage damage at the time of surgery, meniscectomy, Lachman test and pivot-shift test results (classified at the time of final follow-up as normal, nearly normal, abnormal, or severely abnormal, per the International Knee Documentation Committee classification[10]) and side-to-side difference (SSD) between the operated and unoperated sides in anterior tibial translation on stressed X-ray (Telos SE).[11] SSD<3 mm was classified as normal. Mean values and the number of patients with a mean SSD< 3 mm were compared between groups. The Mann-Whitney test, Fisher's test, and multiple logistic regression analysis were used for statistical analysis, with values of $p<0.05$ regarded as significant. In addition, necessary sample size for Fisher's test was 32 when α value is 0.05, $(1-\beta)$ value is 0.8, effect size is 0.5, and free value is 1 for the power analysis.

Results

No significant difference in patient demographics was evident between the non-OA group and OA group (Table 1). Meniscectomy was performed significantly more frequently in the OA group (14/16, 88%) than in the non-OA group (9/24, 38%; $p<0.01$) (Table 2). No significant difference in the location of either medial meniscectomy or lateral meniscectomy was seen between groups (Table 3). Twelve patients (50%) in the non-OA group were classified as normal on the Lachman test, a higher proportion than the four patients (25%) in OA group, but this difference was not significant. Twelve patients (50%) in the non-OA group were also classified as normal on the pivot-shift test, compared with six patients (38%) in the OA group, but this difference was also not significant. Mean SSD tended to be better for the non-OA group (3.9±3.9 mm) than for the OA group (5.2±2.7 mm), but the difference was not significant. The proportion of normal patients with SSD<3 mm was also higher in the non-OA group (10 patients, 42%) than in the OA group (3 patients, 19%), but again, this difference was not significant. Multiple logistic regression analysis identified meniscectomy as the only risk factor for OA progression ($p=0.01$) (Table 4).

Discussion

These results show that meniscectomy represented the only significant risk factor for the progression of OA after ACL reconstruction. Ahn et al.[6] reported that 91.4% of patients who underwent ACL reconstruction also suffered from meniscal injury and that meniscectomy was a risk factor for the development of OA in the medial compartment. Although the patients in that study showed a higher rate of concomitant meniscal injury compared with those in this study, this similarly constituted a risk factor. Shelbourne et al.[12]

Table 1 Patient demographics

		Non-OA (n=24)	OA (n=16)	p
Age (years)		28.0±9.4	28.3±10.5	0.75
Waiting time (months)		27.8±64.8	44.6±65.7	0.45
Female		10/24	8/16	0.75
Graft material				0.99
	BTB	16	10	
	STG	8	6	
Cartilage damage		5/24	2/16	0.68

Values are given as mean ± standard deviation or number.
Waiting time: time from injury to surgery, OA: osteoarthritis, BTB: bone-patellar tendon-bone, STG: quadrupled semitendinosus and gracilis
No significant difference in patient demographics.

Table 2 Total number of subjects who underwent meniscectomy

	Non-OA	OA
Meniscectomy performed	9	14
Meniscectomy not performed	15	2
Total	24	16

OA: osteoarthritis
Meniscectomy was performed significantly more frequently in the OA group ($p<0.01$).

Table 3 Details of meniscus injuries

	Breakdown of meniscectomies (%)	
	Non-OA (n=9/24)	OA (n=14/16)
Medial meniscectomy	6 (25%)	8 (50%)
Lateral meniscectomy	2 (8%)	3 (19%)
Both meniscectomy	1 (4%)	3 (19%)

OA: osteoarthritis
No significant difference in the location of meniscectomy was seen between groups ($p=0.17$).

Table 4 Multiple logistic regression

Factor	Odds ratio	95%CI	p
Age	1.1	0.9-1.2	0.33
Waiting time	1.0	1.0-1.0	0.87
Sex	1.0	0.1-8.8	0.99
Graft material	0.5	0.1-4.0	0.52
Cartilage damage	1.5	0.1-23.4	0.75
Meniscectomy	34.1	2.2-522.4	0.01*
Lachman test	0.9	0.1-11.7	0.96
Pivot-shift test	2.1	0.2-24.8	0.56
SSD	1.2	0.8-1.7	0.32

*: Significant difference
Waiting time: time from injury to surgery, SSD: side-to-side difference
Meniscectomy was the only risk factor for osteoarthritis progression.

also found that more patients with concomitant meniscal injury developed OA compared with those with no injury.

Many authors reported that OA progressed if the ACL was torn. Amin et al.[5] investigated whether the ACL was torn or not in patients with OA, and suggested that, after correcting for age, BMI, and sex, a torn ACL was a risk factor for OA. Swärd et al.[13] reported that knees in which 15 years had elapsed since an ACL rupture progressed to OA more frequently than the contralateral knee. When meniscus injury was also considered, van Meer et al.[14] reported that meniscal injury and meniscectomy had a strong relationship to OA development. In addition, Neuman et al.[15] prospectively followed patients after ACL rupture for 15 years, and found no OA among patients without

meniscal injury, but OA in 37% of those with meniscal injury. Therefore, there was an association between torn ACL and OA, but meniscal injury accompanied by torn ACL may have a stronger association with OA.

Keene et al.[16] reported that prevalence of meniscal injury increased in knees with a deficient ACL. Cipolla et al.[17] reported that the acute period after ACL rupture was associated with many lateral meniscal injuries, and that medial meniscal injuries increased in the chronic period. The abovementioned results all consistently show that the incidence of meniscal injury is increased in knees with torn ACLs.

Dong et al.[18] showed that contact pressure on the cartilage became greater after meniscal injury or meniscectomy. Roos et al.[19] reported that patients with meniscectomy had a 14-fold higher risk of OA, and Englund et al.[20] described meniscectomy as a risk factor of OA over 15 years of follow-up. These results confirm that meniscal damage has a strong association with OA.

We did not find any significant differences in factors associated with anterior instability or rotatory instability. Shelbourne et al.[12] reported that KT 1000 score was not a risk factor for the progression of OA. Murray et al.[8] investigated the association between instability-associated scores and OA, and also found no significant difference. As mentioned previously, however, there is now a unified consensus that meniscal injury increases in ACL-deficient knees, and a link between ACL stability and the development of OA cannot be entirely ruled out. The establishment of numerical scores for rotatory instability will be required in the future, as will further studies on the relation between ACL stability and OA.

As stated by Oiestad et al.,[21] the use of the unoperated knee as a control is an effective method of controlling for factors such as BMI and activity, which are in constant flux. If OA develops owing to these factors, it should progress at the same rate on both sides, and this study therefore did not classify patients with similar degrees of progression in both legs into the OA group. This is a significant point of differentiation of our study from previous studies.

The present study has limitations that need to be considered when interpreting the results. First, a retrospective study was applied, and the proportion of patients who were followed-up was quite low (74/349, 21%). Many of those patients had to be excluded, leaving only 40 participants (11%) in the study. Furthermore, the sample size is insufficient for multiple logistic regression analysis. However, because the effect size is 1.03, and $1-\beta$ is 0.99 according to a post hoc test, the sample size was sufficient for Fisher's test. Second, all subjects with meniscal injury underwent meniscectomy, and as a result, no patients underwent meniscal repair. If menisci were repaired, we believe there would have been less progression of OA.

Conclusion

Meniscectomy is a risk factor for the progression of OA after ACL reconstruction.

Compliance with Ethical Standards

Disclosure of potential conflicts of interest: None
Ethical Approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.
Informed consent: Informed consent was obtained from all individual participants included in the study
Conflicts of interest: None

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