Knee Surgery, Sports Traumatology, Arthroscopy (2020) 28:881–887
https://doi.org/10.1007/s00167-019-05535-x

KNEE

Medial collateral ligament (MCL) reconstruction results in improved medial stability: results from the Danish knee ligament reconstruction registry (DKRR)

Martin Lind[1] · **Kevin Jacobsen**[1] · **Torsten Nielsen**[1]

Received: 14 January 2019 / Accepted: 7 May 2019 / Published online: 23 May 2019

Abstract

Purpose The aim of this study was to compare outcome data after isolated and combined (MCL) plus anterior cruciate ligament (ACL) reconstruction based on objective and subjective measures using data from the (DKRR). There are only a few small-sized case studies on outcomes after MCL reconstruction. MCL reconstruction was hypothesised to improve both objective and subjective outcomes.

Methods All patients who were registered in the DKRR between 2005 and 2016 ($N = 25{,}281$) and who underwent isolated ACL ($n = 24{,}683$), isolated MCL ($n = 103$) or combined MCL plus ACL ($n = 495$) reconstructions were retrospectively identified. Objective (valgus knee stability and sagittal knee laxity) and subjective (Knee Injury and Osteoarthritis Outcome Score (KOOS) and Tegner activity scale score) outcomes in these three cohorts were evaluated at the 1-year follow-up by comparing pre- and post-operative values.

Results Medial stability improved significantly pre- to post-operatively after both isolated MCL and combined MCL plus ACL reconstruction, with 26 (53%) and 195 (69%) of the patients, respectively, having normal valgus stability (0–2 mm laxity). Sagittal stability was similar after MCL plus ACL reconstruction and isolated ACL reconstruction (1.7 and 1.5 mm, respectively). At the 1-year follow-up, although the KOOS of the patients in the isolated MCL and combined MCL plus ACL reconstruction cohorts improved significantly, they were lower than those of the patients in the isolated ACL reconstruction cohort.

Conclusion Both isolated MCL reconstruction and combined MCL plus ACL reconstruction resulted in significant and clinically relevant improvements in the subjective outcomes from pre-operative conditions to the 1-year follow-up. Valgus stability also improved significantly, with two-thirds of patients obtaining normal valgus stability after MCL reconstruction. Subjective outcomes were similar between isolated MCL reconstruction and combined MCL plus ACL reconstructions, but were poorer than isolated ACL reconstructions.

Level of evidence Level III.

Keywords Medial collateral ligament · MCL · Anterior cruciate ligament · ACL · Reconstruction · Clinical outcomes

Introduction

The medial collateral ligament (MCL) is one of the most commonly injured knee structures, and an anterior cruciate ligament (ACL) injury is the ligament injury most frequently accompanying an MCL injury [23, 30, 39]. According to the American Medical Association classification [2], MCL injuries can be divided into three categories (grades I–III) according to the level of medial structural injury and valgus laxity. Grade III MCL injuries often present in combination with ACL tears [1, 31]. A recent epidemiological study on knee injuries among 17,397 patients with 19,530 sports-related injuries over a 10-year period found 7.9% of isolated MCL lesions [23].

Isolated MCL injuries are common in young males playing sports that involve contact (e.g., football, judo, skiing, wrestling, and hockey) [23]. Valgus stress is the most common mechanism of injury [30], and most injuries

✉ Martin Lind
martinlind@dadlnet.dk

[1] Department of Orthopaedics, Aarhus University Hospital, Palle Juul-Jensens Boulevard 99, 8200 Aarhus, Denmark

result from direct contact or cutting manoeuvres with the foot planted on the ground [33].

The treatment options for isolated MCL injuries range from non-operative to surgical reconstruction. Most MCL injuries are treated conservatively due to the excellent healing capacity of the MCL and good clinical outcomes with non-operative treatments [3, 6, 9]. However, more severe grade III injuries involving both the superficial and deep MCL fibres and the posterior oblique ligament may result in chronic valgus instability [14]. Although several surgical techniques for the treatment of chronic valgus instability have been described [4, 18, 20, 28], no single method of isolated MCL reconstruction has yet proven to be superior [16, 38].

Current studies on the management of combined ACL and MCL injuries include results on ACL surgery alone, MCL surgery alone, non-operative treatment only or a combination of these approaches [5, 8, 29, 35]. Recent systematic reviews have found no clear consensus on the optimal method to treat an MCL injury in combination with an ACL injury [12, 29]. Yoshiya et al. [40] investigated outcomes after combined ACL and MCL reconstructions and found normal or near-normal knee function and medial stability in 88% of patients. Another case series demonstrated satisfactory results in a 2-year follow-up on isolated ACL reconstruction in combination with conservative MCL treatment for grade II and III injuries [26]. The same study reported a mean Lysholm score of 94.5, an ACL stability side-to-side difference of 2.3 mm and no valgus or rotational instability at follow-up. Nakamura et al. [31] compared MCL reconstruction versus conservative MCL treatment in combination with ACL knee injuries and found no between-group differences in subjective or objective (valgus laxity) outcomes.

The vast majority of the current orthopaedic literature on outcomes of isolated MCL and combined MCL and ACL lesions is based on isolated case series of surgical or non-operative treatment. Studies with outcome data from large cohorts with prospective data collection would potentially provide more representative outcome data. National registers from Scandinavian countries [11, 21, 27] and large cohort studies from other countries [7, 24, 25] provide such data. The Danish Knee Ligament Reconstruction Registry (DKRR) includes a large volume of outcome data on patients who underwent surgical treatment for knee ligament injuries, including collateral ligament injuries.

The aim of this study was to compare objective and subjective outcomes after isolated MCL reconstruction, combined MCL plus ACL reconstruction and isolated ACL reconstruction in a large DKRR cohort representative of the general surgical population. The hypothesis was that MCL reconstruction would improve objective (valgus knee stability) and subjective clinical outcomes, and that combined MCL plus ACL reconstruction outcomes would be inferior to those of isolated ACL reconstruction.

Materials and methods

The DKRR is a nationwide, prospective web-based clinical quality database established in 2005 [21]. The registry contains data on primary and revision anterior and posterior cruciate ligament reconstructions, as well as collateral ligament and multi-ligament reconstruction. The register does not contain data on ligament injuries treated conservatively. Data collection is compulsory by Danish legislation, and data is prospectively collected pre-operatively, intra-operatively and 1-year post-surgery by the operating surgeon in both public ($n=30$) and private ($n=33$) hospitals. As of 2016, 30,726 procedures had been registered, and 93.9% of these had been entered in the registry. This percentage corresponds to the registration completeness, which is determined by correlating the registry data with data from the Danish National Patient Registry. Furthermore, patients independently report on subjective knee function before surgery and 1 year after surgery using self-assessment questionnaires: the Knee Injury and Osteoarthritis Outcome Score (KOOS) [34] and the Tegner activity scale [36]. In terms of registration completeness, in 2016, an average of 33% and 18% of patients reported data pre-operatively and at the 1-year follow-up, respectively.

All patients who were registered in the DKRR between 2005 and 2016 and who had undergone isolated ACL, isolated MCL or combined MCL plus ACL reconstructions were retrospectively identified ($N=25,281$). Of these cases, 24,683 (97.6%) were isolated ACL reconstructions, 103 (0.4%) were isolated MCL reconstructions and 495 (2.0%) were combined MCL and ACL reconstructions.

The epidemiological characteristics of the three patient cohorts are shown in Table 1. Table 1 also provides information on the number of meniscus lesions found and managed at surgery, in addition to the number of cartilage lesions greater than International Cartilage Research Society grade 2 found at surgery. In Denmark, the indication for MCL reconstruction is generally chronic medial instability or medial instability after failed conservative treatment of MCL lesions. Therefore, the data do not include surgical treatment performed for acute medial lesions. Such treatment is performed only in very rare cases in Denmark.

Outcomes

The subjective outcomes were based on the KOOS [10] and the Tegner activity scale score [37]. The KOOS4 denoted the average KOOS for the four most responsive sub-scores [10]. Valgus knee stability and sagittal laxity (objective measures)

Table 1 Baseline patient characteristics

	Isolated ACL injury *n* (%)	Isolated MCL injury *n* (%)	Combined ACL + MCL injury *n* (%)	*P* value
Number of patients	24,683	103	495	
Patient characteristics				
Male	14,987 (61)	68 (66)	345 (70)	< 0.05[a,b]
Female	9696 (39)	35 (34)	150 (30)	
Age, years (mean SD)	28.3 (range 7–74)	37.5 (range 16–67)	33.2 (range 14–74)	< 0.05[c]
Trauma mechanism				
ADL	1939 (8)	21 (21)	80 (16)	
Traffic accidents	754 (3)	25 (25)	71 (14)	
Pivot sports	14,632 (59.4)	21 (21)	165 (30)	
Skiing/snowboarding	3072 (12)	8 (8)	102 (21)	
Others	4230 (17)	27 (26)	75 (15)	
Concomitant injuries				
Meniscus tear	10,594 (43%)	17 (17%)	192 (39%)	
Cartilage damage	16 (16%)	3232 (13%)	68 (14%)	

ACL anterior cruciate ligament, *MCL* medial cruciate ligament, *ADL* activities of daily living

[a]Significant difference between isolated ACL injuries and isolated MCL injuries

[b]Significant difference between isolated MCL injuries and combined ACL and MCL injuries

[c]Significant difference between isolated ACL injuries and combined ACL and MCL injuries

were determined using the evaluation scoring system of the International Knee Documentation Committee (IKDC) and a KT1000 arthrometer, respectively. In terms of the subjective outcomes, the criterion for success was a score of > 44 on the quality of life (QoL) subscale of the KOOS.

This study was approved by the Danish Board of Health and the Danish Data Protection Agency (approval no.: 1-16-02-46-18). National clinical registry studies do not require local ethical committee approval in Denmark.

Statistics

Differences among the pre-operative baseline data and differences among the post-operative 1-year follow-up data were calculated using the Student's *t* test and a χ^2 test.

Results

Epidemiology

Age and sex were comparable in the three cohorts, with no statistical differences, except for a minor difference in the number of males. In the study, males accounted for 61, 66, and 70% of isolated ACL, isolated MCL and combined MCL plus ACL reconstructions, respectively (Table 1).

In the MCL reconstruction cohort, ligament reconstructions accounted for 2.4% of all the reconstructions. Of these, 0.4% of cases were isolated MCL reconstructions, and 2.0% were combined ACL and MCL reconstructions.

The main causes of isolated MCL injuries were traffic accidents. Among the combined ACL and MCL injuries, pivoting sports injuries were the most common cause of trauma. Associated meniscus and cartilage lesions were seen in 17% and 13% of all isolated MCL injuries, respectively.

Subjective outcomes: KOOS and Tegner activity scale at the 1-year follow-up

At the 1-year follow-up, all KOOS sub-scores improved from the baseline in the isolated MCL reconstruction and combined MCL plus ACL reconstruction cohorts. In both cohorts, the greatest improvements were in the category of sports and QoL, with improvements ranging from 15 to 25 points. The KOOS sub-scores of the MCL reconstruction cohort were higher (2–8 points higher) than those of the MCL plus ACL reconstruction cohort, but the difference was not statistically significant (Table 2).

At the 1-year follow-up, the isolated MCL and combined MCL plus ACL cohorts had significantly low sports and QoL sub-scores. Improvements in these two cohorts from the baseline to the follow-up ranged between 10 and 15 points for sports activity and 8 and 10 points for QoL (Table 2).

The KOOS4 in both the isolated MCL and combined MCL plus ACL reconstruction cohorts was lower than that of the ACL reconstruction cohort; however, the scores improved in all the cohorts at the 1-year follow-up.

Table 2 Pre-operative and post-operative 1-year follow-up data

	Isolated ACL		Isolated MCL		Combined ACL + MCL	
	Pre-operative	1-year follow-up	Pre-operative	1-year follow-up	Pre-operative	1-year follow-up
Number of KOOS responses, *n*	8497	6236	23	22	156	126
KOOS	–	–	–	–	–	–
KOOS4[‡]	42 (17)	68 (16.4)[a]	55 (16)	59 (21)[a]	50 (75)	61 (18)[a]
Symptoms	71 (16)	71 (13)[a]	60 (20)	64 (17)[a,b,c]	69 (15)	67 (13)[a,c]
Pain	71 (17)	83 (15)[a]	60 (22)	76 (18)[a,c]	68 (19)	77 (19)[a,c]
ADL	79 (18)	89 (13)[a]	64 (21)	83 (14)[a,c]	72 (20)	83 (17)[a]
Sports	38 (26)	61 (25)[a]	21 (23)	46 (29)[a,c]	28 (23)	51 (27)[a,c]
QoL	39 (16)	58 (21)[a]	29 (16)	51 (25)[a,c]	35 (17)	50 (21)[a,c]
QoL > 40, (%)	45	78[a]	17	64[a,c]	36	63[a,c]
Tegner activity score	3.0 (2.0)	5.0 (2.0)[a]	2.1 (2.3)	3.5 (1.9)[a,c]	2.5 (1.5)	4.2 (2.1)[a,c]
Number of objective data, *n*	21,537	13,035	77	40	412	280
Number of valgus IKDC grade A, *n* (%)	–	–	3 (3)	26 (53)[a]	44 (9)	195(69)[a]
KT-1000 side-to-side distance, mm	5.2 (2.3)	1.5 (1.5)[a]	–	–	6.2 (3.0)	1.7 (1.8)[a]

ACL anterior cruciate ligament, *MCL* medial collateral ligament, *KOOS* Knee Injury and Osteoarthritis Outcome Score, *ADL* activities of daily living, *QoL* quality of life, *IKDC* International Knee Documentation Committee

[†]Data are the mean (SD), and an independent *t* test was used for comparison of two means

[a]Significant difference from pre-operative to 1-year follow-up

[b]Significant difference between the isolated MCL and combined MCL plus ACL cohorts at the 1-year follow-up

[c]Significant difference between the isolated ACL and both MCL reconstruction cohorts at the 1-year follow-up

At the 1-year follow-up, based on a KOOS of > 44 points for QoL, 64% of isolated MCL reconstructions and 63% of combined MCL plus ACL reconstructions were subjective successes, compared with a subjective success rate of 78% in the isolated ACL reconstructions.

The Tegner activity scale improved in both the isolated MCL and MCL plus combined ACL reconstruction cohorts at the 1-year follow-up, with no significant difference between the two cohorts. The Tegner scores of both cohorts were significantly lower than those of the isolated ACL reconstruction cohort (Table 2).

Objective outcome: Valgus laxity at the 1-year follow-up

At the 1-year follow-up, 26 (53%) and 195 (69%) of the patients who had undergone isolated MCL and combined MCL plus ACL reconstructions, respectively, had valgus IKDC grade A. The sagittal laxity improved significantly in both the isolated ACL reconstruction cohort and the combined MCL plus ACL reconstruction cohort. At the 1-year follow-up, the side-to-side difference was 1.7 mm for combined MCL plus ACL reconstruction. In comparison, the sagittal laxity in cases of isolated ACL reconstructions was 1.5 mm at the follow-up (Table 2).

Discussion

The primary findings of the present study were that 53% and 69% of patients obtained normal valgus stability 1 year after isolated MCL and combined MCL plus ACL reconstructions, respectively. In our study, we found significant improvements in valgus stability after both isolated MCL and combined ACL and MCL reconstructions. Normalisation of valgus stability (IKDC grade A) was achieved in 53% and 68% of isolated MCL and combined MCL plus ACL reconstruction cases, respectively. This finding is in accordance with that of a larger case series that studied MCL reconstruction outcomes [19, 20].

The study also revealed improved subjective outcomes in both isolated MCL reconstruction and combined MCL plus ACL reconstruction at the 1-year follow-up compared to the baseline.

Overall, the greatest improvement in KOOS was found with isolated MCL reconstruction, especially in sports and QoL sub-scores. However, in terms of subjective outcomes of isolated MCL reconstruction and combined MCL plus ACL reconstruction at the 1-year follow-up, there was no significant difference between the cohorts. Another key finding was that the subjective success rate, defined as a KOOS for QoL of > 44 at the 1-year follow-up, was lower

for isolated MCL reconstruction (64%) and combined MCL plus ACL reconstruction (63%) compared with that of isolated ACL reconstruction (78%).

The findings of improved valgus stability and improved subjective outcomes after MCL reconstruction are similar to those of several large case series studies of different anatomical MCL reconstruction techniques. In a study by Lind et al. [23] on 61 patients, 95% of patients who underwent isolated MCL reconstruction or MCL multi-ligament reconstruction obtained IKDC A or B valgus stability and improvements in subjective outcomes to levels comparable to those in primary ACL reconstructions. In a study by LaPrade et al. [22], 28 patients with anatomical MCL reconstruction had improved valgus stability (from 6.2 to 1.3 mm) as evaluated by stress X-rays and subjective IKDC score improvements from 44 to 76. In the present study, in terms of the objective outcomes, valgus stability was good after MCL reconstruction, but a significant proportion (one-third) of patients reported knee-injury-related complaints at the 1-year follow-up. This finding can be expected in cases of multi-ligament injury (i.e., combined MCL plus ACL and MCL injuries), with continued knee dysfunction, despite acceptable knee stability. The poorer subjective outcome after isolated MCL reconstruction compared with that of isolated ACL reconstruction is more difficult to explain. It is most likely that grade III MCL lesions, which resulted in chronic MCL instability requiring MCL reconstruction, were associated with marked extra-articular soft tissue injury. The latter may have led to post-traumatic symptoms that were not relieved by the stability obtained by MCL reconstruction.

The results of the present study also revealed no difference in the subjective outcomes of the isolated MCL reconstruction and combined MCL plus ACL reconstruction cohorts. In the existing orthopaedic literature, only a few studies have compared isolated MCL injuries directly with ALC and MLC injuries. Al-Hourani et al. [1] followed a large cohort of patients with MCL injuries ($N=82$) over a 1-year follow-up period and found no significant differences in objective functional outcomes between isolated and combined MCL and ACL injuries. However, they did not include an assessment of subjective outcome scores. In contrast, the present study included both objective and subjective (KOOS and Tegner scores) outcome assessments. To the best of our knowledge, this is the first national register study to directly compare outcomes of isolated MCL reconstruction with those of isolated ACL reconstruction. Such a comparison was possible due to the inclusion of both cruciate and collateral ligament reconstruction data in the DKRR. Previous studies on MCL and ACL reconstructions were largely based on case series and compared outcomes of combined MCL and ACL reconstruction with those of isolated ACL reconstruction. Thus, the possible benefits of surgical treatment of isolated MCL lesions have received little attention. In a study by Lundberg et al. [25], 38 patients with grade I and II MCL injuries were treated conservatively. After a 4-year follow-up, all the patients had a Lysholm score of 95 points or higher, and 32 of the 38 patients were able to return to pre-injury activity levels. In the study, only two patients had minor residual valgus laxity. Another study on a small subset of patients with isolated MCL injuries reported that chronic symptoms persisted after conservative treatment [16]. The current study contains data only on outcomes after surgical management of MCL lesions. In Denmark, the indication for surgical treatment of an isolated MCL lesion is significant subjective instability, together with clear, objective grade II or III valgus instability after conservative treatment. The findings of the present study add to the current literature by showing that reconstruction in cases of an isolated MCL injury may benefit patients with chronic laxity when conservative treatment has failed.

However, as demonstrated by the KOOS and Tegner scores, the subjective outcome of the MCL reconstruction cases was significantly poorer than those of the isolated ACL reconstruction cases.

A possible cause of the observed lower KOOSs and Tegner scores after MCL reconstruction compared with those after ACL reconstruction may be symptoms associated with lesions deep in MCL structures that are not addressed by superficial MCL reconstruction. In a study in which patients ($N=34$) with grade II and III injuries were treated with steroid injections for deep MCL inflammation ($n=34$), Jones et al. [13] concluded that the deep MCL was a potential cause of chronic symptoms. Hence, failing to take account of the deep portion of the ligament during surgical reconstruction of the MCL may explain the lower KOOSs and Tegner scores found in the present study.

In the present study, both isolated MCL and combined MCL plus ACL reconstructions were associated with lower subjective and objective outcomes than those of isolated ACL injuries. The underlying reason is not clear, and the explanation could be multifactorial. One possible explanation could be a different injury mechanism. Lundblad et al. [22] performed a prospective cohort study on professional football players for 11 years and found that most MCL injuries were due to direct contact resulting in valgus overload. The same trauma mechanism was not reported for ACL injuries, which were most often caused by non-contact mechanisms [15, 22].

Outcomes after MCL reconstruction may also be dependent on the surgical technique. The anatomy of the MCL ligament is complex; it consists of a superficial and deep structure and a posterior oblique ligament [17]. Recent research highlighted the need to focus on all these anatomical components during MCL reconstruction [6]. Research also suggested that surgical reconstruction of these structures seemed to be related to the outcome of

MCL reconstruction. According to one study, successful outcomes of MCL reconstructions appeared to depend on the strength of the graft, accurate placement of the attachment and solid fixation [40].

The current study did not compare conservative treatment with reconstructive treatment of combined MCL and ACL injuries. A few randomised controlled studies specifically compared conservative treatment of combined ACL and MCL injuries with that of reconstructive treatment. In a recent randomised trial, the authors found no difference in valgus stability between conservative and reconstructive management of grade III MCL tears in combined ACL and MCL injuries [14]. In the study, stability was normal or nearly normal in 96% of cases following conservative MCL treatment and in 100% of cases following surgical treatment. The authors concluded that the results of non-operative treatment of grade III MCL lesions were similar to those obtained with operative treatment when the ACL was reconstructed in the early phase.

This study was based on a large knee ligament reconstruction patient cohort, thereby enabling an analysis and comparison of the incidence of isolated MCL reconstructions and combined MCL plus ACL reconstructions. Given that the registry contains data on more than 90% of all ligament reconstruction procedures, extrapolating the results to the general population is reasonable. In addition, as the data were obtained from a national cohort in which the operations were performed by different surgeons, the findings are more representative and generalised than single-surgeon and single-clinic studies.

A limitation of the study is that not all the baseline characteristics of the patients in the cohorts were homogenous. Thus, variations between the study cohorts may have influenced the results. Moreover, the study considered only the outcome of MCL reconstruction 1 year after treatment. It would be of interest to examine long-term objective and subjective outcomes. Another limitation was the completeness of the subjective outcome parameters. In the present study, an average of 33% and 18% of patients reported data pre-operatively and at the 1-year follow-up, respectively. This raises the possibility of selection bias in the evaluation of the patient reported outcome data. However, a previous validation study found no difference in the subjective outcomes of responders versus non-responders [32]. Finally, this study examined only the clinical outcome after surgical treatment of MCL injuries that resulted in chronic instability or early instability after failed brace treatment. As such, the study lacks data on non-surgical treatment, which is the main initial treatment modality for acute grade II and III MCL lesions. The clinical impact of the present study is that MCL reconstruction should be considered when significant valgus instability is present after MCL lesions both for isolated lesions and combined with ACL lesions.

Conclusion

Both isolated MCL reconstruction and combined MCL plus ACL reconstruction resulted in significant and clinically relevant improvements in the subjective outcomes from pre-operative conditions to the 1-year follow-up. Valgus stability also improved significantly, with two-thirds of patients obtaining normal valgus stability after MCL reconstruction. At the 1-year follow-up, there was no difference in the subjective outcomes between the isolated MCL reconstruction and combined MCL reconstruction, but these results were poorer than for isolated ACL reconstruction cohorts. The study data demonstrate that even in a multi-clinic national cohort, MCL reconstruction of valgus-unstable knees results in an acceptable clinical outcome (valgus stability) and an improvement in subjective outcomes.

Funding The study was completed without funding.

Compliance with ethical standards

Conflict of interest The authors have declared that no conflict of interest exists.

Ethical approval This study was approved by the Danish Board of Health and the Danish Data Protection Agency (approval no.: 1-16-02-46-18). National clinical registry studies do not require local ethical committee approval in Denmark.

References

1. Al-Hourani K, Jefferies J, Will E, Keating JF (2015) Recovery of knee function in the isolated MCL and combined ACL-MCL deficient knee. J Clin Orthop Trauma 6(2):89–93
2. Council on Scientific Affairs (American Medical Association) Advisory Panel on Standard Nomenclature of Athletic Injuries, American Medical Association (1976) Standard nomenclature of athletic injuries. American Medical Association, Monroe, WI
3. Azar FM (2006) Evaluation and treatment of chronic medial collateral ligament injuries of the knee. Sports Med Arthrosc Rev 14(2):84–90
4. Bosworth DM (1952) Transplantation of the semitendinosus for repair of laceration of medial collateral ligament of the knee. J Bone Jt Surg Am 34-A(1):196–202
5. Chen LC, Cooley VJ, Rosenberg TD (2002) Medial collateral ligament healing response technique: microperforation. Tech Knee Surg 1(1):36–42
6. DeLong JM, Waterman BR (2015) Surgical Techniques for the reconstruction of medial collateral ligament and posteromedial corner injuries of the knee: a systematic review. Arthroscopy 31(11):2258–2272 **(e2251)**
7. Domnick C, Garcia P, Raschke MJ, Glasbrenner J, Lodde G, Fink C, Herbort M (2017) Trends and incidences of ligament-surgeries and osteotomies of the knee: an analysis of German inpatient records 2005–2013. Arch Orthop Traum Surg 137(7):989–995

8. Edson CJ (2006) Conservative and postoperative rehabilitation of isolated and combined injuries of the medial collateral ligament. Sports Med Arthrosc Rev 14(2):105–110
9. Ellsasser JC, Reynolds FC, Omohundro JR (1974) The non-operative treatment of collateral ligament injuries of the knee in professional football players. An analysis of seventy-four injuries treated non-operatively and twenty-four injuries treated surgically. J Bone Jt Surg Am 56(6):1185–1190
10. Frobell RB, Roos EM, Roos HP, Ranstam J, Lohmander LS (2010) A randomized trial of treatment for acute anterior cruciate ligament tears. N Engl J Med 363(4):331–342
11. Granan LP, Bahr R, Steindal K, Furnes O, Engebretsen L (2008) Development of a national cruciate ligament surgery registry: The Norwegian National Knee Ligament Registry. Am J Sports Med 36(2):308–315
12. Grant JA, Tannenbaum E, Miller BS, Bedi A (2012) Treatment of combined complete tears of the anterior cruciate and medial collateral ligaments. Arthroscopy 28(1):110–122
13. Jones L, Bismil Q, Alyas F, Connell D, Bell J (2009) Persistent symptoms following non operative management in low grade MCL injury of the knee—the role of the deep MCL. Knee 16(1):64–68
14. Kannus P (1988) Long-term results of conservatively treated medial collateral ligament injuries of the knee joint. Clin Orthop Relat Res 226:103–112
15. Kim C, Chasse PM, Taylor DC (2016) Return to play after medial collateral ligament injury. Clin Sports Med 35(4):679–696
16. Konstantinos M, Georgios K, Konstantinos S, Georgios T (2016) The evolution of the surgical treatment of sports injuries in the 20th century: a historical perspective. Surg Innov 23(5):538–542
17. LaPrade RF, Engebretsen AH, Ly TV, Johansen S, Wentorf FA, Engebretsen L (2007) The anatomy of the medial part of the knee. J Bone Jt Surg Am 89(9):2000–2010
18. Laprade RF, Wijdicks CA (2012) The management of injuries to the medial side of the knee. J Orthop Sports Phys Ther 42(3):221–233
19. Laprade RF, Wijdicks CA (2012) Surgical technique: development of an anatomic medial knee reconstruction. Clin Orthop Relat Res 470(3):806–814
20. Lind M, Jakobsen BW, Lund B, Hansen MS, Abdallah O, Christiansen SE (2009) Anatomical reconstruction of the medial collateral ligament and posteromedial corner of the knee in patients with chronic medial collateral ligament instability. Am J Sports Med 37(6):1116–1122
21. Lind M, Menhert F, Pedersen AB (2009) The first results from the Danish ACL reconstruction registry: epidemiologic and 2 year follow-up results from 5,818 knee ligament reconstructions. Knee Surg Sports Traumatol Arthrosc 17(2):117–124
22. Lundblad M, Waldén M, Magnusson H, Karlsson J, Ekstrand J (2013) The UEFA injury study: 11-year data concerning 346 MCL injuries and time to return to play. Br J Sports Med 47(12):759–762
23. Majewski M, Susanne H, Klaus S (2006) Epidemiology of athletic knee injuries: a 10-year study. Knee 13(3):184–188
24. Maletis GB, Inacio MC, Funahashi TT (2013) Analysis of 16,192 anterior cruciate ligament reconstructions from a community-based registry. Am J Sports Med 41(9):2090–2098
25. Mall NA, Chalmers PN, Moric M, Tanaka MJ, Cole BJ, Bach BR Jr, Paletta GA Jr (2014) Incidence and trends of anterior cruciate ligament reconstruction in the United States. Am J Sports Med 42(10):2363–2370
26. Millett PJ, Pennock AT, Sterett WI, Steadman JR (2004) Early ACL reconstruction in combined ACL-MCL injuries. J Knee Surg 17(2):94–98
27. Nordenvall R, Bahmanyar S, Adami J, Mattila VM, Fellander-Tsai L (2014) Cruciate ligament reconstruction and risk of knee osteoarthritis: the association between cruciate ligament injury and post-traumatic osteoarthritis. a population based nationwide study in Sweden, 1987–2009. PLoS ONE 9(8):e104681
28. O'Donoghue DH (1973) Reconstruction for medial instability of the knee. J Bone Jt Surg Am 55(5):941–954
29. Papalia R, Osti L, Del Buono A, Denaro V, Maffulli N (2010) Management of combined ACL-MCL tears: a systematic review. Br Med Bull 93(1):201–215
30. Phisitkul P, James SL, Wolf BR, Amendola A (2006) MCL injuries of the knee: current concepts review. Iowa Orthop J 26:77–90
31. Piatkowski K, Plominski J, Sowinski T, Piekarczyk P, Kwiatkowski K, Golos J (2014) Results of two-stage operative treatment of anteromedial instability of the knee. Ortop Traumatol Rehabil 16(1):33–45
32. Rahr-Wagner L, Thillemann TM, Lind MC, Pedersen AB (2013) Validation of 14,500 operated knees registered in the Danish Knee Ligament Reconstruction Register: registration completeness and validity of key variables. Clin Epidemiol 5:219–228
33. Roach CJ, Haley CA, Cameron KL, Pallis M, Svoboda SJ, Owens BD (2014) The epidemiology of medial collateral ligament sprains in young athletes. Am J Sports Med 42(5):1103–1109
34. Roos EM, Toksvig-Larsen S (2003) Knee injury and Osteoarthritis Outcome Score (KOOS)—validation and comparison to the WOMAC in total knee replacement. Health Qual Life Outcomes 1:17
35. Stannard JP (2010) Medial and posteromedial instability of the knee: evaluation, treatment, and results. Sports Med Arthrosc Rev 18(4):263–268
36. Tegner Y, Lysholm J (1985) Rating systems in the evaluation of knee ligament injuries. Clin Orthop Relat Res 198:43–49
37. Tegner Y, Lysholm J, Lysholm M, Gillquist J (1986) A performance test to monitor rehabilitation and evaluate anterior cruciate ligament injuries. Am J Sports Med 14(2):156–159
38. Whelan D, Chowdhry M, Hantes M, Nakamura N, Yonetani Y (2017) Treatment of MCL injury in combined ACL/MCL injury. In: Controversies in the technical aspects of ACL reconstruction: an evidence-based medicine approach. pp 371–387
39. Wijdicks CA, Griffith CJ, Johansen S, Engebretsen L, LaPrade RF (2010) Injuries to the medial collateral ligament and associated medial structures of the knee. J Bone Jt Surg Am 92(5):1266–1280
40. Yoshiya S, Kuroda R, Mizuno K, Yamamoto T, Kurosaka M (2005) Medial collateral ligament reconstruction using autogenous hamstring tendons: technique and results in initial cases. Am J Sports Med 33(9):1380–1385