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Female gender and medial meniscal lesions are associated with increased pain and symptoms following anterior cruciate ligament reconstruction in patients aged over 50 years

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Abstract

Purpose Several studies report satisfactory clinical outcomes following ACLR in older patients, but none evaluated the effects of meniscal and cartilage lesions. The aim was to evaluate the influence of meniscal and cartilage lesions on outcomes of ACLR in patients aged over 50 years.

Methods The authors prospectively collected records of 228 patients that underwent primary ACLR, including demographics, time from injury to surgery, whether injuries were work related, and sports level (competitive, recreational, or none). At a minimum follow-up of 6 months, knee injury and osteoarthritis outcome scores (KOOS), International Knee Documentation Committee (IKDC) score and Tegner activity level were recorded, and differential laxity was measured as the side-to-side difference in anterior tibial translation (ATT) using instrumented laximetry devices. Regression analyses were performed to determine associations between outcomes and meniscal and cartilage lesions as well as nine independent variables.

Results A total of 228 patients aged 54.8 ± 4.3 years at index ACLR were assessed at a follow-up of 14.3 ± 3.8 months. KOOS subcomponents were 85 ± 13 for symptoms, 91 ± 10 for pain, 75 ± 18 for daily activities, 76 ± 18 for sport, and 88 ± 12 for quality of life (QoL). The IKDC score was A for 84 (37%) knees, B for 96 (42%) knees, C for 29 (13%) knees, and D for 8 (4%) knees. Tegner scores showed a decrease (median 0, range −4 to 4) and differential laxity also decreased (median − 4, range − 23.5 to 6.0). KOOS symptoms worsened with higher BMI ($p = 0.038$), for women ($p = 0.007$) and for knees that had medial meniscectomy ($p = 0.029$). KOOS pain worsened with higher BMI ($p \leq 0.001$), for women ($p = 0.002$) and for knees with untreated ($p = 0.047$) or sutured ($p = 0.041$) medial meniscal lesions. Differential laxity increased with follow-up ($p = 0.024$) and in knees with lateral cartilage lesions ($p = 0.031$).

Conclusion In primary ACLR for patients aged over 50 years, female gender and medial meniscal lesions significantly compromised KOOS symptoms and pain, while lateral cartilage lesions significantly increased differential laxity. Compared to knees with an intact medial meniscus, those with sutured or untreated medial meniscal lesions had worse pain, while those in which the medial meniscus was resected had worse symptoms. These findings are clinically relevant as they could help surgeons with patient selection and adjusting expectations according to their functional demands.

Level of evidence III.

Keywords ACL reconstruction · Anterior cruciate ligament · Meniscus · Cartilage

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Introduction

With an annual incidence of isolated anterior cruciate ligament (ACL) tears of 68.6 per 100,000 person-years [25], those injured may have to give up strenuous sports, reduce their workload, or adopt a sedentary lifestyle. Better life expectancy and health conditions allow a greater proportion of middle-aged individuals to participate in physically demanding sports [6, 9], which increases the risks of ACL injuries [11, 14].

Anterior cruciate ligament reconstruction (ACLR) has become a reliable procedure with excellent outcomes in young patients [3, 10, 11, 14, 16, 21], but has less consistent outcomes in middle-aged patients, who tend to have more concomitant or degenerative lesions. Conservative treatment is therefore sometimes preferred in patients aged over 50 years, especially those with low functional demands, mainly due to fear of poor surgical outcomes [9]. Chronic ACL deficiency is however known to increase risks of residual instability, cartilage injuries, irreparable meniscal tears, and development of arthritis [13, 29]. For those reasons, patients aged over 50 years who want to maintain an active lifestyle increasingly opt for ACLR, to prevent anatomical and functional decline [27, 31]. Recent studies have also suggested that ACLR offers greater improvements in quality-adjusted life years than conservative treatments [6, 19].

Numerous studies have reported satisfactory clinical outcomes following ACLR in older patients [7, 14, 17, 21, 31]. It remains unclear, however, whether and to what extent concomitant meniscal and cartilage lesions affect clinical outcomes of ACLR in older patients, both of which are clinically relevant to patient selection and adjustment of expectations. The purpose of this study was therefore to evaluate the influence of meniscal and cartilage lesions on outcomes of ACLR in patients aged over 50 years. The hypothesis was that meniscal and cartilage lesions significantly compromise clinical outcomes in this age group.

Materials and methods

This study was approved by the institutional review board in advance (Conseil d'Orientation Scientifique Ramsay Santé, COS-RGDS-2019-12-002-DEJOUR-D). The authors prospectively collected the records of 228 patients that underwent primary ACLR between April 2015 and November 2017 by ten surgeons at ten centers (SFA symposium 2018). The inclusion criteria were (i) primary ACLR in (ii) patients aged over 50 years. The exclusion criteria were (iii) severe concomitant ligament injury (grade 3), (iv) tibiofemoral osteoarthritis visible on weight-bearing anteroposterior and/or sagittal radiographs (> 50% joint space narrowing), and (v) history of intra- or extra-articular ligament surgery in either knee. All patients provided written informed consent for the use of their data and images for research and publication.

Preoperative assessment

Patient demographics were collected, as well as time from injury to surgery, whether injuries were work related, and sports level (competitive, recreational, or none). The knee injury and osteoarthritis outcome scores (KOOS) with five subcomponents (symptoms, pain, daily activities, sport and quality of life) [23] were recorded, as well as the International Knee Documentation Committee (IKDC) functional score [12], and Tegner activity score [30]. Differential laxity was measured with an accuracy of 0.1 mm as the side-to-side difference in anterior tibial translation (ATT) using instrumented laximetry devices (TelosTM stress radiography, GNRB, or KT1000).

Surgical technique

All operations were performed under general anesthesia with a tourniquet placed high on the thigh. The autograft was harvested either from the patellar tendon (PT) using the Kenneth-Jones technique or the hamstrings tendon (HT) including the semitendinosus and gracilis. The choice of graft was discussed with the patients, considering their type of sport and type of work. Meniscal lesions were diagnosed by direct vision intraoperatively and sutured, resected or left untreated. An extra-articular Lemaire procedure was performed for knees with clunk or gross pivot shift or > 20° genu recurvatum.

Postoperative rehabilitation

Progressive, non-aggressive rehabilitation was engaged immediately after surgery, avoiding hyperextension, but with no restriction of flexion. Partial weight-bearing (50% body weight) was allowed during the first 3 postoperative weeks, and progressive full weight-bearing was allowed between 3 and 6 weeks. The rehabilitation protocol was identical at all centers, irrespective of whether patients received meniscal treatment or extra-articular procedures. Cycling and swimming were allowed after 6 weeks, and return to sports began at 6–8 months.

Postoperative assessment

Length of hospital stay as well as any complications were recorded. Patients underwent clinical and radiographic examination after a minimum of 6 months, during which the KOOS, IKDC scores, Tegner scores, differential laxity, as well as time to return to sport and work were recorded. Psychological aspects of sports recovery were evaluated with the anterior cruciate ligament-return to sport after injury (ACL-RSI) scale [4], which assesses apprehension felt during sport activities.

Statistical analysis

The Shapiro–Wilk test was used to check normality of distributions. Continuous variables were compared using non-parametric Spearman correlations or Mann–Whitney *U* tests with Bonferroni correction. Kruskall–Wallis tests were used when comparing three or more groups. For categorical variables, significance of differences among groups was determined using Chi-square tests or Fisher exact tests. As the study was not designed to compare pre-determined groups, a priori power analysis was not performed. Post hoc analysis indicated that 45 patients per group were needed to detect a minimal clinically important difference in KOOS subcomponents of 8–10 points [22], with a standard deviation (SD) of 14 and a statistical power of 0.85. Univariable linear regression analyses were performed to determine associations of three continuous outcomes (KOOS symptoms, KOOS pain, and postoperative differential laxity) with 14 independent variables (gender, age, BMI, follow-up, sports level, time from injury to surgery, preoperative laxity, adjuvant Lemaire procedure, medial meniscal lesion, lateral meniscal lesion, medial cartilage lesion, lateral cartilage lesion, patella cartilage lesion, medial meniscal treatment, and lateral meniscal treatment). Multivariable linear regression analyses were performed for the same outcomes and variables excluding the presence of meniscal lesions due to excessive collinearity with meniscal treatment. Models were deemed sufficiently powered, considering the recommendations of Austin and Steyerberg of two subjects per variable [1]. Statistical analyses were performed using R version 3.5.2 (R Foundation for Statistical Computing, Vienna, Austria). p values < 0.05 were considered statistically significant.

Table 1 Patients demographics

	Cohort	
	Mean ± SD	(Range)
Age at surgery (years)	54.8 ± 4.3	(50–72)
BMI (kg/m^2)	24.0 ± 3.6	(17–36)
Time from injury to surgery (months)	23.6 ± 59.0	(0.3–414)
Sex		
Men	94 (41%)	
Women	134 (59%)	
Work accident	14 (6%)	
Sports level		
Competitive	18 (8%)	
Recreational	192 (84%)	
None	18 (8%)	

Results

Demographics

All 228 patients were assessed at a follow-up of 14.3 ± 3.8 months (range 6–30) (Table 1). The cohort was aged 54.8 ± 4.3 years (range 50–72) at index ACLR and comprised 94 (41%) men and 134 (59%) women.

Intraoperative data

Intraoperative diagnosis revealed that meniscal lesions were present in 154 (68%) knees, while cartilage lesions were found in 128 (56%) knees (Table 2). Medial and lateral meniscal lesions were, respectively, left untreated in 17 and 29 knees, sutured in 25 and 16 knees, whereas meniscectomies were performed in 87 and 26 knees (Fig. 1).

Clinical outcomes

Early complications occurred in 34 knees (14.8%), 1 (0.4%) of which required reoperation (Table 3). Late complications occurred in 33 knees (14.5%), 20 (8.8%) of which required reoperation.

At last follow-up, KOOS subcomponents, IKDC, ACL-RSI, Tegner activity level, and differential laxity (ATT) improved significantly (Table 4). No significant differences were noted in KOOS pain or symptoms subcomponents among patients that received HT versus BPTB autografts. Compared to the 180 patients evaluated at ≥ 1 year, the 48 patients evaluated at < 1 year had significantly higher KOOS sport and QoL (Table 5).

Table 2 Intraoperative data

	Cohort	
	$n=228$	
	n	(%)
Meniscal lesions		
None	74	(32%)
Isolated medial	83	(36%)
Isolated lateral	25	(11%)
Bicompartmental	46	(20%)
Cartilage lesions		
None	100	(44%)
Isolated medial	40	(18%)
Isolated lateral	7	(3%)
Isolated patellar	22	(10%)
Multi-compartmental	59	(26%)
Medial meniscal treatment		
Lesion untreated	17	(7%)
Resected/prior meniscectomy	87	(38%)
Sutured	25	(11%)
Lateral meniscal treatment		
Lesion untreated	29	(13%)
Resected/prior meniscectomy	26	(11%)
Sutured	16	(7%)
Extra-articular tenodesis (Lemaire)	37	(16%)
Graft type		
Hamstring tendon	197	(86%)
Patellar tendon	31	(14%)
Femoral fixation		
Cortical (endobutton)	135	(59%)
Screw	76	(33%)
Pressfit	17	(7%)
Tibial fixation		
Screw	190	(83%)
Cortical (endobutton)	38	(17%)

Effects of meniscal and cartilage lesions

The KOOS symptoms subcomponent was significantly worse for knees with medial (82.9 ± 12.6, $p=0.009$) and bicompartmental (82.8 ± 14.1 $p=0.012$) meniscal lesions compared to knees with no meniscal lesions (89.2 ± 11.5) (Fig. 2). The KOOS pain subcomponent was also significantly worse for knees with medial meniscal lesions (84.9 ± 13.3, $p=0.004$) compared to knees with no meniscal lesions (91.2 ± 9.6). The KOOS daily activities, sport, and QoL subcomponents were not significantly affected by meniscal lesions. There were no significant differences in any of the KOOS subcomponents among knees with meniscal lesions, regardless whether theyremained untreated, or were resected or sutured (Fig. 3).

The KOOS symptoms subcomponent was significantly worse for knees with multi-compartmental cartilage lesions (82.9 ± 13.9, $p=0.001$) compared to knees with no cartilage lesions (87.9 ± 11.6) (Fig. 4). By contrast, none of the other KOOS subcomponents were significantly affected by the presence of cartilage lesions.

Multivariable analysis

Adjusting for confounding variables, the KOOS symptoms subcomponent was worse for women ($p=0.007$), for patients with higher BMI ($p=0.038$), and in knees where medial meniscal lesions were resected ($p=0.029$) or sutured ($p=0.048$) (Table 6). Similarly, the KOOS pain subcomponent was worse for women ($p=0.002$), for patients with higher BMI ($p \leq 0.001$), and in knees where medial meniscal lesions were left untreated ($p=0.047$) or sutured ($p=0.041$) (Table 7). Finally, differential laxity increased with follow-up ($p=0.024$) and in knees with lateral cartilage lesions ($p=0.031$) (Table 8). It is worth noting that of the 151 knees with medial cartilage lesions, 100 (66%) had concomitant medial meniscal lesions, and of the 93 knees with lateral cartilage lesions, 53 (57%) had concomitant lateral meniscal lesions (Fig. 5).

Discussion

The most important finding of this study is that in primary ACLR for patients aged over 50 years, female gender and medial meniscal lesions significantly compromise KOOS symptoms and pain, while lateral cartilage lesions significantly increase differential laxity. While the differences in KOOS subcomponents did not reach the minimal clinically important difference (MCID) of 8–10 points [22], nor did the differences in laxity exceed 1 mm, the presence of a medial meniscal lesion in combination with another significant risk factor such as female gender or excess weight exceeded the MCID. These trends confirm the hypothesis that meniscal and cartilage lesions significantly compromise the clinical outcomes of ACLR in this age group. These findings are clinically relevant, as they could help surgeons with patient selection and adjusting expectations.

The present findings suggest that female gender and medial meniscal lesions are associated with worse KOOS symptoms and pain subcomponents, whereas lateral meniscal lesions had no effect on any of the KOOS subcomponents. This is in partial agreement with Cox et al. [8], who found worse scores for all KOOS subcomponents following ACLR in young patients with medial meniscal lesions, whereas lateral meniscal lesions were found to have no effect. The differences in constraints and mobility of the two menisci may explain why medial lesions are associated with

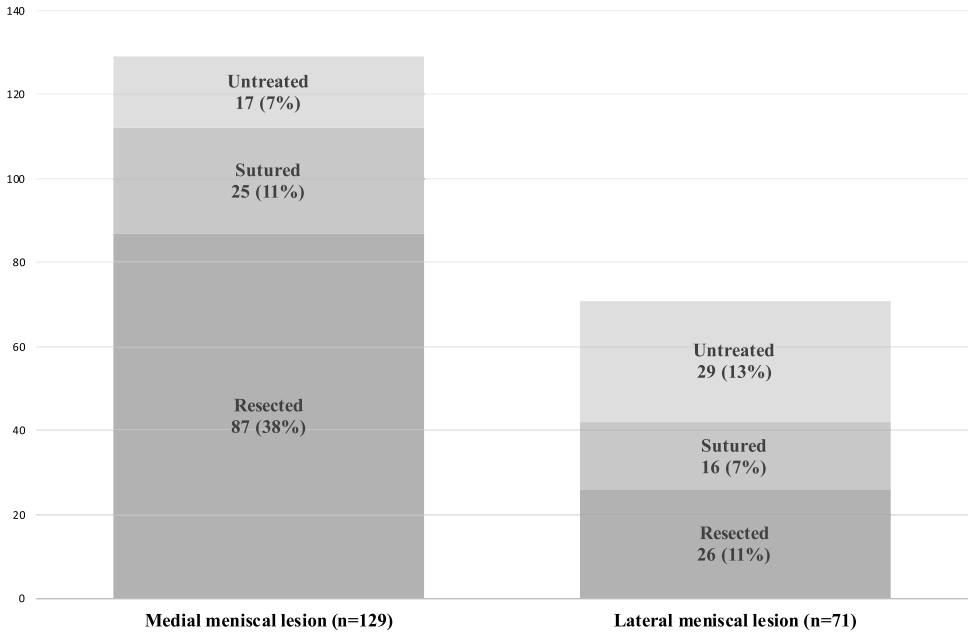

Fig. 1 Of the 228 knees, 129 had medial meniscal lesions (87 resected, 25 sutured, and 17 untreated) and 71 had lateral meniscal lesions (26 resected, 16 sutured, and 29 untreated). It is worth noting that 46 knees had bicompartmental meniscal lesions, while 83 had isolated medial meniscal lesions, and 25 had isolated lateral meniscal lesions. All percentages calculated using the same denominator of 228 knees

Table 3 Postoperative complications

	Cohort	
	$n = 228$	
	n	(%)
Early complications (< 1 month)		
Reoperated		
Hematoma	1	(0.4%)
Non reoperated		
Hematoma	19	(8.3%)
Pain (> 6 on VAS)	14	(6.1%)
Late complications (> 1 month)		
Reoperated		
Pain (> 6 on VAS)	6	(2.6%)
Flexion stiffness	5	(2.2%)
Extension stiffness	4	(1.8%)
Unstable meniscal lesion	3	(1.3%)
Traumatic re-tear	2	(0.9%)
Non reoperated		
Patellar syndrome	6	(2.6%)
Reflex sympathetic dystrophy	3	(1.3%)
Donor site pain	3	(1.3%)
Persistent swelling	1	(0.4%)

more symptoms and pain than lateral lesions [28].Furthermore, Capogna et al. [5] reported that female gender is a risk factor for reoperation following ACLR.

The outcomes of ACLR in knees with medial meniscal lesions could leave surgeons in a dilemma, whether to leave the meniscus untreated, or to suture or resect it. Compared to knees with intact medial menisci, those with sutured or untreated medial meniscal lesions had significantly worse pain, while those in which the medial meniscus was resected had significantly worse symptoms. The differences in pain and symptoms were not significant, however, among the subgroup of patients that had meniscal lesions that were either sutured, resected or left untreated. Therefore treating the medial meniscus and trying to preserve it could leave some residual pain, compared to knees with no medial meniscal lesions, but could improve control of laxity. In the light of these results, it seems important to consider the individual characteristics and functional demands of each patient when deciding how to manage medial meniscal lesions, as pain can compromise satisfaction and function, while symptoms can increase risks of graft failure and degenerative decline. It has been reported that a partial meniscectomy at the time of ACLR could be a risk factor for the progression of chondral lesions [20]. Furthermore, the present findings corroborate those of Cox et al. [8] in a younger cohort, as well as those of the Swedish National Knee Ligament Register [2], which reported medial meniscal repair to be a risk for "treatment failure" (KOOS QoL < 44). In addition, a recent systematic review reported that ACLR with adjuvant meniscectomy results in better KOOS symptoms compared to ACLR with adjuvant meniscal repair [26].

The outcomes of ACLR in knees with lateral cartilage lesions were not different to those with no cartilage lesions, but had significantly greater differential laxity. It is worth noting that 66% of the knees with medial cartilage lesions had concomitant medial meniscal lesions, and 57% of the knees with lateral cartilage lesions had concomitant lateral meniscal lesions. Univariable analyses also revealed that

Table 4 Postoperative complications

	Preoperative			Postoperative			Net change		
	Mean ± SD	Median	(Range)	Mean ± SD	Median	(Range)	Mean ± SD	Median	(Range)
Length of hospital stay (days)				1.1 ± 1.3		(0–15)			
Follow-up (months)				14.3 ± 3.8		(6–30)			
Days before return to									
Sport				266.8 ± 107.4		(26–651)			
Work				106.9 ± 108.7		(7–518)			
KOOS (0–100)									
Symptoms	63 ± 20	64	(0–100)	85 ± 13	88	(38–100)	22 ± 23	21	(− 39 to 79)
Pain	61 ± 20	65	(6–100)	88 ± 12	91	(39–100)	26 ± 23	22	(−33 to 94)
Daily activities	67 ± 21	72	(0–100)	91 ± 10	94	(44–100)	24 ± 24	20	(−29 to 100)
Sport	34 ± 20	35	(10–100)	75 ± 18	77	(10–100)	40 ± 26	40	(− 50 to 100)
Quality of life	35 ± 21	31	(0–100)	76 ± 18	76	(0–100)	42 ± 26	44	(− 32 to 100)
Tegner score (1–9)	5.2 ± 2	6	(2–9)	4.9 ± 1.6	5	(1–9)	− 0.3 ± 1.2	0	(− 4 to 4)
Differential laxity (ATT) (mm)	6.5 ± 3	6	(2–18)	2.2 ± 2.4	2	(6–13)	− 4.2 ± 3.9	-4	(− 24 to 6)
ACL RSI (0–100)	25 ± 20	28	(0–82)	71 ± 20	73	(0–100)	46 ± 29	43	(−20 to 100)
IKDC score									
A	0 (0%)			84 (37%)					
B	13 (6%)			96 (42%)					
C	111 (49%)			29 (13%)					
D	104 (46%)			8 (4%)					

Table 5 Comparison of postoperative outcomes between patients with < 1 year vs ≥ 1 year of follow-up

	< 1 year ($n = 48$)			≥ 1 year (n = 180)			p value[a]
	Mean ± SD	Median	(Range)	Mean ± SD	Median	(Range)	
Age at surgery (years)	54.6 ± 4.0	53	(50–66)	55.0 ± 4.4	54	(50–72)	n.s
KOOS (0–100)							
Symptoms	86 ± 14	90	(38–00)	84 ± 13	86	(43–100)	n.s
Pain	89 ± 14	94	(47–100)	87 ± 12	89	(39–100)	n.s
Daily activities	91 ± 9	94	(65–100)	91 ± 10	94	(44–100)	n.s
Sport	78 ± 18	80	(25–100)	74 ± 18	75	(10–100)	0.044
Quality of life	82 ± 18	88	(19–100)	75 ± 18	75	(0–100)	0.008
Tegner score (1–9)	4.7 ± 2	5	(2–9)	5.0 ± 1.5	6	(1–9)	n.s
Differential laxity (ATT) (mm)	2.2 ± 2	2	(−1 to 9)	2.2 ± 2.4	2	(−6 to 13)	n.s
ACL RSI (0–100)	69 ± 21	72	(3–100)	71 ± 19	75	(0–100)	n.s
IKDC score							n.s
A	20 (42%)			63 (35%)			
B	15 (31%)			81 (45%)			
C	8 (17%)			21 (12%)			
D	2 (4%)			6 (3%)			

[a]Mann-Withney *U*-test test for continuous outcomes and Chi-squared test for categorical outcomes

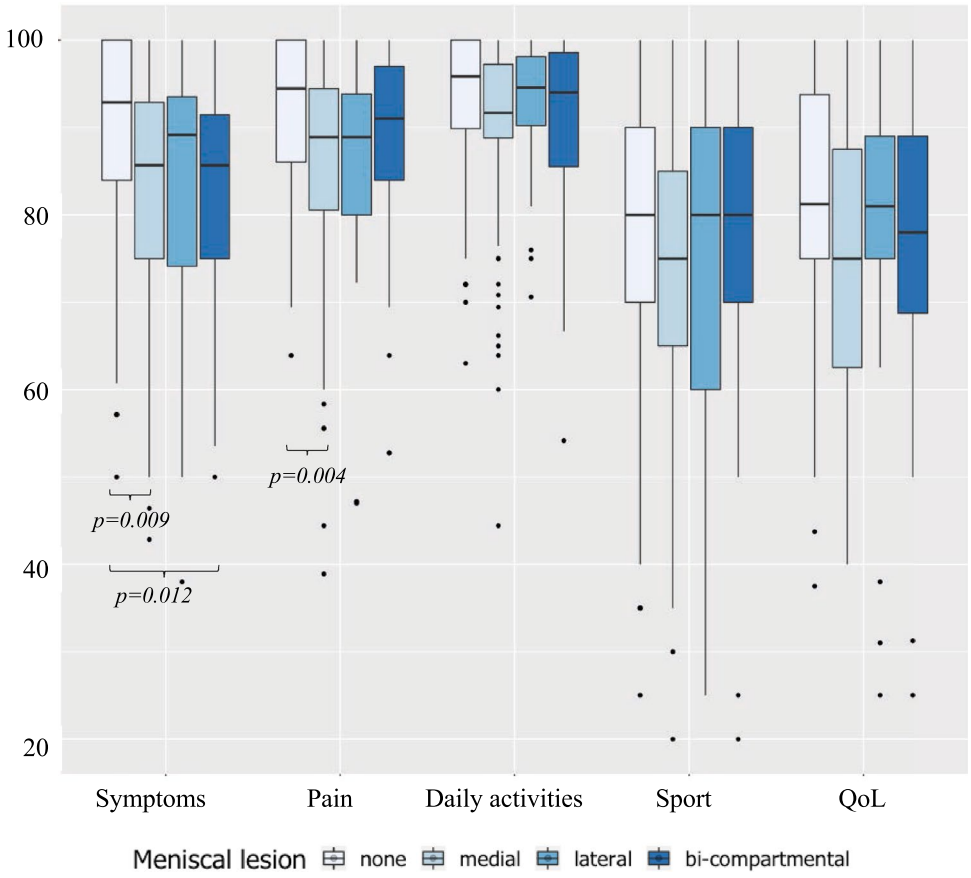

Fig. 2 The KOOS symptoms subcomponent was significantly worse for knees with medial and bicompartmental meniscal lesions compared to knees with no meniscal lesions. The KOOS pain subcomponent was also significantly worse for knees with medial meniscal lesions compared to knees with no meniscal lesions. The KOOS daily activities, sport, and QoL subcomponents were not significantly affected by meniscal lesions

multi-compartmental cartilage lesions affected KOOS symptoms. Røtterrud et al. [24] found that full-thickness cartilage lesions impair all KOOS subcomponents in patients aged 30.4 ± 7.0. These findings are not directly comparable to the present series in which the patients were on average 24 years older, and for which the grades and sizes of cartilage lesions

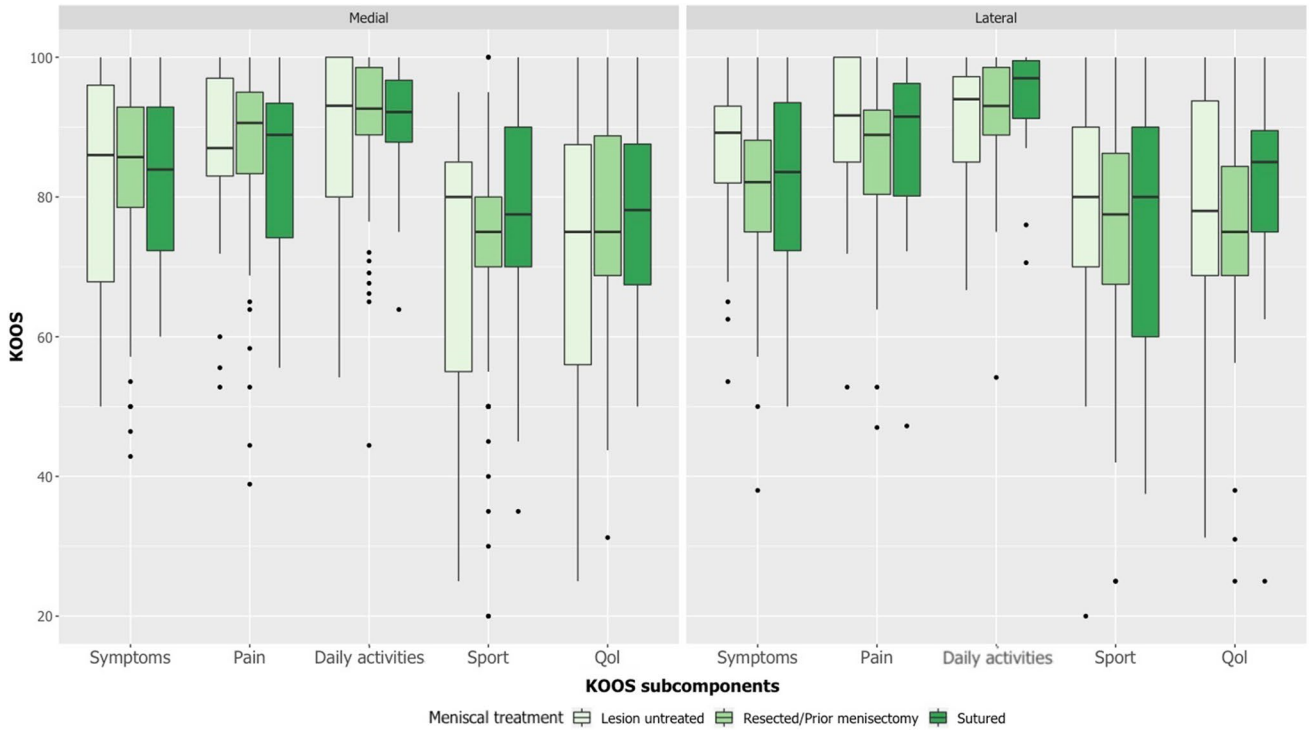

Fig. 3 There were no significant differences in any of the KOOS subcomponents among knees with meniscal lesions, regardless of whether they remained untreated, or were resected or sutured

were not documented. In a recent study, Marot et al. [18] reported KOOS subcomponents for different age groups of healthy asymptomatic volunteers, and found similar values in patients aged 55–64 years in comparison to the values reported in the present study (< MCID [22]). In addition, Costa et al. [7] found that a chronological age over 50 years should not be a contraindication for surgery as physiological age, clinical symptoms, and functional requests are more important in considering ACLR. In the present study, IKDC increased significantly after ACLR in patients aged over 50 years, which is in agreement with Osti et al. [21] who reported 85% of a similarly aged cohort scoring either A or B at a minimum follow-up of 2 years. In addition, Tegner activity scores decreased, with postoperative values comparable to those reported for similarly aged cohorts by Iorio et al. [11], and Cinque et al. [6]. Finally, ATT was successfully reduced, which is also in agreement with Toanen et al. [31]. Graft failure rates (0.9%) were lower in comparison to both Osti et al. [21] (5%) and Dahm et al. [9] (8.6%).

The results of the present study must be interpreted with the following limitations in mind. First, this was a retrospective study that included ten surgeons from ten centers, which may have introduced multiple confounding factors. Therefore, the surgical techniques were not consistent, and the use of three different laximetry devices may introduce bias [15], though this heterogeneity was limited by reporting side-to-side differences. Second, while the short minimum follow-up of 6 months is relevant for return to sports, it is insufficient to confirm that outcomes are maintained in the long term, which would also require radiographic assessment to monitor potential arthritic degeneration. Finally, the types, sizes and locations of meniscal and cartilage lesions were not considered, when these are known to have variable effects on choice and outcome of meniscal treatment. Nevertheless, the present series is one of the largest cohorts of ACLR in older patients, which enabled detailed analysis of independent variables that could improve or compromise outcomes. The clinical relevance of the present findings is that ACLR in patients aged over 50 years who wish to resume physical activity renders satisfactory outcomes, which may be compromised by the presence of medial meniscal lesions or lateral cartilage lesions.

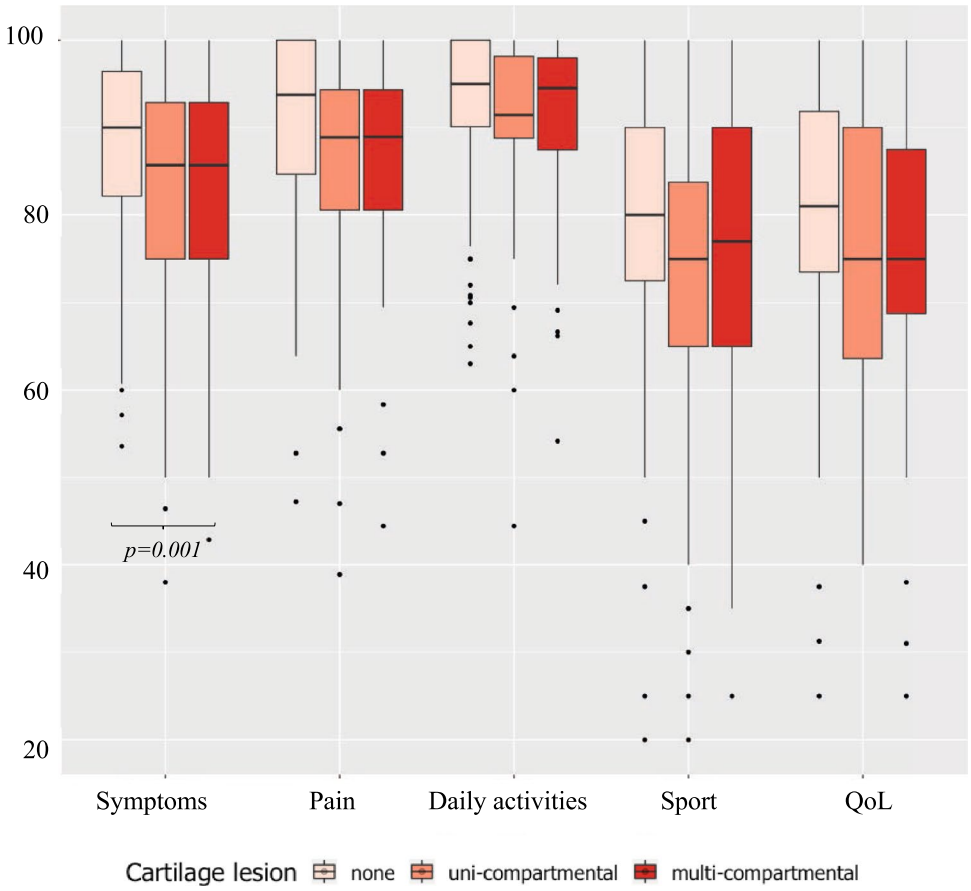

Fig. 4 The KOOS symptoms subcomponent was significantly worse for knees with multi-compartmental cartilage lesions compared to knees with no cartilage lesions. By contrast, none of the other KOOS subcomponents were significantly affected by the presence of cartilage lesions

Conclusion

In primary ACLR for patients aged over 50 years, female gender and medial meniscal lesions significantly compromised KOOS symptoms and pain, while lateral cartilage lesions significantly increased differential laxity. Compared to knees with an intact medial meniscus, those with sutured or untreated medial meniscal lesions had worse pain, while those in which the medial meniscus was resected had worse symptoms. These findings could help surgeons with patient selection and adjusting expectations according to their functional demands.

Table 6 Uni- and multi-variable regression analysis to identify factors associated with post-operative KOOS symptoms

	Univariable ($n=228$)				Multivariable ($n=210$)		
	$n=$	β (pts)	95% C.I	p value	β (pts)	95% C.I	p value
Female sex	134	− 3.7	(− 7.3 to − 0.1)	*0.047*	− 6.4	(− 10.9 to − 1.9)	*0.005*
Age (years)		− 0.0	(− 0.4 to– 0.4)	n.s	− 0.0	(− 0.4 to − 0.4)	n.s
BMI (kg/m^2)		− 0.4	(− 1.0 to – 0.1)	n.s	− 0.6	(− 1.2 to − 0.0)	*0.037*
Follow-up (months)		0.1	(− 0.4 to – 0.6)	n.s	0.2	(− 0.3 to − 0.7)	n.s
Sports level							
Competitive	18	2.5	(− 4.1 to – 9.0)	n.s	0.5	(− 6.5 to − 7.6)	n.s
Recreational	192	REF			REF		
None	18	− 0.6	(− 7.7 to – 6.6)	n.s	− 2.4	(− 10.1 to − 5.3)	n.s
Time from injury to surgery (months)		0.0	(− 0.0 to – 0.1)	n.s	0.0	(− 0.0 to − 0.1)	n.s
Pre-operative differential laxity (mm)		0.1	(− 0.5 to – 0.6)	n.s	0.3	(− 0.3 to − 0.9)	n.s
Adjuvant Lemaire procedure		− 2.0	(− 7.0 to – 3.0)	n.s	− 2.6	(− 8.0 to − 2.8)	n.s
Meniscal lesion[a]							
None	74	REF					
Medial[b]	129	− 4.7	(− 8.3 to − 1.1)	*0.010*			
Lateral[c]	71	− 3.0	(− 6.9 to – 0.9)	n.s			
Cartilage lesion							
None	100	REF			REF		
Medial[d]	99	− 3.0	(− 6.6 to – 0.6)	n.s	− 2.3	(− 6.5 to − 1.9)	n.s
Lateral[e]	66	− 2.5	(− 7.0 to – 1.9)	n.s	− 0.5	(− 6.1 to − 5.0)	n.s
Patellar[f]	81	− 4.6	(− 8.6 to – − 0.5)	*0.027*	− 2.6	(− 7.2 to − 1.9)	n.s
Medial meniscal treatment							
No lesion	99	REF			REF		
Untreated	17	− 4.6	(− 11.6 to – 2.3)	n.s	− 5.3	(− 12.9 to − 2.4)	n.s
Resected/prior meniscectomy	87	− 4.6	(− 8.5 to – − 0.6)	*0.023*	− 4.5	(− 8.9 to − 0.1)	*0.045*
Sutured	25	− 5.3	(− 11.5 to – 1.0)	n.s	− 6.6	(− 13.1 to − 0.1)	*0.048*
Lateral meniscal treatment							
No lesion	157	REF			REF		
Untreated	29	0.5	(− 4.9 to – 5.9)	n.s	1.7	(− 4.2 to − 7.6)	n.s
Resected/prior meniscectomy	26	− 6.3	(− 12.1 to – − 0.5)	*0.034*	− 5.8	(− 12.1 to − 0.6)	n.s
Sutured	16	− 4.5	(− 11.9 to – 2.9)	n.s	− 8.2	(− 17.0 to − 0.7)	n.s

Italics indicate significant differences or trends ($p < 0.05$)

[a]Excluded from the multivariable model because of excessive collinearity with meniscal treatment

[b]Includes isolated medial meniscal lesions and bicompartmental meniscal lesions

[c]Includes isolated lateral meniscal lesions and bicompartmental meniscal lesions

[d]Includes isolated medial cartilage lesions and multi-compartmental cartilage lesions

[e]Includes isolated lateral cartilage lesions and multi-compartmental cartilage lesions

[f]Includes isolated patellar cartilage lesions and multi-compartmental cartilage lesions

Table 7 Uni- and multi-variable regression analysis to identify factors associated with post-operative KOOS pain

	n =	Univariable (*n* = 228)			Multivariable (*n* = 210)		
		β (pts)	95% C.I	*p*-value	β (pts)	95% C.I	*p*-value
Female sex	134	− 3.2	(− 6.5 to 0.1)	n.s	− 6.6	(− 10.6 to − 2.5)	*0.002*
Age (years)		− 0.2	(− 0.6 to 0.2)	n.s	− 0.1	(− 0.5 to − 0.3)	n.s
BMI (kg/m^2)		− 0.6	(− 1.1 to − 0.2)	*0.008*	− 1.0	(− 1.5 to − 0.4)	*< 0.001*
Follow-up (months)		− 0.2	(− 0.7 to 0.2)	n.s	− 0.1	(− 0.6 to − 0.4)	n.s
Sports level							
Competitive	18	2.0	(− 4.0 to 7.9)	n.s	− 1.7	(− 8.1 to − 4.6)	n.s
Recreational	192	REF			REF		
None	18	− 3.6	(− 10.0 to 2.9)	n.s	− 4.7	(− 11.7 to − 2.3)	n.s
Time from injury to surgery (months)		0.0	(− 0.0 to 0.0)	n.s	0.0	(− 0.0 to − 0.0)	n.s
Pre-operative differential laxity (mm)		− 0.2	(− 0.7 to 0.3)	n.s	− 0.0	(− 0.6 to − 0.5)	n.s
Adjuvant Lemaire procedure		− 1.5	(− 6.0 to 3.0)	n.s	− 2.2	(− 7.1 to − 2.7)	n.s
Meniscal lesion[a]							
None	74	REF					
Medial[b]	129	− 3.5	(− 6.8 to − 0.2)	*0.036*			
Lateral[c]	71	− 0.6	(− 4.1 to 3.0)	n.s			
Cartilage lesion							
None	100	REF			REF		
Medial[d]	99	− 3.1	(− 6.4 to 0.2)	n.s	− 3.1	(− 6.9 to − 0.7)	n.s
Lateral[e]	66	− 1.3	(− 5.3 to 2.8)	n.s	0.1	(− 4.9 to − 5.0)	n.s
Patellar[f]	81	− 1.9	(− 5.6 to 1.8)	n.s	0.4	(− 3.7 to − 4.6)	n.s
Medial meniscal treatment							
No lesion	99	REF			REF		
Untreated	17	− 5.9	(− 12.2 to 0.4)	n.s	− 7.1	(− 14.1 to − 0.2)	*0.044*
Resected/prior meniscectomy	87	− 2.4	(− 6.0 to 1.2)	n.s	− 1.9	(− 5.8 to − 2.1)	n.s
Sutured	25	− 6.0	(− 11.7 to − 0.3)	*0.038*	− 6.2	(− 12.1 to − 0.3)	*0.039*
Lateral meniscal treatment							
No lesion	157	REF			REF		
Untreated	29	2.3	(− 2.6 to 7.2)	n.s	4.0	(− 1.3 to − 9.4)	n.s
Resected/prior meniscectomy	26	− 3.6	(− 8.9 to 1.7)	n.s	− 3.6	(− 9.4 to − 2.1)	n.s
Sutured	16	− 1.5	(− 8.3 to 5.2)	n.s	− 2.9	(− 10.9 to − 5.1)	n.s

Italics indicate significant differences or trends ($p < 0.05$)

[a]Excluded from the multivariable model because of excessive collinearity with meniscal treatment

[b]Includes isolated medial meniscal lesions and bicompartmental meniscal lesions

[c]Includes isolated lateral meniscal lesions and bicompartmental meniscal lesions

[d]Includes isolated medial cartilage lesions and multi-compartmental cartilage lesions

[e]Includes isolated lateral cartilage lesions and multi-compartmental cartilage lesions

[f]Includes isolated patellar cartilage lesions and multi-compartmental cartilage lesions

Table 8 Uni- and multi-variable regression analysis to identify factors associated with post-operative instrumented differential laxity (ATT)

	n =	Univariable (*n* = 228)			Multivariable (*n* = 210)		
		β (mm)	95% C.I	*p*-value	β (mm)	95% C.I	*p*-value
Female sex	134	0.3	(− 0.3 to 1.0)	n.s	0.3	(− 0.4 to 1.1)	n.s
Age (years)		0.1	(− 0.0 to 0.1)	n.s	0.0	(− 0.0 to 0.1)	n.s
BMI (kg/m^2)		0.0	(− 0.1 to 0.1)	n.s	0.0	(− 0.1 to 0.1)	n.s
Follow-up (months)		0.1	(− 0.0 to 0.2)	n.s	0.1	(− 0.0 to 0.2)	*0.022*
Sports level							
Competitive	18	− 1.0	(− 2.1 to 0.2)	n.s	− 0.6	(− 1.8 to 0.5)	n.s
Recreational	192	REF			REF		
None	18	0.9	(− 0.4 to 2.2)	n.s	0.6	(− 0.8 to 1.9)	n.s
Time from injury to surgery (months)		0.0	(− 0.0 to 0.0)	n.s	0.0	(− 0.0 to 0.0)	n.s
Pre-operative differential laxity (mm)		0.1	(− 0.0 to 0.2)	n.s	0.0	(− 0.1 to 0.1)	n.s
Adjuvant Lemaire procedure		− 0.1	(− 1.0 to 0.8)	n.s	− 0.0	(− 0.9 to 0.9)	n.s
Meniscal lesion[a]							
None	74	REF					
Medial[b]	129	0.4	(− 0.2 to 1.1)	n.s			
Lateral[c]	71	1.0	(0.3 to 1.7)	*0.004*			
Cartilage lesion							
None	100	REF			REF		
Medial[d]	99	0.2	(− 0.5 to 0.8)	n.s	− 0.2	(− 0.9 to 0.5)	n.s
Lateral[e]	66	1.2	(0.5 to 2.0)	*0.002*	1.0	(− 0.1 to 1.9)	*0.028*
Patellar[f]	81	− 0.5	(− 1.3 to 0.2)	n.s	− 0.6	(− 1.3 to 0.2)	n.s
Medial meniscal treatment							
No lesion	99	REF			REF		
Untreated	17	1.2	(− 0.1 to 2.4)	n.s	0.4	(− 0.9 to 1.7)	n.s
Resected/prior meniscectomy	87	0.2	(− 0.5 to 0.9)	n.s	0.3	(− 0.5 to 1.0)	n.s
Sutured	25	0.7	(− 0.4 to 1.9)	n.s	0.8	(− 0.3 to 1.9)	n.s
Lateral meniscal treatment							
No lesion	157	REF			REF		
Untreated	29	0.8	(− 0.1 to 1.7)	n.s	0.6	(− 0.4 to 1.5)	n.s
Resected/prior meniscectomy	26	1.2	(0.1 to 2.2)	*0.030*	0.7	(− 0.3 to 1.8)	n.s
Sutured	16	1.2	(− 0.1 to 2.5)	n.s	1.1	(− 0.4 to 2.6)	n.s

Italics indicate significant differences or trends ($p < 0.05$)

[a]Excluded from the multivariable model because of excessive collinearity with meniscal treatment

[b]Includes isolated medial meniscal lesions and bicompartmental meniscal lesions

[c]Includes isolated lateral meniscal lesions and bicompartmental meniscal lesions

[d]Includes isolated medial cartilage lesions and multi-compartmental cartilage lesions

[e]Includes isolated lateral cartilage lesions and multi-compartmental cartilage lesions

[f]Includes isolated patellar cartilage lesions and multi-compartmental cartilage lesions

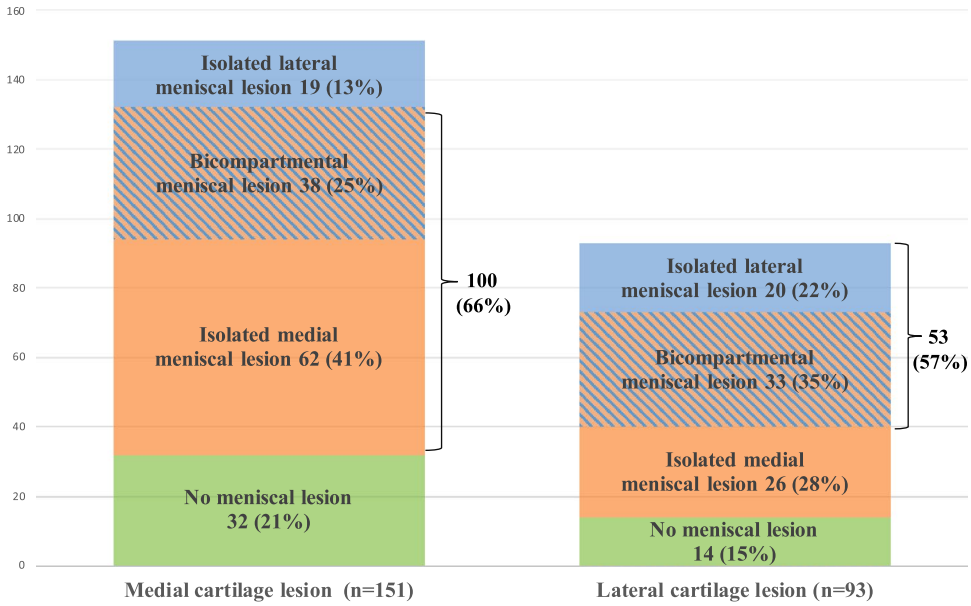

Fig. 5 Cartilage lesions were often present concomitantly with meniscal lesions within the same compartment. Of the 151 knees with medial cartilage lesions, 100 (66%) had concomitant medial meniscal lesions, and of the 93 knees with lateral cartilage lesions, 53 (57%) had concomitant lateral meniscal lesions

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Compliance with ethical standards

Conflict of interest JCP receives royalties from SBM, from BBraun Aesculap, and Xnov. DD receives royalties from SBM. JFG receives personal consulting fees from Corin and from Leo Pharma. SL receives personal consulting fees from Stryker, from Smith Nephew, from Heraeus, from Medacta, from DePuy Synthes, from Groupe Lepine, and royalties from Amplitude and from Corin. None of the author authors have any conflicts of interest.

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