

Augmentation does not improve clinical and radiological outcomes after repair of Stener-like medial collateral ligament (MCL) lesions: Comparative cohort at mid-term follow-up

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Abstract

Purpose: To compare radiographic valgus stability, patient-reported outcome measures (PROMs), and complication and failure rates between patients treated with isolated repair of Stener-like medial collateral ligament (MCL) lesions and those who received repair with augmentation. We hypothesised that repair with augmentation would result in superior radiographic stability and improved clinical outcomes.

Methods: A retrospective cohort study was performed on consecutive patients aged ≥ 18 years who underwent surgical treatment for distal MCL avulsion injuries with pes anserinus interposition between January 2015 and December 2022 at a single institution, with a minimum follow-up of 24 months. Surgical treatment consisted of isolated repair or repair with biological augmentation using autograft or allograft tissue. Functional outcomes were assessed using Lysholm and Knee Osteoarthritis Outcome Score (KOOS) scores. Radiographic valgus stability was evaluated using stress radiographs obtained at 3 months post-operatively.

Results: Twenty-nine patients were included, of whom 19 (65.5%) underwent isolated repair and 10 (34.5%) underwent repair with augmentation. Eighteen patients (62.1%) had multiligament injuries, and the mean time from injury to surgery was 33.1 ± 17.8 days. Both groups showed a significant reduction in medial joint gapping on valgus stress radiographs, with no differences between techniques ($p = 0.985$). The mean Lysholm score for the entire cohort was 89.3 ± 15.4 , with no significant differences between groups ($p = 0.940$). Similarly, no differences were observed in any KOOS subscale. Seven complications (24.1%) were recorded, most commonly post-operative stiffness requiring arthroscopic lysis of adhesions. Complication rates were comparable between groups ($p = 0.664$). One failure occurred in the isolated repair group, requiring MCL reconstruction.

Abbreviations: ACL, anterior cruciate ligament; BMI, Body Mass Index; IKDC, International Knee Documentation Committee; IQR, interquartile range; KD, knee dislocations; KOOS, Knee Osteoarthritis Outcome Score; MCL, medial collateral ligament; MRI, magnetic resonance imaging; PCL, posterior cruciate ligament; PLC, posterolateral corner; PROMs, patient-reported outcome measures; QoL, Quality of Life; REDCap, Research Electronic Data Capture; SD, standard deviation; S-L, Stener-like; sMCL, superficial medial collateral ligament; STG, semitendinosus-gracilis.

Conclusions: Surgical treatment of Stener-like MCL lesions provides good radiographic and functional outcomes at mid-term follow-up. Repair with augmentation does not result in superior outcomes compared with isolated repair, suggesting that anatomic repair alone may be sufficient in most cases.

Level of Evidence: Level III, retrospective cohort study.

KEYWORDS

augmentation, knee instability, medial collateral ligament, repair, Stener-like lesion

INTRODUCTION

The medial collateral ligament (MCL), which comprises the superficial and deep MCL and functions together with the posterior oblique ligament as part of the medial ligament complex, is the primary restraint to valgus stress and an important contributor to rotational knee stability [4, 5, 17, 23]. Owing to its anatomical orientation and biomechanical function, it is among the most frequently injured knee ligaments, accounting for 8%–36% of ligamentous knee injuries [13, 18]. These injuries typically result from direct valgus force, non-contact pivoting mechanisms, or combined ligament trauma [16].

Historically, most isolated MCL injuries have been managed non-operatively [16, 19]. Prospective and retrospective studies have demonstrated favourable clinical outcomes with conservative treatment, even in complete (Grade III) ruptures [3, 12]. This has been largely attributed to the ligament's rich vascular network, particularly in its proximal segment, which promotes efficient healing and tissue remodelling [2, 28]. As a result, surgical intervention has traditionally been reserved for chronic instability, complex multiligament injuries, or cases in which healing is mechanically impeded.

A distinct injury pattern has been described in which the distal MCL is avulsed from its tibial insertion and becomes displaced superficial to the pes anserinus tendons. This interposition prevents direct ligament-to-bone apposition, thereby preventing spontaneous healing. Because of its resemblance to the classic Stener lesion of the thumb's ulnar collateral ligament, this entity has been termed a 'Stener-like' lesion of the MCL. First described by Corten in 2010 [7], the original report emphasised that surgical repair was required to restore anatomical continuity and joint stability.

Since that first description, the literature has been limited to small retrospective case series [1, 6, 9, 14, 15, 27], and isolated case reports [8, 24]. The largest previously published series included 23 patients [26]. These studies are constrained by small sample sizes, heterogeneous surgical techniques and limited outcome reporting, precluding definitive conclusions regarding optimal management.

Given the limited evidence and absence of comparative studies evaluating surgical strategies, the optimal surgical management of Stener-like MCL lesions remains unclear. In particular, it is unknown whether isolated anatomic repair is sufficient to restore medial stability or whether augmentation with graft tissue provides superior biomechanical and clinical outcomes.

The purpose of this study was to compare radiographic valgus stability, patient-reported outcomes (PROMs), complication rates, and failure rates between patients undergoing isolated repair of Stener-like MCL lesions and those undergoing repair with augmentation. We hypothesised that repair with augmentation would result in superior radiographic stability and improved clinical outcomes compared with isolated repair.

MATERIALS AND METHODS

Study design and patient selection

This study was conducted in accordance with the STROBE guidelines. A retrospective cohort study was performed on a consecutive series of patients aged ≥ 18 years who underwent surgical treatment for distal avulsion injuries of the MCL with interposition of the pes anserinus tendons (Stener-like MCL lesions) between January 2015 and December 2022 at a single academic tertiary referral centre.

Patients were eligible for inclusion if they had:

- A diagnosis of distal MCL avulsion with interposition of the pes anserinus tendons between the ligament and its tibial insertion confirmed on magnetic resonance imaging (MRI),
- Surgical treatment consisting of either isolated repair or repair with augmentation, and
- A minimum clinical follow-up of 24 months.

Patients were excluded if they had incomplete imaging, prior surgery on the affected knee, or insufficient follow-up.

All MRI scans were reviewed by a fellowship-trained musculoskeletal radiologist who was blinded to clinical outcomes. Coronal and axial sequences were evaluated using a standardised protocol to identify distal MCL avulsion and interposition of the pes anserinus tendons between the ligament and its tibial insertion [6].

Stener-like MCL lesions were included whether isolated or in the context of multiligament knee injuries, which were classified according to the Schenck system (Grades I–V) [21]. Both isolated repair and repair with augmentation were considered eligible surgical techniques. In the present study, the term 'isolated repair' referred specifically to the surgical management of the MCL and did not exclude the presence of associated ligament injuries that did not require surgical treatment. Augmentation procedures included the use of autograft (semitendinosus–gracilis) or allograft (posterior tibial tendon). Concomitant procedures, including anterior cruciate ligament (ACL), posterior cruciate ligament (PCL) and posterolateral corner (PLC) reconstruction, as well as meniscal repair or partial meniscectomy, were permitted.

All surgeries were performed by the same team of fellowship-trained knee surgeons. The choice between isolated repair and repair with augmentation was determined by the operating surgeon based on intraoperative assessment and overall surgical considerations, including perceived tissue quality, injury characteristics, and

surgeon preference, as part of routine clinical practice. No standardised institutional protocol was in place during the study period. When augmentation was performed, graft type was selected according to surgeon preference and graft availability. Patients were informed about the general characteristics, risks, and benefits of each surgical option prior to decision-making.

Surgical technique

All procedures were performed by the same team of five fellowship-trained knee surgeons from our unit.

a) Isolated repair

A diagnostic arthroscopy was first performed to assess medial compartment widening and associated intra-articular pathology. Through a longitudinal medial approach, the displaced distal superficial MCL (sMCL) was identified beneath the pes anserinus tendons, which were preserved. The distal stump was prepared and secured using high-strength Krackow sutures.

With the knee positioned at 30° of flexion and in neutral rotation under gentle varus stress, distal fixation of the sMCL was performed using either a metallic staple or a 5.5-mm suture anchor (Figure 1). Valgus stability was confirmed intraoperatively.

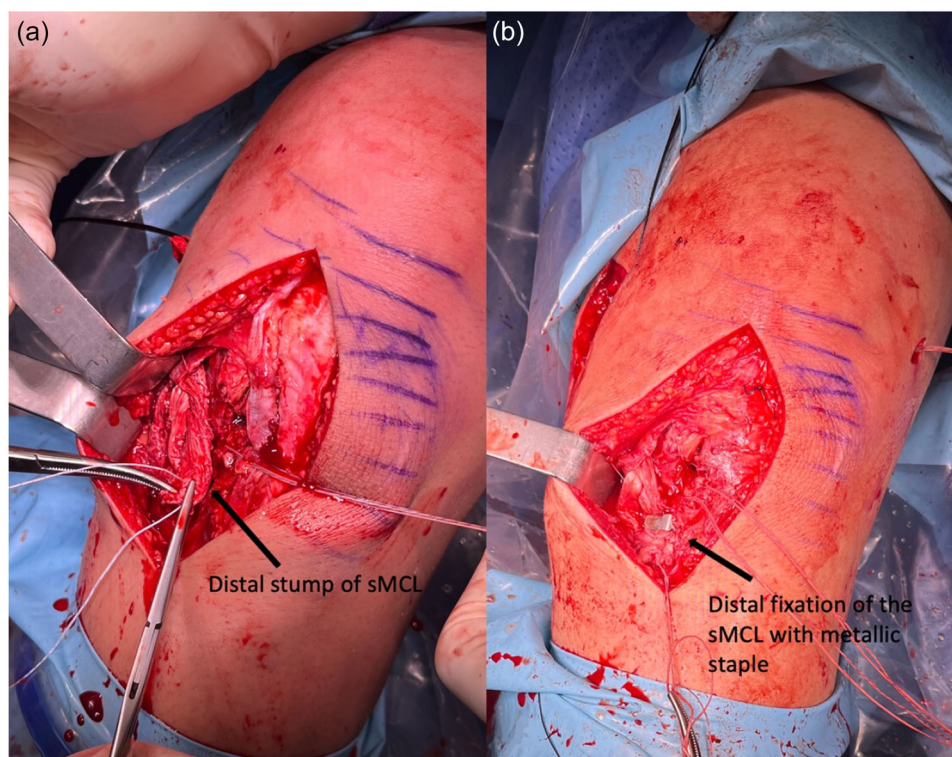


FIGURE 1 Isolated repair of a Stener-like MCL lesion. (a) Distal stump prepared with high-strength Krackow sutures. (b) Distal fixation of the ligament using a staple. MCL, medial collateral ligament.

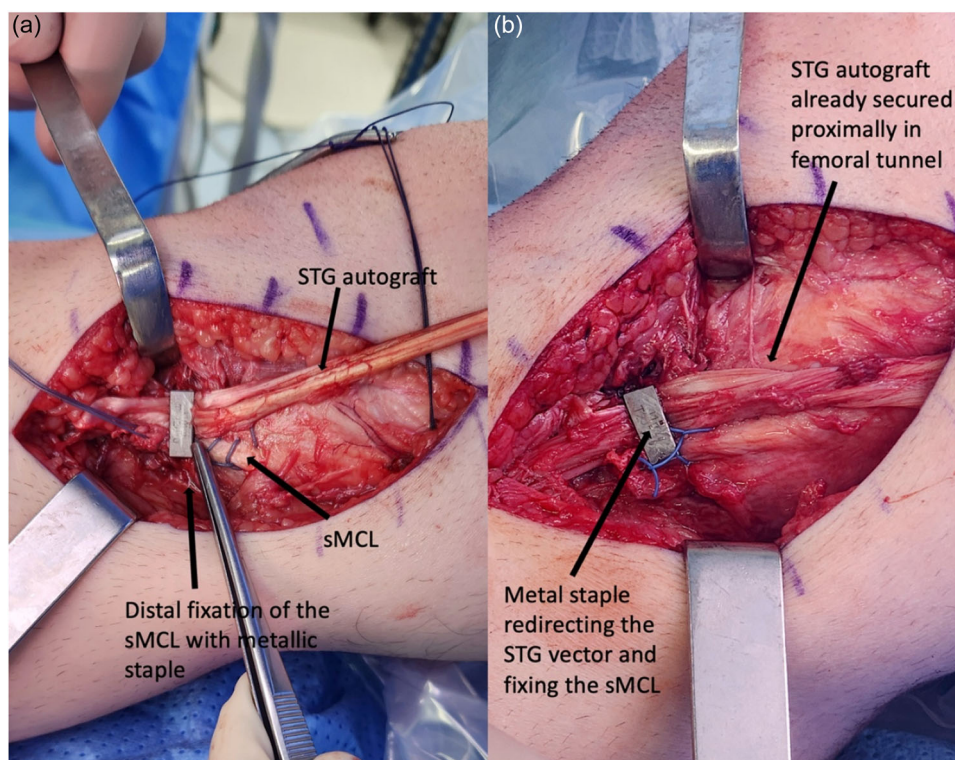


FIGURE 2 Repair with anatomic augmentation of a Stener-like MCL lesion. (a) Semitendinosus–gracilis autograft (STG) with preserved distal tibial insertion. (b) Fixation of the graft. MCL, medial collateral ligament.

b) Repair with anatomic augmentation

The procedure was initiated as described for isolated repair. Augmentation was performed using either a semitendinosus–gracilis autograft with preserved distal insertion or a posterior tibial tendon allograft.

For autograft augmentation, both the semitendinosus and gracilis tendons were proximally released while maintaining their distal tibial insertion. A femoral tunnel was created at the anatomic origin of the sMCL, as previously described by Serra Cruz et al. [22]. The graft was secured in the femoral tunnel using an interference screw with the knee at 20°–30° of flexion and neutral rotation under gentle varus stress (Figure 2).

For allograft augmentation, a posterior tibial tendon graft was fixed proximally in a femoral tunnel at the anatomic sMCL origin and distally on the medial tibial surface. Final tensioning was performed at 20°–30° of knee flexion in neutral rotation. In all cases, valgus stability was verified prior to layered closure.

Post-operative rehabilitation

Both groups followed an identical standardised post-operative rehabilitation protocol. Patients remained non-weightbearing for 6 weeks with a hinged brace allowing progressive range of motion from 0° to 90°

during the first 6 weeks. Full range of motion was permitted after Week 6. Strengthening exercises were initiated at 2 months post-operatively. Rehabilitation protocols were modified when concomitant meniscal repair was performed.

Patient evaluation

Demographic characteristics, surgical technique (isolated repair or repair with augmentation), graft type in augmentation cases, complications and post-operative outcomes were recorded. Complications included infection, post-operative stiffness (defined as knee range of motion <120°), and failure of repair or augmentation.

Failure was defined as a new episode of clinical Grade 3 medial instability on valgus stress testing at 30° of knee flexion and/or MRI findings consistent with graft re-rupture or tibial avulsion. The need for surgical reintervention for any cause was also documented.

Clinical follow-up

Demographic data, injury mechanism, and surgical details were extracted from institutional electronic medical records. Post-operative complications and re-operations were documented.

At final follow-up, patients were evaluated either in person or by telephone by a single physician, who collected PROMs and inquired about subsequent procedures or late complications.

Functional outcomes were assessed at final follow-up in patients who did not experience graft re-rupture or require revision surgery. Knee-specific PROMs included the Lysholm score and the Knee Injury and Osteoarthritis Outcome Score (KOOS). Lysholm scores were categorised as excellent (95–100), good (84–94), fair (65–83) or poor (<65) [25].

A minimum follow-up of 24 months was required to ensure adequate detection of post-operative complications.

Study data were collected and managed using REDCap (Research Electronic Data Capture), a secure web-based software platform for research data management.

Radiological assessment

Post-operative valgus stress radiographs were obtained at three months according to institutional protocol. Radiographs were taken with the knee positioned at 20° of flexion under manual valgus stress.

Medial compartment gapping was measured on digital radiographs by a single orthopaedic surgeon (R.O.) using a standardised technique described by Sawant et al. [20], as described in detail in Figure 3. Radiographs obtained before three months post-operatively or those with inadequate positioning were excluded from analysis.

Statistical analysis

An a-priori power analysis for sample size calculation was based on the primary outcome of the medial compartment gapping. Due to the lack of similar comparative studies, a difference between the two groups of 1.5 ± 1.0 mm with an Alpha error (significance) of 0.05 and a Beta error (1-power) of 0.10 was used to determine the sample size. According to the calculation, a total of 10 patients per group were required.

Two groups were compared in the present study: patients who underwent isolated repair of Stener-like MCL lesions (Group 1) and those who underwent repair with augmentation (Group 2).

Continuous variables were expressed as mean $\pm$ standard deviation (SD) for normally distributed data or median with interquartile range (IQR) for non-normally distributed data. Categorical variables were presented as counts and percentages.

Normality of continuous variables was assessed using the Shapiro–Wilk test. Between-group comparisons of continuous variables were performed using the

independent samples t-test when normal distribution was confirmed and the Mann–Whitney *U* test when non-normal distribution was identified. Categorical variables were analysed using the chi-square test or Fisher exact test when expected cell counts were < 5.

All statistical analyses were conducted using STATA (version 17; StataCorp, College Station, TX, USA). A two-sided *p*-value < 0.05 was considered statistically significant.

RESULTS

A total of 149 surgically treated MCL injuries were identified in our institutional database during the study period. Among these, 36 corresponded to Stener-like MCL lesions. Three cases were excluded based on the predefined exclusion criteria, and four were excluded due to insufficient follow-up. Ultimately, 29 patients (81%) were included in the final analysis. Nineteen (66%) were treated with isolated repair, whereas 10 (34%) underwent repair with augmentation—three using a semitendinosus–gracilis autograft and seven using a posterior tibial tendon allograft (Figure 4).

Patients characteristics

Twenty-nine knees in 29 patients were included, of whom 25 were male (86.2%). The mean age was 39.1 years (standard deviation [SD], 13.4 years), and the mean body mass index (BMI) was 29.6 kg/m² (SD 5.1 kg/m²). In 13 knees (44.8%), surgery was performed on the right side. Mean follow-up was 61.6 months. No significant differences between the two groups were present in the demographic characteristics (Table 1).

The most frequently reported injury mechanism was motor vehicle accidents, accounting for 16 cases (55.2%), followed by pivoting injuries with or without a ground-level fall in eight cases (27.6%) and sports-related injuries in five knees (17.2%). Overall, these findings indicate that Stener-like MCL lesions in our cohort were predominantly associated with high-energy trauma.

In the isolated repair group, the MCL lesion was repaired with a staple in 12 cases and with a suture anchor in seven. In the augmentation group, repair was performed with a suture anchor in eight knees and with a staple in two.

Stener-like lesions occurred in the context of multiligament knee injuries in 12 patients (63.2%) in the isolated repair group and in six patients (60.0%) in the repair with augmentation group, with no significant difference between groups (Table 2).

Concomitant meniscal procedures (partial meniscectomy or meniscal repair) were performed in 11

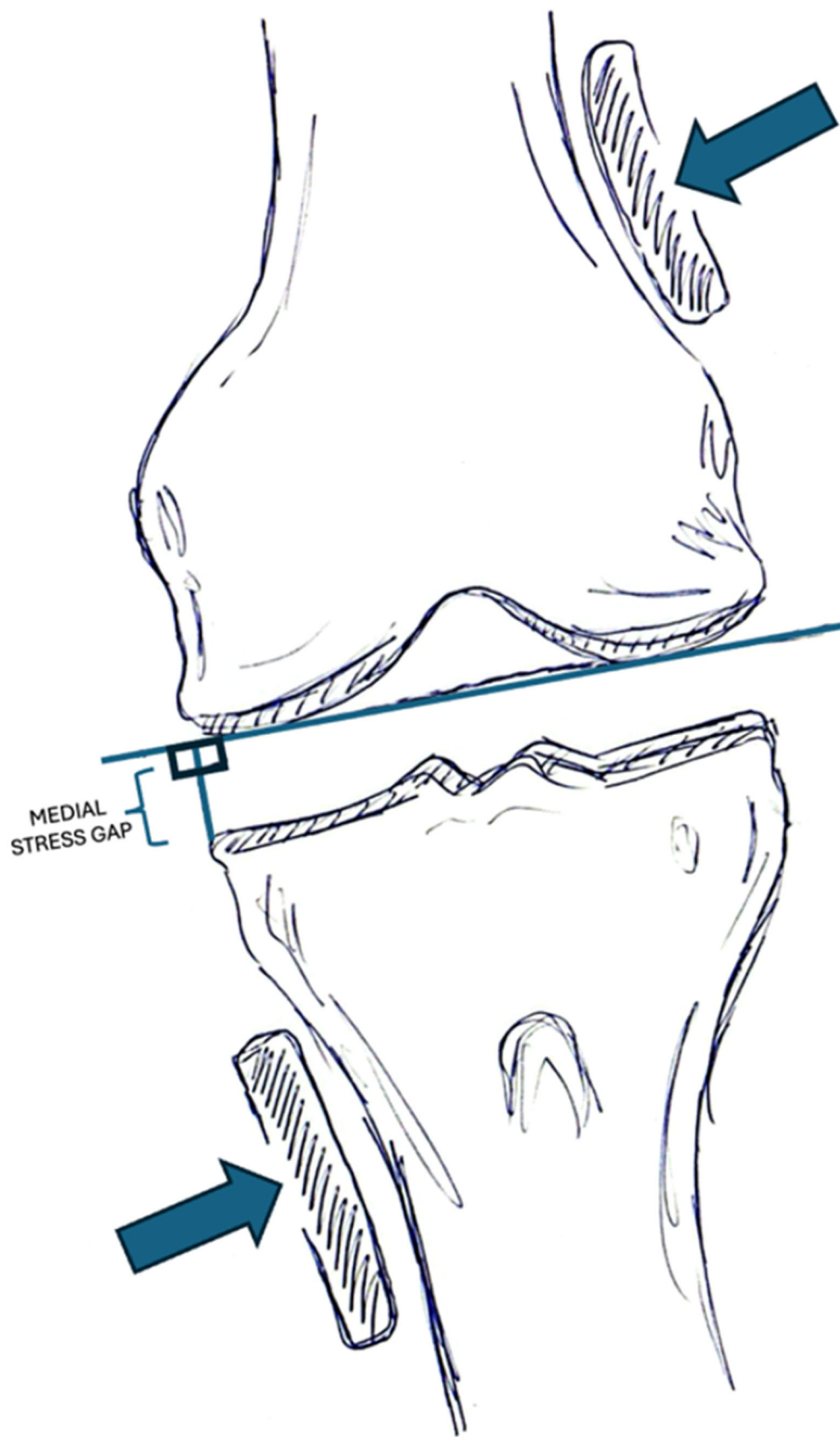


FIGURE 3 Medial compartment gapping measurement as described by Sawant et al. [20]. A tangent line is drawn in the most distal point of the femoral condyles. Then, a perpendicular line is drawn from this line into the most medial part of the medial tibial plateau.

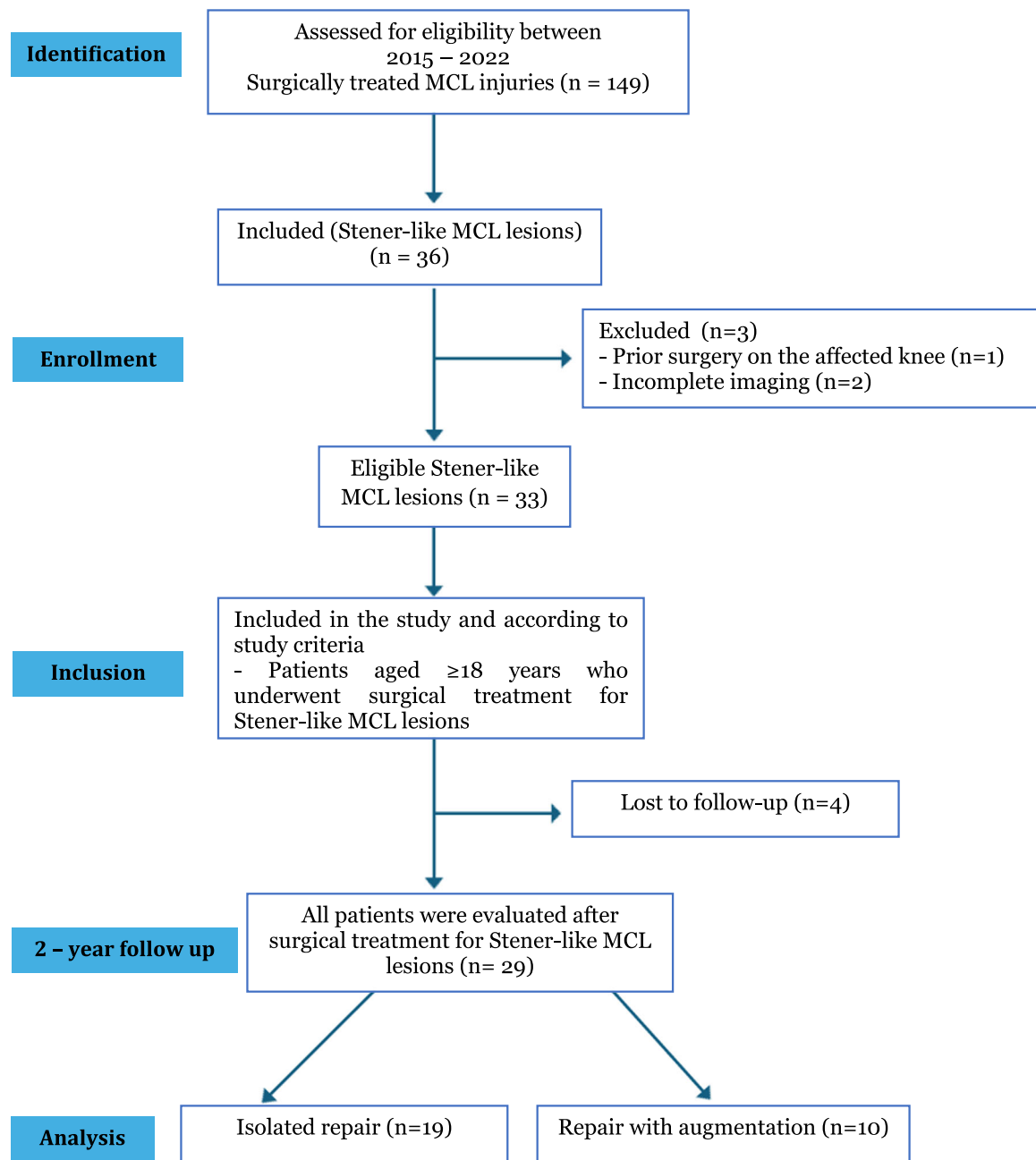


FIGURE 4 Flow diagram of patient selection and inclusion. MCL, medial collateral ligament.

patients (57.9%) in the isolated repair group and in four patients (40.0%) in the augmentation group ($p = 0.694$).

Associated fractures were identified in two patients (10.5%) in the isolated repair group, including one patellar fracture and one fibular head avulsion fracture, whereas no fractures were observed in the augmentation group ($p = 0.533$).

The mean time from injury to surgery was 29.9 ± 19.9 days in the isolated repair group and 39.2 ± 12.8 days in the repair with augmentation group, with no statistically significant difference between groups ($p = 0.199$) (Table 3).

Radiographic outcomes

Post-operative valgus stress radiographs demonstrated a significant reduction in medial joint gapping in both groups. In the isolated repair group, medial gapping decreased from 10.6 ± 2.9 mm pre-operatively to 7.1 ± 1.4 mm post-operatively, corresponding to a mean reduction of 3.4 ± 2.3 mm ($p < 0.001$). In the repair with augmentation group, medial gapping decreased from 10.8 ± 2.0 mm to 7.3 ± 1.8 mm, with a mean reduction of 3.4 ± 2.1 mm ($p = 0.021$).

TABLE 1 Demographics.

	Total (<i>n</i> = 29)	S-L MCL subgroups		<i>p</i> -Value
		Repair (<i>n</i> = 19)	Repair + Augmentation (<i>n</i> = 10)	
Age, mean (SD)	39.1 (13.4)	39.7 (12.4)	37.8 (13.0)	0.704
Male, <i>n</i> (%)	25 (86.2)	16 (80.2)	9 (90.0)	1.000
Right, <i>n</i> (%)	13 (44.8)	8 (42.1)	5 (50.0)	0.714
Smoker	8 (27.6)	5 (26.3)	3 (30.0)	1.000
BMI, mean (SD)	29.6 (5.1)	29.5 (5.9)	29.8 (4.5)	0.869
Follow up, mean (SD)	61.6 (27.2)	61.6 (26.4)	61.5 (30.8)	0.992

Note: Age expressed in years. Follow-up expressed in months.

Abbreviations: BMI, Body Mass Index; MCL, medial collateral ligament; SD, standard deviation; S-L, Stener-like.

TABLE 2 Injury pattern and surgical characteristics.

	Total (<i>n</i> = 29)	S-L MCL subgroups		<i>p</i> -Value
		Repair (<i>n</i> = 19)	Repair + Augmentation (<i>n</i> = 10)	
Isolate injury, <i>n</i> (%)	11 (37.9)	7 (36.8)	4 (40.0)	1.000
Multiligament injury, <i>n</i> (%)	18 (62.1)	12 (63.2)	6 (60.0)	1.000
ACL reconstruction, <i>n</i> (%)	16 (55.2)	11 (57.9)	5 (50.0)	0.728
PCL reconstruction, <i>n</i> (%)	3 (10.3)	1 (5.3)	2 (20.0)	0.256
PLC reconstruction, <i>n</i> (%)	1 (3.4)	1 (5.3)	0 (0.0)	1.000

Abbreviations: ACL, anterior cruciate ligament; MCL, medial collateral ligament; PCL, posterior cruciate ligament; PLC, posterolateral corner; S-L, Stener-like.

TABLE 3 Injury characteristics and associated procedures.

	Total (<i>n</i> = 29)	S-L MCL subgroups		<i>p</i> -Value
		Repair (<i>n</i> = 19)	Repair + Augmentation (<i>n</i> = 10)	
Isolated Stener-like lesion, <i>n</i> (%)	11 (37.9)	7 (36.8)	4 (40.0)	1.000
Multiligament injury, <i>n</i> (%)	18 (62.1)	12 (63.2)	6 (60.0)	
Meniscal procedures, <i>n</i> (%)	15 (51.7)	11 (57.9)	4 (40.0)	0.694
Associated fracture	2 (6.9)	2 (10.5)	0 (0.0)	0.533
Time from injury to surgery, mean (SD)	33.1 (17.8)	29.9 (19.9)	39.2 (12.8)	0.199

Note: Time to surgery expressed in days.

Abbreviations: MCL, medial collateral ligament; SD, Standard deviation; S-L, Stener-like.

The magnitude of medial gapping reduction did not differ significantly between groups (3.4 ± 2.3 mm vs. 3.4 ± 2.1 mm, $p = 0.985$) (Table 4).

Patient-reported outcomes (PROMs)

Regarding PROMs, the mean Lysholm score for the entire cohort was 89.3 (SD 15.4), with no significant differences between groups ($p = 0.940$). Similarly, no significant differences between groups were observed in any KOOS subscale. Based on the predefined

cutoffs, the distribution of Lysholm score categories was similar between groups ($p = 0.292$) (Table 5).

Failures, reoperations and complications

A total of seven post-operative complications were recorded (24.1%). In the isolated repair group, four complications occurred (21.1%), including one deep infection successfully managed with surgical irrigation and antibiotic therapy, two cases of post-operative stiffness requiring arthroscopic lysis of adhesions, and

TABLE 4 Radiographic outcomes (valgus stress radiographs).

	S-L MCL subgroups		p-Value
	Repair (n = 19)	Repair + Augmentation (n = 10)	
Preoperative medial gapping, mean (SD)	10.6 (2.9)	10.8 (2.0)	0.873
Post-operative medial gapping, mean (SD)	7.1 (1.4)	7.3 (1.8)	0.817
Reduction in medial gapping, mean (SD)	3.4 (2.3)	3.4 (2.1)	0.985

Note: Medial gapping expressed in millimetres.

Abbreviations: MCL, medial collateral ligament; SD, standard deviation; S-L, Stener-like.

TABLE 5 Patient-reported outcome measures.

	Total (n = 29)	S-L MCL subgroups		p-Value
		Repair (n = 19)	Repair + Augmentation (n = 10)	
Lysholm, mean (SD)	89.3 (15.4)	89.5 (14.6)	89.0 (17.7)	0.940
Lysholm categorised				0.292
Excellent (95–100)	18 (62.1%)	10 (52.6%)	8 (80.0%)	
Good (84–94)	1 (3.4%)	1 (5.3%)	0 (0%)	
Fair (65–83)	7 (24.1%)	6 (31.6%)	1 (10.0%)	
Poor (< 65)	3 (10.3%)	2 (10.5%)	1 (10.0%)	
KOOS symptoms, mean (SD)	87.7 (13.5)	89.4 (11.1)	84.4 (17.5)	0.706
KOOS Pain, mean (SD)	92.6 (11.0)	93.4 (10.5)	91.0 (12.3)	0.630
KOOS Function daily living, mean (SD)	96.9 (6.5)	97.8 (3.6)	95.3 (10.0)	0.604
KOOS Function sports and recreation, mean (SD)	82.2 (22.7)	81.4 (19.2)	83.8 (29.4)	0.362
KOOS QoL, mean (SD)	89.1 (20.8)	90.3 (19.1)	86.7 (24.7)	0.820

Abbreviations: KOOS, Knee Injury and Osteoarthritis Outcome Score; MCL, medial collateral ligament; QoL, quality of life; S-L, Stener-like; SD, standard deviation.

TABLE 6 Post-operative complications.

	Total (n = 29)	S-L MCL subgroups		p-Value
		Repair (n = 19)	Repair + Augmentation (n = 10)	
Deep infection, n (%)	2 (6.9)	1 (5.3)	1 (10.0)	1.000
Arthroscopic lysis of adhesions, n (%)	4 (13.8)	2 (10.5)	2 (20.0)	0.596
Failure requiring MCL reconstruction, n (%)	1 (3.4)	1 (5.3)	0 (0.0)	1.000
Total complications, n (%)	7 (24.1)	4 (21.1)	3 (30.0)	0.664

Abbreviations: MCL, medial collateral ligament; S-L, Stener-like.

one failure of the repair that required MCL reconstruction 22 months after the initial surgery due to persistent medial instability. In the repair with augmentation group, three complications were observed (30.0%), including one deep infection successfully treated with surgical irrigation and antibiotics and two cases of post-operative stiffness requiring arthroscopic lysis of adhesions. The overall complication rate did not differ significantly between groups ($p = 0.664$) (Table 6).

DISCUSSION

The most important finding of this study was that both isolated repair and repair with augmentation for Stener-like MCL lesions resulted in satisfactory radiographic stability, as both groups demonstrated a significant reduction in medial gapping on valgus stress radiographs. In addition, favourable functional outcomes were observed, with the majority of patients achieving excellent Lysholm scores and high KOOS subscale

scores at mid-term follow-up. However, contrary to our hypothesis, augmentation did not result in superior radiographic or clinical outcomes compared with isolated repair. These findings should be interpreted with caution, as the relatively small sample size and low number of events may have limited the ability to detect clinically meaningful differences between techniques. Furthermore, the incorporation of augmentation with autograft or allograft was not associated with a higher rate of complications or reoperations in this population.

The optimal surgical management of Stener-like MCL injuries remains poorly defined, particularly with respect to whether isolated anatomic repair is sufficient or whether augmentation may provide additional stability and improved clinical outcomes. In our cohort, the predominance of motor vehicle accidents suggests a high-energy injury pattern, which may contribute to the relatively high proportion of associated multiligament injuries. In this context, several case series have reported favourable outcomes following surgical treatment of Stener-like MCL lesions. Desai et al. [9] reported good functional outcomes in a series of 20 patients treated with isolated repair of Stener-like MCL lesions, most of them in the context of multiligament knee injuries, with mean Lysholm and International Knee Documentation Committee (IKDC) scores of 91.5 and 88.8, respectively. Similarly, Thompson et al. [26] reported a 100% return-to-sport rate in a cohort of 23 athletes who underwent surgical repair of Stener-like lesions, 10 of whom received additional augmentation using the ligament augmentation and reconstruction system (LARS). Jokela et al. [14] also reported satisfactory functional and radiological outcomes in a series of seven patients with Stener-like MCL lesions associated with Schenck II/III multiligament knee injuries; six patients underwent repair and one reconstruction, with median Lysholm and IKDC2000 scores of 75 and 62, respectively, and a median side-to-side medial opening difference of 2.5 mm. In our cohort, the mean Lysholm score was approximately 89 in both groups, which is comparable to the functional outcomes reported by Desai et al. Furthermore, the mean reduction in medial joint opening on valgus stress radiographs was approximately 3.4 mm compared with preoperative values, indicating substantial restoration of medial stability following surgical treatment. Nevertheless, the absence of consistent side-to-side comparison with the contralateral knee limits the ability to determine whether native valgus stability was fully restored.

Data regarding complications after surgical treatment of Stener-like MCL lesions remain scarce. In a recent systematic review, Grassi et al. [11] reported an overall complication rate of 10% among 70 patients described in the literature, with reoperation being the most frequent event (8.6%), including hardware removal, LARS removal, arthroscopic lavage, and MCL refixation. In the present study, the overall reoperation

rate was higher than that reported in the literature (24%), most commonly due to arthroscopic lysis of adhesions performed for post-operative stiffness (13.8%). However, no significant differences in complication rates were observed between the isolated repair and repair with augmentation groups. The relatively high rate of post-operative stiffness in our cohort may be partially explained by the high proportion of multiligament knee injuries and by the need to modify the post-operative rehabilitation protocol in some patients with associated procedures, such as meniscal repairs, which may have required more protective rehabilitation and temporary restrictions in early range of motion.

The absence of superior outcomes with augmentation observed in the present study may be explained by the biological characteristics of the MCL. Unlike intra-articular ligaments, the MCL has a rich vascular supply and a well-documented intrinsic healing capacity, consistent with the well-established regenerative potential of the MCL reported in previous studies [10, 17, 28]. In Stener-like lesions, the primary barrier to ligament restoration is mechanical rather than biological, as interposition of the pes anserinus tendons prevents direct ligament-to-bone contact at the distal tibial insertion. Once this interposition is removed and anatomic fixation of the distal MCL is restored, the native ligament may regain its stabilising function through biological recovery. In this context, additional augmentation with autograft or allograft may not provide a substantial biomechanical advantage over anatomic repair alone, which could explain the comparable radiographic and functional outcomes observed in the present study.

This study has several limitations. First, its retrospective design introduces inherent limitations, including the absence of randomisation and the potential for selection bias. Although baseline characteristics were comparable between groups, the decision to perform isolated repair or repair with augmentation was made intraoperatively based on surgeon judgement, including assessment of tissue quality and injury characteristics. This may have influenced treatment allocation and represents a potential source of selection bias. Furthermore, the interval between injury and surgery was relatively long in some patients, which may have influenced tissue quality and the stage of the healing process at the time of surgical treatment. The inclusion of patients with multiligament knee injuries may represent a potential source of confounding by indication, as associated ligament injuries could have influenced both treatment allocation and post-operative outcomes. Given the relatively small sample size and low number of events, subgroup analyses were not feasible and would likely be underpowered to detect meaningful differences. Second, the relatively small sample size and low number of events limit the statistical power of

the study, particularly for detecting differences in complications, failure rates, and PROMs. Therefore, the absence of statistically significant differences should not be interpreted as evidence of equivalence between techniques. This limitation is largely related to the low incidence of Stener-like MCL lesions. Moreover, the assumptions used for the a priori power analysis were based on limited data and not on a well-established clinically meaningful threshold, potentially underestimating the required sample size. In addition, a variety of repair and augmentation techniques were used across the cohort, reflecting the absence of a standardised surgical strategy for this uncommon injury pattern and potentially introducing additional heterogeneity in the analysis. Furthermore, all procedures were performed at a single institution by the same surgical team, which may limit the generalisability of our findings to other clinical settings. Finally, post-operative radiographic evaluation was limited to valgus stress radiographs. Medial compartment gapping was assessed using absolute values rather than side-to-side comparison with the contralateral knee, which may limit the ability to account for individual baseline laxity. Although these measurements provide an objective assessment of medial stability, additional imaging modalities or instrumented laxity measurements could have provided further insight into the biomechanical performance of each surgical strategy.

Despite these limitations, the present study has several strengths. To our knowledge, this is the first study to directly compare isolated repair and repair with augmentation for Stener-like MCL lesions. Additionally, the study includes a relatively large cohort for this uncommon injury pattern and provides mid-term follow-up of more than 5 years. Another strength is the inclusion of both radiographic and patient-reported outcomes, allowing a comprehensive evaluation of medial stability and functional recovery. Finally, all procedures were performed by the same team of fellowship-trained knee surgeons using standardised surgical principles and post-operative rehabilitation protocols, which contributes to the internal consistency of the results.

CONCLUSION

Surgical treatment of Stener-like MCL lesions resulted in good radiographic and functional outcomes at mid-term follow-up. Both isolated repair and repair with augmentation achieved significant reduction in medial gapping and comparable PROMs. Augmentation with autograft or allograft was not associated with superior clinical or radiographic benefit compared with isolated repair. These findings suggest that anatomic repair alone may be sufficient to restore medial stability in most cases of Stener-like MCL lesions, although this

should be interpreted with caution given the limited sample size.

AUTHOR CONTRIBUTIONS

We declare that all authors have seen and agreed to the submitted version of the article, and are responsible for it, and that all authors have participated in authorship and the article has not been submitted to any other journal. Rodrigo Olivieri designed the study, coordinated the team, participated in data collection, abstract writing, manuscript drafting, and bibliographic references, and is the corresponding author. José Tomás Muñoz participated in data collection and development for approval by the ethics committee of our institution. Marco Koch was responsible for synthesis and writing of results, statistical analysis, and tables preparation. Rodrigo Rojas participated in data collection and worked on abstract writing and methods. Nicolás Franulic, Piero Innocenti and Tomás Pineda worked on introduction and methods writing. Alberto Grassi participated in advising the statistical analysis and in correcting the drafting of the introduction, methods, and discussion sections of the manuscript.

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CONFLICT OF INTEREST STATEMENT

The author, Rodrigo Olivieri, reports speaking fees from Johnson & Johnson Medtech. The remaining authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

ETHICS STATEMENT

The study was conducted in accordance with the ethical standards outlined in the Declaration of Helsinki and Resolution 008430 of 1993. It was approved by the Institutional Ethics Committee (internal code CEC/05/2026), and informed consent was obtained from all patients participating in the study at the time the functional scales were administered.

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