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Original Article

Meniscus repair with simultaneous anterior cruciate ligament reconstruction: Clinical outcomes, failure rates and subsequent processing

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ABSTRACT

Purpose: To retrospectively analyze the clinical outcomes of meniscus repair with simultaneous anterior cruciate ligament (ACL) reconstruction and explore the causes of failure of meniscus repair.
Methods: From May 2013 to July 2018, the clinical data of 165 patients who were treated with meniscus surgery and simultaneous ACL reconstruction, including 69 cases of meniscus repair (repair group) and 96 cases of partial meniscectomy (partial meniscectomy group) were retrospectively analyzed. The exclusion criteria were as follows: (1) ACL rupture associated with fracture, collateral ligament injury, or complex ligament injury; (2) a history of knee surgery; or (3) a significant degree of osteoarthritis. The 69 patients in the repair group were divided into the non-failure group (62 cases) and the failure group (7 cases) depending on the repair effect. Postoperative outcomes of the repair group and the partial meniscectomy group were compared. General conditions and postoperative outcomes of the failure group and the non-failure group were compared. During the median follow-up period of 28 months (range, 4 - 65 months) after the second arthroscopy, postoperative outcomes of seven patients in the failure group were summarized. SPSS 25.0 statistical software was used for statistical analysis. A p value less than 0.05 was considered statistically significant.
Results: Seven patients in the failure group who underwent the second arthroscopy were followed up for (30 ± 17.4) months and their postoperative outcomes were summarized. Compared with the partial meniscectomy group, the International Knee Documentation Committee scores of patients in the repair group improved significantly ($p = 0.031$). Compared with the non-failure group, more patients in the failure group were younger than 24 years ($p = 0.030$). The median follow-up period was 39.5 months. All patients recovered well after subsequent partial meniscectomy and relieved clinical symptoms. Visual analog scale scores decreased significantly ($p = 0.026$), and the International Knee Documentation Committee and Lysholm scores improved significantly ($p = 0.046$ for both).
Conclusion: The failure rate of meniscus repair in this study was 10.1% (7/69), all of which were medial meniscus tears. However, the surgical outcomes of ACL reconstruction were not affected, and there might be a role for graft protection. Therefore, meniscus retears can be successful treated by performing subsequent partial meniscectomy in patients with repair failure.

Introduction

The meniscus is a fibrous cartilaginous structure located between the tibial plateau and condyles on both sides of the femur in the knee joints. The meniscus has several functions, including withstanding gravity, reducing the impact of exercise on the knee, ensuring the stability of the knee joint, and protecting and lubricating the knee.[1] Previous research has found that after medial meniscus resection, the initial relaxation of the knee increased by 14% on average, and relaxation of the medial collateral ligament increased by 3 times, which affected anterior cruciate ligament (ACL) reconstruction and tension strength decreased by 10%.[2–4] Therefore, the meniscus plays an important role in whole-knee motion.

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ACL injuries are often accompanied by meniscal tears. The strategy for treating injured meniscus in the process of ACL reconstruction has been a popular research topic. Given the risk of osteoarthritis, the application of meniscectomy has gradually decreased, and the indications for meniscal repair have gradually increased.[5] Successful meniscus repair is also biomechanically important for the stability of the ACL, in particular when repairing the meniscus root.

The success rate of meniscus repair can reach 75%–92% during ACL reconstruction.[6–9] Even so, the possibility of failure of meniscus repair still exists. The subsequent treatment includes revision meniscal repair or partial meniscectomy. Some researchers have described that revision meniscal repair can achieve satisfactory clinical results for retorn menisci, but few studies have investigated the clinical effects of partial meniscectomy.[10,11]

This study retrospectively analyzed the data of patients being performed meniscus surgery with simultaneous ACL reconstruction by the same doctor from May 2013 to July 2018, and aimed to analyze the mid-term clinical outcomes and the causes of failure of postoperative meniscus repair. Additionally, the outcomes of secondary arthroscopic surgery in patients with repair failure were evaluated.

Methods

Clinical materials

This retrospective case series were conducted to evaluate the clinical outcomes and failure rates of primary meniscus repair with simultaneous ACL reconstruction in patients operated by the same physician at our institution. The study was approved by the institutional review board (Project Number: M2020024). The electronic medical records of 296 patients with ACL reconstruction were screened to identify all patients who underwent meniscus surgery and simultaneous ACL reconstruction between May 2013 and July 2018. The inclusion criteria were as follows: (1) patients with intraoperatively confirmed ACL rupture combined with medial, lateral, or medial and lateral meniscal injury; (2) aged <60 years; and (3) no history of previous ipsilateral knee meniscal injury. The exclusion criteria were as follows: (1) ACL rupture associated with fracture, collateral ligament injury, or complex ligament injury; (2) a history of knee surgery; or (3) a significant degree of osteoarthritis.

One hundred and sixty-five patients were finally identified. Sixty-nine patients were included in the repair group and 96 patients in the partial meniscectomy group. Of the 69 patients in the repair group, 47 were male and 22 were female. The mean age of patients with primary meniscus repair was 27.66 years (range, 13–57 years), and the median time between injury and primary repair was 4 months (range, 1 day–12 years). Failure of meniscus repair occurred in 7 patients. Of the 96 patients in the partial meniscectomy group, 69 were male and 27 were female. The mean patient age in the partial meniscectomy was 32.91 years (range, 14–60 years), and the median time between injury and primary repair was 2 months (range, 1 day–28 years).

In this study, 165 patients were followed up for a median of 39.5 months. A total of 7 patients had failed repair and these patients were followed up for an additional average of 30 months after revision arthroscopy. The records of all patients were reviewed to collect the demographics, meniscus injury patterns, and details regarding primary and second arthroscopic surgeries.

Surgical techniques and postoperative rehabilitation

The decision to choose meniscus repair or partial meniscectomy was made intraoperatively based on the indications, which were as follows: (1) longitudinal tears with red-red or red-white areas, including bucket-handle tears; (2) simple tears spanning red, red-white, and white areas; and (3) short petal T-shaped lacerations. The edge of the tear is normally polished and freshened to promote healing.

According to the position of meniscus injury, 2 main suture methods were adopted. Meniscus injury located in the anterior horn and anterior part of the meniscus body, the suture method was from outside to inside (method 1). A 16-G trocar was used to suture the torn part of the meniscus from outside to inside through the skin and joint capsule, and the knot was then buried under the skin. Multiple stitches could be sutured according to the injury. Meniscus injury located in the posterior root, posterior horn (PH), and posterior body of the meniscus, the suture method was an all-inside technique (method 2). An all-inside suture was performed with a FasT-FiX meniscus suture device. The superior or inferior surface of the meniscus was sutured. A combination of horizontal and vertical sutures was used, and the number of stitches depended on the size of the tear. All lacerations were sutured tightly with intact meniscal tension.

Eighty cases of meniscus tears were repaired using arthroscopic techniques in the 69 patients. Among them, 1 case (1.25%) was repaired by method 1, 74 cases (92.5%) by method 2, and 5 cases (6.25%) by a combination of methods 1 and 2.

The indication of partial meniscectomy was as follows: (1) the tear was located in the white-white area; (2) the meniscus was severely degenerated; and (3) the menisci could not be stabilized by surgery. The meniscus with poor texture was partially excised, and the rest was freshened. All 7 patients in the failure group underwent secondary arthroscopic partial meniscectomy.

Postoperatively, all patients could only withstand partial weight bearing (20 kg) for the first 6 weeks, with weight-bearing tolerance gradually increasing over the next 2–4 weeks. During the first 6 weeks, knee flexion was limited to 90°. Complete squatting could be performed 4 months after surgery, and normal activities could be resumed after 6 months.

Follow-up evaluation

All patients underwent semiannual check-ups at the hospital after surgery, including the following scores. The visual analog scale (VAS) was used to assess the pre- and post-operation degree of knee pain. The functions of the knee were assessed using standardized subjective scoring instruments, including the Lysholm knee scoring scale, the international knee documentation committee (IKDC) score, and the Tegner activity scale. KT-2000 system was used to measure the deficit (mm) of the affected to non-affected knee. The shift was recorded automatically when the force reached 44 N, 66 N, 88 N and 132 N. The difference of the shifts in 132 N between affected and unaffected knee was used as a statistic to assess the effectiveness of the surgery. Each patient was in a supine position with knee flexed to 30°. Some patients were followed up by telephone to assess the effect of the operation.

Statistical methods

SPSS 25.0 statistical software was used for statistical analysis. The Fisher exact probability method was used to compare

differences in age distribution, sex and meniscus injury circumstances. The data had a normal distribution, and were analyzed using the Kolmogorov-Smirnov test and an independent samples *t*-test. The rest had a non-normal distribution and were analyzed using the Kolmogorov-Smirnov test and Mann-Whitney *U* test. For evaluating the efficacy of second arthroscopy, postoperative Tegner scores were compared using paired *t*-test. The rest of the scores had a non-normal distribution and were analyzed using the Kolmogorov-Smirnov test and Wilcoxon test. Differences were statistically significant if *p* value was less than 0.05.

Results

Comparison of demographic data in the repair group

The failure rate among the patients that underwent meniscus repair was 10.1% (7/69). No significant difference was observed in age, sex, disease course, height, weight or body mass index between the failure and non-failure groups. The difference in age distribution between the 2 groups was statistically significant ($p = 0.030$) (Table 1).

Data of two operations

The length of the lesion and the number of stitches were noted in arthroscopy and were classified into one of the following 3 types: (1) limited to the PH, (2) including the PH and midbody (PH-MB), or (3) extending to the anterior horn (PH-MB-AH). Injury-specific information and surgical details in this study are listed in Table 2. There was no significant difference between the failure and non-failure groups in term of type, side, meniscus injury location, meniscus tear length and number of stitches.

The second arthroscopy showed 7 patients of meniscus injury in the failure group (Table 3). In 5 patients (71.4%), a traumatic retear was the reason for subsequent partial meniscectomy. Traumatic retears occurred during sports in 2 patients (40%) and during activities of daily living in 3 patients (60%). Failed healing (biologic failure) was considered the main reason for subsequent partial meniscectomy in 2 patients (17%). The mean time from primary repair to second arthroscopy was 32.4 months (range, 15–48 months). All injured menisci needing repaired involved the original repair site. Medial meniscus injuries were observed in 7 patients (100%). Four patients (57.1%) had tears from the body to the PH, 1 patient (14.3%) had tears from the anterior body to the PH, and 2 patients (28.6%) had posterior body tears. At the time of primary repair, there were 2 cases (28.6%) of bucket-handle tears, 3 cases (42.8%) of longitudinal tears, and 2 cases (28.6%) of complex tears. At the time of second arthroscopy, there were 3 cases (42.8%) of horizontal tears, 2 cases (28.6%) of complex tears, 1 case (14.3%) of longitudinal tears, and 1 case (14.3%) of longitudinal tears. The tear types changed between primary repair and second arthroscopy in 3 cases (42.9%). Partial meniscectomy was performed in all 7 patients (100%).

Comparison of preoperative and postoperative evaluation indexes between the repair group and the partial meniscectomy group

Compared with the partial meniscectomy group, the IKDC scores of the repair group increased significantly ($p = 0.031$). Other changes in evaluation indexes were not statistically significant (Table 4).

Comparison of preoperative and postoperative evaluation indexes between the failure group and the non-failure group

Except for preoperative IKDC scores ($p = 0.016$) and Lysholm scores ($p = 0.039$), no significant difference was observed in other scores between the 2 groups (Table 5). It can be concluded that no significant difference was observed in surgical outcomes between the failure and non-failure groups. Compared with the failure group, the IKDC scores of the non-failure group increased significantly ($p = 0.004$). Other changes in scores were not statistically significant (Table 5).

Outcomes of the second arthroscopic surgery in the failure group

All patients in the failure group were followed up for (30.3 ± 17.4) months after secondary partial meniscectomy. The mean postoperative Tegner score was 3.5 ± 1.64 (1–6). The mean time between the primary repair operation and the second operation was 32.4 months (range, 15–48 months). The outcomes of the second arthroscopy were satisfactory, and postoperative IKDC, Lysholm, and VAS scores significantly improved ($p < 0.05$). No significant difference was observed between preoperative and postoperative Tegner scores (Table 6).

Discussion

The main finding of this study is that meniscus repair performed during ACL reconstruction may fail, and that medial meniscus repair has a higher risk of failure. However, the secondary partial meniscectomy for retorn menisci can achieve satisfactory mid- and long-term clinical results.

Secondary injury to the meniscus is likely to occur after ACL injury. Through arthroscopy, Hagino et al.[12] found that meniscus tears occurred at a rate of 79.2% in all patients with ACL injuries and were more likely to occur during chronic injuries (more than 8 weeks) (84.8%). Therefore, the clinician has to decide the optimal strategy for managing a meniscal tear during ACL reconstruction. Options for management of a meniscal tear can be broadly classified into 3 categories: nonoperative, meniscal repair, and meniscectomy or partial meniscectomy.[5]

Table 1
Comparison of general data of patients.

Index	Failure group ($n = 7$)	Non-failure group ($n = 62$)	Test value	*p value*
Age (M (Q1, Q3), years)	22 (18, 33)	27 (21.5, 33.5)	$Z = -1.142$	0.253
Age (*n*, %)				0.030
<24 years	5 (71.4)	17 (27.4)		
≥24 years	2 (28.6)	45 (72.6)		
Sex (male/female)	5/2	42/20		1.000
Course of disease (M (Q1, Q3), months)	6 (1, 13)	2 (1, 8.5)	$Z = -0.652$	0.514
Height (mean ± SD, cm)	176.6 ± 9.24	173.34 ± 8.95	$t = -0.780$	0.438
Body weight (mean ± SD, kg)	71.80 ± 10.55	74.33 ± 13.42	$t = 0.410$	0.683
BMI index (mean ± SD, kg/m^2)	23.04 ± 3.00	24.65 ± 2.65	$t = 0.960$	0.341

BMI: body mass index.

Table 2
Injury-specific information and surgical details of the injured sides, *n* (%).

Index	Failure group ($n = 9$)	Non-failure group ($n = 71$)	*p* value
Type of meniscus tear			0.450
Longitudinal	3 (33.3)	38 (53.5)	
Horizontal	0	2 (2.8)	
Transverse	1 (11.1)	4 (5.6)	
Oblique	0	2 (2.8)	
Bucket-handle	2 (22.2)	5 (7.0)	
Complex	3 (33.3)	20 (28.2)	
Side of meniscus injury			0.154
Lateral	2 (22.2)	38 (53.5)	
Medial	7 (77.8)	33 (46.5)	
Position of meniscus injury			0.142
PH-MB-AH	1 (11.1)	2 (2.8)	
PH-MB	2 (22.2)	7 (9.9)	
PH	6 (66.7)	62 (87.3)	
Length of the lesion (M (Q1, Q3), mm)	20 (10, 20)	18 (15, 20)	1.000
Number of stitches (M (Q1, Q3), needle)	3 (2, 4)	2 (2, 3)	0.297

PH: posterior horn; MB: midbody; AH: anterior horn.

Table 3
Specific operation information of the second arthroscopy.

Patient no.	Time between two operations (months)	Cause of meniscus injury	Tear location	Primary tear type	Secondary tear type	Primary suture technique
1	20	Traumatic re-tear	Medial meniscus (MB + PH)	CT	CT	A-I (2x)
2	48	Traumatic re-tear	Medial meniscus (PH)	BH	HT	O-I (2x) A-I (2x)
3	15	Traumatic re-tear	Medial meniscus (MB + PH)	LT	CT	A-I (2x)
4	48	Traumatic re-tear	Medial meniscus (AH + MB + PH)	BH	BH	O-I (2x) A-I (2x)
5	48	Failed healing	Medial meniscus (PH)	LT	LT	O-I (2x) A-I (3x)
6	16	Traumatic re-tear	Medial meniscus (MB + PH)	LT	HT	A-I (3x)
7	32	Failed healing	Medial meniscus (MB + PH)	CT (HT + OT)	HT	A-I (1x)

MB: midbody; PH: posterior horn; CT: complex tears; BH: bucket-handle; HT: horizontal tears; LT: longitudinal tears; AH: anterior horn; OT: oblique tears; O-I: outside-in; A-I: all-inside.

Table 4
Comparison of preoperative and postoperative evaluation indexes, M (Q1, Q3).

Index	Repair group ($n = 69$)	Partial meniscectomy group ($n = 96$)	Test value	*p* value
Preoperative				
IKDC (mean ± SD)* score	49.98 ± 19.09	50.90 ± 17.02	$t = -0.299$	0.766
Lysholm score	61.50 (38.50, 74.75)	50.00 (35.00, 72.25)	$Z = -0.947$	0.344
VAS score	3.00 (2.00, 5.00)	3.00 (2.00, 5.00)	$Z = -0.836$	0.403
Tegner score	2.00 (1.00, 3.00)	2.00 (1.00, 4.00)	$Z = -0.436$	0.663
KT-2000 (mm)	4.49 (2.75, 5.36)	4.41 (2.60, 5.47)	Z = -0.334	0.738
Postoperative				
IKDC score	86.21 (79.30, 90.80)	85.06 (76.00, 90.80)	$Z = -0.659$	0.510
Lysholm score	95.00 (86.50, 100.00)	95.00 (84.00, 100.00)	$Z = -0.629$	0.529
VAS score	0 (0, 1.00)	0.50 (0, 2.00)	$Z = -0.923$	0.356
Tegner score	4.00 (3.00, 6.00)	3.00 (2.00, 6.00)	$Z = -0.106$	0.916
KT-2000 (mean ± SD, mm)*	0.74 ± 1.24	1.71 ± 2.34	t = -2.010	0.051
Increased IKDC score (mean ± SD)*	40.54 ± 25.10	31.63 ± 20.32	$t = 2.185$	0.031
Increased Lysholm scores	32.00 (15.00, 60.00)	36.00 (16.00, 60.50)	Z = -0.369	0.768
Decreased vas score	3.00 (1.00, 4.75)	2.00 (0, 4.00)	Z = -1.683	0.092
Increased Tegner score	1.00 (0, 3.00)	1.00 (0, 3.00)	Z = -0.295	0.768

IKDC: international knee documentation committee; VAS: visual analog scale.

Some researchers have suggested that the time for ACL reconstruction should be within 6 or 12 months to prevent the damage of the meniscus or cartilage.[13–16] After researching data from Korea and Japan, respectively, both Chung et al.[17] and Kawata et al.[18] have found that the proportion of meniscal repair showed a clear upward trend, indicating the recognition of the importance of preserving the meniscus. Phillips et al.[19] found that ACL reconstruction with simultaneous meniscectomy produced poorer clinical outcomes than ACL reconstruction alone, with no significant difference seen in the meniscus repair group. Through a follow-up of up to 25 years, Pernin et al.[20] also found a significant correlation between poor long-term outcomes during ACL reconstruction and medial meniscus resection. In this study, compared with in the partial meniscectomy group, the IKDC scores in the repair group increased more significantly ($p = 0.031$). Therefore, performing ACL reconstruction and meniscus repair as soon as possible is the key to improve knee function.

Table 5
Comparison of preoperative and postoperative evaluation indexes, M (Q1, Q3).

Index	Failure group ($n = 7$)	Non-failure group ($n = 62$)	Test value	p value
Preoperative				
IKDC (mean ± SD) score	65.02 ± 17.98	47.36 ± 17.77	$t = -2.482$	0.016
Lysholm score	77.00 (71.00, 80.00)	56.00 (37.00, 71.00)	$Z = -2.062$	0.039
VAS score	4.00 (1.00, 4.00)	3.00 (2.00, 5.00)	$Z = -0.826$	0.409
Tegner score	2.00 (0.00, 4.00)	2.00 (1.00, 3.00)	$Z = -0.691$	0.490
Postoperative				
IKDC score	82.76 (77.01, 90.80)	86.21 (79.30, 90.80)	$Z = -0.585$	0.559
Lysholm score	95.00 (88.00, 100.00)	95.00 (86.00, 100.00)	$Z = -0.270$	0.787
VAS score	1.00 (0, 4.00)	0 (0, 0)	$Z = -1.471$	0.141
Tegner score	4.00 (3.00, 7.00)	3.00 (3.00, 5.00)	$Z = -0.922$	0.356
KT-2000	0.75 (0.39, 2.26)	0.59 (−0.15, 1.48)	$Z = -0.671$	0.502
Increased IKDC score (mean ± SD)	15.40 ± 13.06	36.40 ± 17.49	$t = 3.046$	0.004
Increased Lysholm scores	15.00 (10.00, 26.00)	32.00 (19.00, 59.00)	Z = -1.908	0.056
Decreased vas score	1.00 (0, 4.00)	3.00 (1.00, 5.00)	Z = -1.622	0.105
Increased Tegner score	3.00 (1.00, 5.00)	1.00 (0, 3.00)	Z = -1.919	0.055

IKDC: international knee documentation committee; VAS: visual analog scale.

Table 6
Outcomes of second arthroscopy, M (Q1, Q3).

Time	IKDC score	Lysholm score	VAS score	Tegner (mean ± SD)* score
Preoperative	66.67 (54.02, 80.46)	81.00 (76.00, 95.00)	4.00 (2.00, 5.00)	3.50 ± 2.59
Postoperative	82.76 (81.61, 90.80)	100.00 (91.00, 100.00)	0 (0, 0)	3.50 ± 1.64
Test value	$Z = -1.992$	$Z = -1.997$	$Z = -2.226$	$t = 0.000$
p value	0.046	0.046	0.026	1.000

IKDC: international knee documentation committee; VAS: visual analog scale.

In the current study, the primary concurrent meniscus repair has been proved effectively, with low likelihood of need for subsequent surgery.[21–23] Taking into account the intra-articular hemorrhage caused by the surgically exposed tunnel and fibrin clot, meniscus repair with ACL reconstruction can achieve a more ideal healing rate.[24] Lyman et al.[25] and Saltzman et al.[26] have also shown that meniscus repair with simultaneous ACL reconstruction could achieve superior clinical outcomes and reduce the risk of failure of meniscus repair. The aforementioned researchers all recommend meniscus repair with simultaneous ACL reconstruction.[22,24–26]

Repaired menisci may not only promote the repair of ACL in the early stage and provide protection for the growth of ACL, but also prevent knee joint degeneration for a long time.[27] In this study, there was a trend towards better postoperative KT-2000 testing in the repair group than that in the partial meniscectomy group (Table 4), but the difference was not statistically significant. It might be related to the insufficient sample size in this group, but it has been shown that meniscus repair in the same period may bring better forward stability to the knee joint after ACL reconstruction. There was no significantly difference in postoperative KT-2000 test between the failure group and the non-failure group (Table 5), indicating that meniscus reinjury did not affect the stability of knee joint after reconstruction. In addition, in contrast to the research of Krych et al.,[10] who performed revision ACL reconstruction with simultaneous revision meniscus repair in 13 patients (38%), none of them in this study had ACL re-injury, which indicated that meniscus repair may improve the effect of ACL reconstruction.

The preoperative IKDC and Lysholm scores of the failure group were significantly higher than those of the non-failure group ($p < 0.05$). This may be due to the small sample size and the preoperative score has nothing to do with whether the meniscus repair ultimately failed. Consistent with the findings of Thaunat et al.,[28] no statistically significant difference was found in postoperative scores between the 2 groups in this study, which may indicate that no correlation exists between postoperative score and failure of meniscus suture. However, further studies are needed to confirm this. Although knee scores improved in both groups after the first operation, the improvement of IKDC scores in the non-failure group was more significant ($p < 0.05$), and the improvement of Lysholm scores ($p = 0.056$) and the reduction of VAS scores ($p = 0.105$) in the non-failure group were also greater than those in the failure group, which indicated that the recovery of the non-failure group was greater than that of the failure group. Overall, meniscal repair during ACL reconstruction can provide great benefits to patients.

In this study, 7 patients had secondary injury of the medial meniscus, but none of them had ACL re-injury. These patients had mechanical symptoms or signs. Markolf et al.[29] proved that the reconstructed ACL might withstand more stress than the natural ACL. In the present study, 31 of all patients (44.9%) and 3 in the failure group (42.9%) were treated with staples in ACL reconstruction, which could further strengthen the ACL. However, under physiologic stress, the meniscus bears more loads from the femur than from the articular cartilage, which may explain why the meniscus may re-tear even when the ACL is undamaged.

It has been reported that the rate of reoperation for medial meniscus repair is higher than that for lateral meniscus repair.[22] Lyman et al.[25] showed that patients undergoing isolated meniscal repairs (without concomitant ACL reconstruction) were at a decreased risk of subsequent meniscus resection if they had lateral meniscal injury ($p = 0.002$). In terms of the failure time, the failure of medial repair was earlier than that of lateral repair.[7] LaPrade et al.[30] found that compared with patients who underwent ACL reconstruction alone, patients with medial meniscus repair and simultaneous ACL reconstruction had considerably lower scores on the other symptoms and quality of life subscales of the postoperative knee injury and osteoarthritis outcome score scales. In this study, the failure of medial meniscus repair occurred in the failure group, whereas successful outcomes were obtained for lateral meniscus repair, which is consistent with the aforementioned results.

The reason for the higher risk of medial meniscus repair failure is related to biomechanics. In the finite element model established

by Zhang et al.,[31] the medial meniscus plays a much central role in load bearing than the lateral meniscus. If the medial meniscus tears longitudinally, the load distribution of the knee joint changes more obviously. The model constructed by Guess et al.[32] also confirmed that the PH region of the medial meniscus withstands much high contact force and hoop tension, which makes this region more susceptible to be injured, particularly with the loss of anterior tibia motion constraint provided by the ACL.

In a systematic review, Rothermel et al.[33] described that age is not a predictive factor for meniscal repair failure. Steadman et al.[34] conducted a retrospective study with a follow-up of at least 10 years, and they found that there was no difference in the failure rate of meniscus repair between patient ages under 40 years and over 40 years index surgery. However, some researchers have concluded that young age and high activity level of patients affect the outcomes of meniscus repair and increase the risk of repair failure.[23,25,28] In this study, the proportion of patients younger than 24 years old in the failure group was 71.4%, which was higher than that in the non-failure group (27.4%); this is consistent with the above results.

Frequent physical exercise is a risk factor for meniscus injuries and other types of knee injuries. Exercises often involve fatigue, and repetitive or acute injury on the knee joints. For example, when playing ball and performing gymnastic activities, the risk of meniscus lesions is high,[35] particularly for the medial meniscus.[36] In this study, the mean postoperative Tegner score in the failure group was (4.86 ± 2.85), which is higher than that in the non-failure group (3.88 ± 1.84). In 5 patients (71.4%), a traumatic re-tear was the reason for partial meniscectomy. Traumatic re-tear occurred in 2 patients (40%) during exercises and in 3 patients (60%) during activities of daily living. Healing failure (biologic failure) was considered the main reason for partial meniscectomy in 2 patients (17%). Hupperich et al.[23] studied the effect of suture on the tear of the meniscus barrel handle. They found that the higher the activity level, the greater the possibility of the meniscus tearing again, which is consistent with the results of this study.

Kalliakmanis et al.[24] found that the location and length of the tear, and the age of patient did not affect clinical outcomes. Perdue et al.[37] reported that the length of the meniscal tear had no effect on clinical outcomes, which is consistent with the results of this study. Our study also found that meniscus tear type and the number of stitches had no effect on clinical outcomes.

Clinical signs of meniscus repair failure include swelling of the joint, tenderness at the joint line, locked-in syndrome and positive McMurray's sign. Arthroscopy is the gold standard for the diagnosis of meniscal injury.[9] According to the second arthroscopic evaluation criteria established by Morgan et al.,[38] when an unstable meniscus fragment is torn again at the original repair site or the meniscus material is torn again in an area different from the original repair site, the repaired site was graded as “unhealed”. Preoperative MRI can effectively determine the extent of re-tear or healing failure (Fig. 1).[39] If a patient had a previous sports injury, a traumatic re-tear of the meniscus might occur, or the meniscus might fail to heal.

The average time between the first meniscus repair and the second arthroscopic operation was 32.4 months (range, 15–48

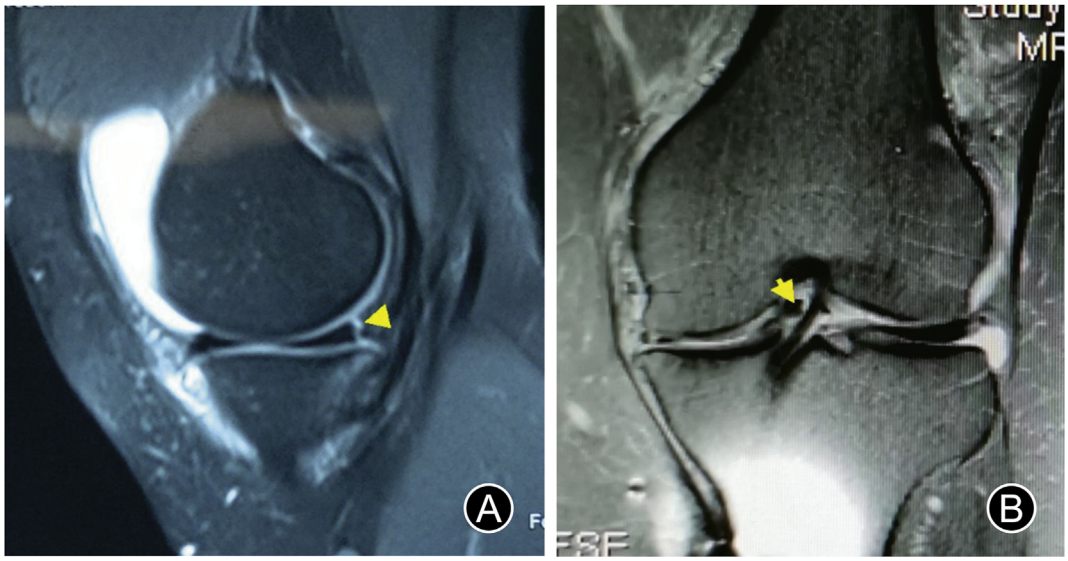

Fig. 1. MRIs of a patient in the failure group. (A) The MRI before primary repair revealed a longitudinal tear in the red area of the medial meniscal posterior horn (triangle). (B) The MRI before second arthroscopy revealed a bucket-handle tear of the medial meniscus (arrow). The right black stripe is the reconstructed ACL.

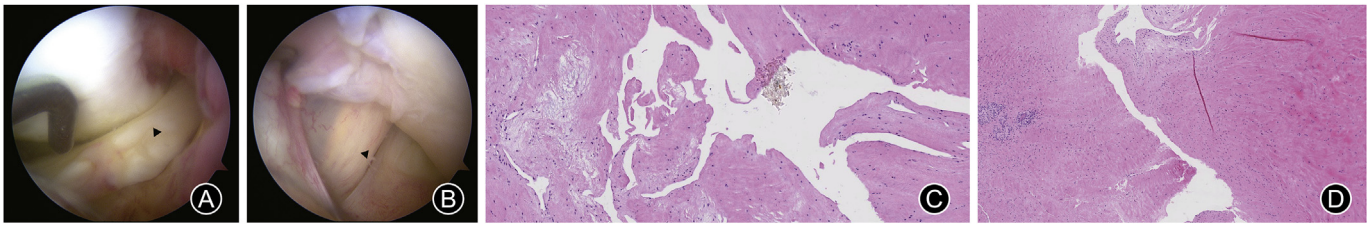

Fig. 2. A second arthroscopic examination revealed: (A) a bucket-handle tear in the medial meniscus (triangle); (B) the ACL healed well (triangle); (C) mucinous changes and (D) small vessel proliferation.

months). Arthroscopy revealed that the second suture of the original repaired site of the meniscus was not feasible because of its poor texture and deep tear (Fig. 2A). However, the reconstructed ACL graft shape was complete and continuous, the vascularized surface synovium was intact, and the tension was normal (probe exploration shows), and no cyclops or cyclops-like lesions were detected, which indicate the ACL was healed well (Fig. 2B). According to the previous pathological studies on meniscus injury, because of the mechanism of autophagy, apoptosis and calcification, etc., the degree of meniscus degeneration will deepen and the rate of healing will gradually decrease as the injury time prolonging.[40,41] This was also observed in our study, where pathology of a retorn meniscus in one of the patients revealed mucinous changes (Fig. 2C) and small vessel proliferation (Fig. 2D) in the meniscus. To avoid a third operation, the meniscus was partially resected in all patients.

Seven patients were followed up after the second arthroscopy. The follow-up results showed that the operation outcomes were optimal. The postoperative IKDC score, Lysholm score and VAS score significantly improved ($p < 0.05$). Therefore, the second arthroscopic operation after meniscus repair failure could effectively solve the problem of meniscus tears. Both Krych et al.[10] and Fuchs et al.[11] have achieved optimal clinical results with revision repairs of failed menisci but with the failure rates of 21% and 25%, respectively. In our study, during the mean follow-up period of 28 months (range, 4–65 months) after the reoperation, the knee function of all patients was significantly improved, indicating that the partial meniscectomy of reinjured menisci is also an alternative strategy that can achieve satisfactory midterm and long-term results. Regarding the possible adverse effects of partial meniscectomy, long-term observation is required.

This study has several limitations. First, the sample size was small, which limits the overall validity of our results. Second, not all patients underwent second arthroscopy, and thus the actual failure rate of meniscal repair might have been higher. Third, the study did not include a control group, and it could not be determined whether partial meniscectomy is more effective than revision repair in case of the repair failure. Fourth, the 7 patients with repair failure should be observed or followed up for a longer time after the second arthroscopy.

The failure rate of meniscus repair in these patients was 10.1% (7/69), all of which were medial meniscus tears. However, the surgical outcomes of ACL reconstruction were not affected, and there might be a role for graft protection. Therefore, the meniscus problem can be solved after secondary arthroscopic surgery in patients with repair failure.

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Ethical statement

All study procedures were reviewed by the Peking University Third Hospital Medical Science Research Ethics Committee.

Declaration of competing interest

The authors have no conflicts of interest to declare.

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Author contributions

Conception and design: Yu-Ping Yang, Xiao Ma; Collection and assembly of data: Yu-Ping Yang, Xiao Ma, Hua An; Data analysis and interpretation: Yu-Ping Yang, Xiao Ma; Manuscript writing: All authors; Final approval of manuscript: All authors.

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