Multiple-Ligament Knee Injuries: A Systematic Review of the Timing of Operative Intervention and Postoperative Rehabilitation

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Background: Traumatic knee dislocations that result in multiple-ligament knee injuries are unusual and are poorly studied. We are not aware of any prospective data regarding their treatment. Both the optimum timing of surgery for repair or reconstruction and the aggressiveness of rehabilitation are debated. The purpose of this systematic review was to compare the outcomes of early, delayed, and staged procedures as well as the subsequent rehabilitation protocols.

Methods: We surveyed the literature and retrieved twenty-four retrospective studies, involving 396 knees, dealing with the surgical treatment of the most severe multiple-ligament knee injuries (those involving both cruciate ligaments and either or both collateral ligaments). Data were extracted, and surgical timing was categorized as acute, chronic, or staged. Early postoperative mobility and immobilization were also compared.

Results: We found that acute treatment was associated with residual anterior knee instability when compared with chronic treatment (odds ratio, 2.58; 95% confidence interval, 1.2 to 5.8; $p = 0.018$). Significantly more patients who were managed acutely were found to have more flexion deficits when compared with those who were managed chronically (odds ratio, 5.18; 95% confidence interval, 1.5 to 17.5; $p = 0.004$). Staged treatments yielded the highest percentage of excellent and good subjective outcomes (79%; 95% confidence interval, 62.2% to 89.3%). Additional treatment for joint stiffness was significantly more likely in association with acute treatment (17%; 95% confidence interval, 13.0% to 22.4%; $p < 0.001$) and staged treatment (15%; 95% confidence interval, 7.6% to 28.2%; $p = 0.001$) when each was compared with chronic treatment (0% [zero of seventy-one]; 95% confidence interval, 0.0% to 5.1%). Early mobility was not associated with increased joint instability in acutely managed patients. Early mobility yielded fewer range-of-motion deficits but did not reduce the rate of follow-up manipulation or arthrolysis.

Conclusions: This review of the available literature suggests that delayed reconstructions of severe multiple-ligament knee injuries could potentially yield equivalent outcomes in terms of stability when compared with acute surgery. However, in the acutely managed patient, early mobility is associated with better outcomes in comparison with immobilization. Acute surgery is highly associated with range-of-motion deficits. Staged procedures may produce better subjective outcomes and a lower number of range-of-motion deficits but are still likely to require additional treatment for joint stiffness. More aggressive rehabilitation may prevent this from occurring in multiple-ligament knee injuries that are treated acutely.

Level of Evidence: Therapeutic Level III. See Instructions to Authors for a complete description of levels of evidence.

Multiple-ligament knee injuries are rare[1-3] and potentially limb-threatening traumatic events that require careful evaluation and thoughtful treatment. Numerous surgical protocols have been proposed for the treatment of these unusual injuries[4-9]. Evidence-based guidelines for operative and postoperative treatment are sparse because of the

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dearth of prospective, randomized, controlled studies in this population. In addition, the severity and classification of the injuries that have been examined, the surgical techniques that have been utilized, the timing of surgical intervention, the postoperative rehabilitation, and the reporting of surgical outcomes have varied greatly among existing case series in the literature.

The degree of ligament, other soft-tissue, and neurovascular injury occurs across a spectrum in patients with traumatic dislocation of the knee. The prevalence of medial and lateral collateral ligament damage in addition to bicruciate ligament disruption has been shown to be highest in association with the most severe knee dislocations that require assisted reduction[10]. Considerations for the timing of surgery and subsequent rehabilitation change dramatically when the medial and/or lateral structures are disrupted in addition to the cruciate ligaments. Despite the need to treat these more severe dislocations differently, they often have been reported in the literature together with less-severe ligament disruptions. Pooling of these data is due to the variations in the classification of knee dislocations.

Schenck[11] proposed a concise knee-injury classification system that is based primarily on which ligaments are torn. Unicruciate and bicruciate knee dislocations (KDI and KDII, respectively) are classified separately from knee dislocations involving both cruciate ligaments and either the medial or lateral collateral ligaments (KDIIIM and KDIIIL, respectively) as well as those with damage to all four ligaments (KDIV). This classification system provides a basis for comparing reports of multiple-ligament knee injuries in the literature that are based on knee injury severity.

There appears to be a lack of consensus among experts regarding how to treat multiple-ligament knee injuries. Many authors have reported acceptable outcomes in association with acute surgical repair and/or reconstruction of damaged ligaments[12-26], whereas others[27-29] have advocated delayed treatment if concomitant medial collateral ligament or posterolateral corner injuries exist. Still others have reported acceptable outcomes when the repair and reconstruction are staged[30-33]. Different rehabilitation protocols are superimposed on these varying surgical approaches. Some authors have advocated early range of motion[18,21,34], whereas others have supported early immobilization[13,27,28,35]. Philosophies with regard to operative timing as well as rehabilitation have differed on the basis of the need to balance the restoration of joint stability and the complication of postoperative joint stiffness. Ultimately, the rarity of severe multiple-ligament knee injuries, combined with these interstudy and intrastudy variations, has impeded our ability to make evidence-based treatment recommendations. An in-depth analysis of the reported literature is therefore indicated to allow for improved treatment and additional study of these injuries.

The purpose of the present systematic review was to review the current literature regarding the operative treatment of multiple-ligament knee injuries that are classified as at least KDIIIM, KDIIIL, or KDIV in an attempt to determine whether early, late, or staged interventions result in better outcomes. Within the early and delayed-treatment groups, the effect of early postoperative mobility as compared with early immobilization will be analyzed separately.

Materials and Methods

Literature Search

A literature search was conducted with use of MEDLINE from 1950 to 2008 and Web of Science from 1970 to 2008. Search terms included "knee dislocation and reconstruction" and "multiple ligament and knee" and were limited to original clinical research articles involving humans that were published in the English language. All potentially relevant articles were retrieved and reviewed. Reference lists of the selected articles were reviewed, and pertinent publications were also included. Review articles, case reports, studies of open knee dislocation, and studies of the treatment of class-KDI and KDII knee dislocations were excluded.

Selection of Studies

All studies that were included in the analysis evaluated outcomes after the surgical treatment of injury of the anterior cruciate ligament, posterior cruciate ligament, and at least one of the collateral ligaments. In order for a study to be included in the present review, at least 75% of the injuries had to be classified as KDIIIM, KDIIIL, or KDIV according to the Schenck classification system. All potential articles were retrospective studies with a level of evidence of III or IV.

Objective Outcome Measures (Table I)

We recorded categories of objective outcomes from reported data on instrumented arthrometry; stress radiography; manual tests, such as the Lachman test, the posterior drawer test, the varus stress test at 30°, and the valgus stress test at 30°; and range of motion.

Subjective Outcome Measures (Table I)

We categorized subjective outcomes on the basis of reported data that included the International Knee Documentation Committee subjective knee-evaluation form (IKDC), the Lysholm scale[36], Meyers ratings[1,2], the Taylor criteria[37], the Cincinnati knee-rating system[38], return-to-work status, and return-to-athletics status. Lysholm scores were treated as a separate data point from the other subjective scoring systems because they were reported as separate entities within the literature as well. More than one-third (146) of the 396 patients who were included in the final analysis had continuous subjective outcomes (Lysholm scores) reported in addition to dichotomous subjective outcomes (the remaining scoring systems). In addition, the Lysholm scoring scale places a higher emphasis on the patient's interpretation of his or her function and the presence or absence of signs of instability[36].

Data Extraction

Retrieved references were evaluated independently by the authors. Outcome data were divided into the three categories: (1) acute treatment (time to surgery, less than three weeks), (2) chronic treatment (time to surgery, more than three weeks), and (3) staged treatment (a combination of both repair and reconstruction in both the acute and chronic periods) (see Appendix). Outcome data for patients managed both acutely and chronically that were averaged or that were not reported separately on the basis of the timing of surgery were excluded. Data were also excluded from comparison if the time from the injury to surgery was not reported. Outcome data were classified within these categories according to the system shown in Table I.

Only data reported as exact measurements were included in the analysis for all of the dichotomous categories. For example, if the average amount of varus or valgus laxity was reported in degrees (i.e., as a continuous variable) as opposed to the exact number of participants who fulfilled the criteria of that variable, then these data were excluded.

Data were then also categorized into two groups of postoperative rehabilitation within the acute and chronic treatment groups. The two rehabilitation groups were (1) early postoperative mobility and (2) postoperative immobilization. Data were included in the early postoperative mobility group if >30° of active or passive range of motion was allowed within the first three postoperative weeks, and they were included in the postoperative immobilization group if active or passive flexion was limited to ≤30° in the first three postoperative weeks. The results of these classifications are listed in tables in the Appendix.

TABLE I Classification of Outcome Data

Classification	Outcome
Objective outcomes	
Anterior instability*	≥5 mm of anterior tibial translation on instrumented arthrometry
	≥2+ (≥6 mm of anterior tibial translation) on Lachman test
Posterior instability*	≥5 mm of posterior tibial translation on instrumented arthrometry
	≥6 mm of posterior translation on stress radiography
	≥2+ (≥6 mm of posterior tibial translation) on posterior drawer test
Valgus laxity	≥2+ (≥6 mm of medial joint opening) with manual valgus stress at 30°
Varus laxity	≥2+ (≥6 mm of lateral joint opening) with manual varus stress at 30°
Range of motion†	Average total arc (in degrees)
	Number of patients with loss of flexion ≥10°
	Number of patients with loss of extension ≥5°
Patients requiring follow-up surgery‡	Number of patients requiring postoperative manipulation under anesthesia
	Number of patients requiring operative arthrolysis
Subjective outcomes	
Excellent or good§	IKDC scores of normal (A) or nearly normal (B)
	Cincinnati knee score of excellent or good
	Meyers rating of excellent
	Taylor rating of good
Poor§	IKDC score of severely abnormal (D)
	Cincinnati knee score of poor
	Meyers rating of poor
	Taylor rating of poor
Lysholm	Average score
Return to work	Number of patients returning to work, regardless of whether or not symptoms were reported in the work environment
Return to athletics	Number of patients returning to athletics at the same, or nearly the same, as pre-injury level as reported by study authors

*Instrumented arthrometry and radiographic stress data took precedence over manual physical examination data when both were reported. †If range of motion was reported as "full" for all patients, a value of 0° of extension and 130° of flexion was assigned. Reference points of 0° of extension and 130° of flexion were also used to determine loss of range of motion when discrete values for total range-of-motion loss in comparison with the contralateral knee were not reported. ‡If postoperative range of motion and complications were both discussed and there was no mention of either of these procedures, for comparison it was assumed that the number for that particular treatment group was zero. §When it was possible to tally the number of IKDC (International Knee Documentation Committee) scores for acutely and chronically managed patients individually and other subjective outcomes scales were also reported, IKDC totals took precedence over other subjective outcome scores.

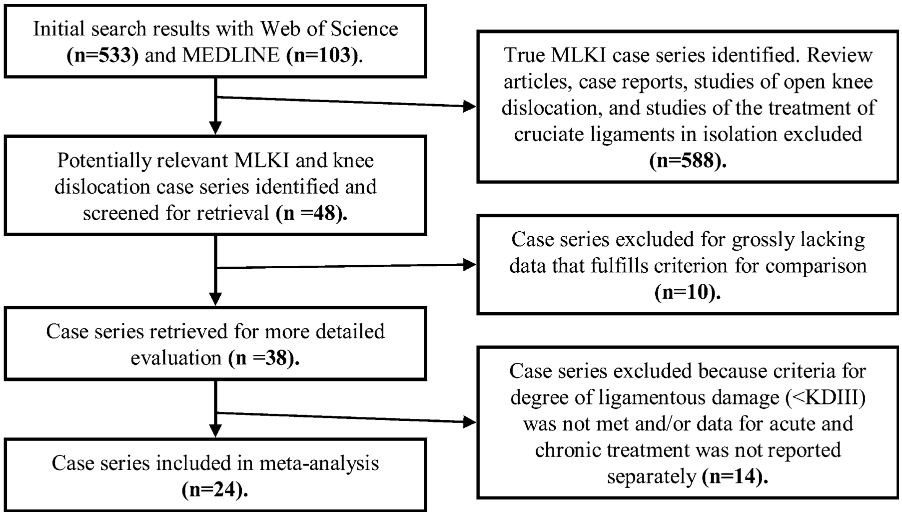

Fig. 1

Summary of literature review and selection process. MLKI = multi-ligament knee injury, and KDIII = knee dislocation involving both cruciate ligaments and either the medial or lateral collateral ligaments.

Statistical Analysis

Weighted means (and their 95% confidence intervals) were calculated for dichotomous variables (that is, all variables except mean range of motion and Lysholm score) by dividing the total number of patients with an outcome of interest by the number of patients without the outcome of interest in each treatment group. The results of all studies for each treatment option were also pooled. Odds ratios were then calculated to compare the prevalence of each dichotomous variable between the different surgical timing and rehabilitation protocols. The following comparisons were made on the basis of the odds ratio (and 95% confidence interval): (1) acute treatment compared with chronic treatment, (2) acute treatment compared with staged treatment, and (3) chronic treatment compared with staged treatment. Within the acute and chronic treatment groups, comparisons were made between the patients who were immobilized postoperatively and those who were permitted early mobility.

Weighted averages, standard deviations, and 95% confidence intervals were calculated for the two continuous variables (the Lysholm score and total range of motion) for the same treatment conditions as described above. For these measures, significant differences were evaluated by observing whether or not there was overlap in the 95% confidence intervals or if the 95% confidence intervals for the odds ratio excluded 1 for the respective treatment conditions. When the confidence interval for the odds ratio excludes 1, there is a 95% chance that the relative risk of a given outcome occurring is due to treatment timing or rehabilitation regimen alone and not to random error. All 95% confidence intervals were calculated with use of Confidence Interval Analysis software version 2.1.2 (University of Southampton, Southampton, United Kingdom). The Pearson chi-square test of independence was also used to determine the probability of observing a difference between dichotomous variables. The criterion for significance was also set at $p < 0.05$.

Source of Funding

There was no external funding received in support of this study.

Results

The initial search of MEDLINE and Web of Science identified 636 studies, forty-eight of which dealt with multiple-ligament knee injuries and were further reviewed (Fig. 1). Ten studies were immediately excluded because they lacked outcome data that met the criterion for comparison. Data from the remaining thirty-eight articles were cataloged. The more stringent criteria (specifically, the requirement that >75% of subjects had to fulfill the injury severity threshold [at least KDIII] and the requirement that the outcomes for acutely and chronically managed subjects had to be reported completely separately) were then applied. Fourteen studies that lacked completely separate reporting of acute and chronic treatment data, as well as the acute cohort in the study by Liow et al.[39] (in which only three of eight patients had an injury severity of at least KDIII), and the chronic cohort in the study by Harner et al.[13] (in which only seven of twelve patients had an injury severity of at least KDIII) were then excluded. A total of twenty-four studies fulfilled our final inclusion criteria. The characteristics of the acute, chronic, and staged treatment groups are shown in tables in the Appendix.

The overall outcomes are summarized in Tables II, III, and IV and Figure 2.

Ligament Stability

Anterior Instability

Acute treatment led to a significantly greater (odds ratio, 2.58; 95% confidence interval, 1.2 to 5.8; p = 0.018) proportion of patients who demonstrated anterior instability (17%; 95% confidence interval, 12.8% to 23.3%) when compared with chronic treatment (7.5%; 95% confidence interval, 3.9% to

TABLE II Outcomes for Each Surgical Timing Group

Timing	N	Anterior Instability	Posterior Instability	Varus Laxity	Valgus Laxity	Average Range of Motion	Flexion Loss ≥10°
Acute	244						
Percentage (95% confidence interval)*		17.4 (12.8 to 23.3)†	15.3 (11.0 to 21.0)	6.7 (3.8 to 11.5)	8.5 (5.1 to 13.7)	124.5°	1.4 (25.1 to 38.0)‡
No. of patients		35 of 201	31 of 202	11 of 165	14 of 165	147	58 of 185
Chronic	106						
Percentage (95% confidence interval)*		7.5 (3.9 to 14.2)	13.2 (8.0 to 21.0)	5.4 (2.3 to 12.1)	4.3 (1.7 to 10.7)	130.5°	8.1 (2.8 to 21.3)
No. of patients		8 of 106	14 of 106	5 of 92	4 of 92	8	3 of 37
Staged	46						
Percentage (95% confidence interval)*		10.9 (4.7 to 23.0)	9.1 (3.1 to 23.6)	3.0 (0.5 to 14.3)	0.0 (0.0 to 10.4)	129.4°	0.0 (0.0 to 17.6)
No. of patients		5 of 46	3 of 33	1 of 33	0 of 33	46	0 of 18

*Applies to all values except for the average range of motion, which is expressed in degrees, and the average Lysholm score, which is expressed in points. †Significantly greater than the chronic treatment group (odds ratio, 2.58; 95% confidence interval, 1.2 to 5.8; p = 0.018). ‡Significantly greater than the chronic group (odds ratio, 5.18; 95% confidence interval, 1.5 to 17.5; p = 0.004) and the staged treatment group (odds ratio not applicable based on 95% confidence interval; p = 0.005). §Significantly less than the staged treatment group (odds ratio, 0.09; 95% confidence interval, 0.02 to 0.39; p < 0.001). #Significantly less than the acute (p < 0.001) and staged (p = 0.001) treatment groups (odds ratio not applicable based on 95% confidence interval). **Significantly greater than the chronic treatment group (odds ratio, 6.25; 95% confidence interval, 2.3 to 16.7; p < 0.001) and the acute treatment group (odds ratio 3.44; 95% confidence interval, 1.4 to 8.3; p = 0.004).

14.2%). There were no significant differences in anterior instability between the acute and staged groups or between the staged and chronic groups. There were no significant differences in anterior instability with regard to postoperative rehabilitation.

Posterior Instability

There were no significant differences between patients with posterior instability when they were compared on the basis of surgical timing. Rehabilitation protocols, however, did significantly affect posterior stability. Within the acute treatment group, posterior instability was found in 28% of patients who were managed with immobilization and 12% of those who were managed with early mobilization (odds ratio, 3.17; 95% confidence interval, 1.4 to 6.9; p = 0.003).

Varus Laxity

There were no significant differences in terms of varus laxity when the comparison was based on surgical timing. Significant differences were found when postoperative rehabilitation protocols differed. Within the acute treatment group, varus laxity was found in 21% of patients managed with immobilization, compared with only 1.6% of patients managed with early mobilization (odds ratio, 16.50; 95% confidence interval,

TABLE III Results of Acute Treatment Based on Rehabilitation Protocol

Postoperative Rehabilitation	N	Anterior Instability	Posterior Instability	Varus Laxity	Valgus Laxity	Average Range of Motion	Flexion Loss ≥10°
Immobilization	75						
Percentage (95% confidence interval)*		20.4 (11.8 to 32.9)	27.8 (17.6 to 40.9)†	21.4 (11.7 to 35.9)†	26.2 (15.3 to 41.1)†	121.8°	47.8 (36.5 to 59.4)†
No. of patients		11 of 54	15 of 54	9 of 42	11 of 42	37	33 of 69
Early mobility	169						
Percentage (95% confidence interval)*		16.2 (11.1 to 23.0)	10.8 (6.8 to 16.8)	1.6 (0.4 to 5.7)	2.4 (0.8 to 6.9)	125.4°	21.6 (15.0 to 29.9)
No. of patients		24 of 148	16 of 148	2 of 123	3 of 123	110	25 of 116

*Applies to all values except for the average range of motion, which is expressed in degrees, and the average Lysholm score, which is expressed in points. †Significantly greater than the early mobility group (p = 0.003 for posterior instability, p < 0.001 for varus laxity, p < 0.001 for valgus laxity, p < 0.001 for flexion loss, p = 0.024 for extension loss, and p = 0.031 for severely abnormal/poor scores). ‡Significantly less than the early mobility group (p = 0.008). §NR = Not reported.

TABLE II (*continued*)

Extension Loss ≥5°	Excellent/ Good Scores	Severely Abnormal/Poor Scores	Average Lysholm Score	Return to Work	Return to Athletics	Manipulation/ Arthrolysis
7.9 (4.8 to 12.8)	51.5 (44.6 to 58.4)	10.1 (6.6 to 15.1)	83.1 points	89.0 (82.6 to 93.2)	43.6 (34.3 to 53.3)§	17.2 (13.0 to 22.4)
14 of 177	102 of 198	20 of 198	165	121 of 136	44 of 101	42 of 244
5.4 (1.5 to 17.7)	37.3 (25.3 to 51.0)	10.8 (4.3 to 24.7)	85.4 points	100.0 (51.0 to 100.0)	68.8 (44.4 to 85.8)	0.0 (0.0 to 5.1)#
2 of 37	19 of 51	4 of 37	73	4 of 4	11 of 16	0 of 71
0.0 (0.0 to 11.0)	78.8 (62.2 to 89.3)**	0.0 (0.0 to 10.4)	85.0 points	100.0 (74.1 to 100.0)	90.0 (69.9 to 97.2)	15.2 (7.6 to 28.2)
0 of 31	26 of 33	0 of 33	37	11 of 11	18 of 20	7 of 46

3.4 to 80.1; $p < 0.001$). One study was much larger than the others within this comparison[16] and was excluded to determine if it might be more useful to examine its results separately. When six of the nine patients who were immobilized and were reported in this single study to have varus instability were excluded from the comparison, this difference remained significant ($p = 0.042$). Within the chronic treatment group, varus laxity was found in 1% of patients managed with immobilization and 20% of patients managed with early mobilization (odds ratio, 0.056; 95% confidence interval, 0.01 to 0.54; $p = 0.001$).

Valgus Laxity

There were no significant differences in valgus laxity on the basis of surgical timing. A significant difference was found on the basis of rehabilitation. Within the acute treatment group, valgus laxity was found in 26% of patients managed with immobilization and 2% of those managed with early mobilization (odds ratio, 14.2; 95% confidence interval, 3.7 to 54.0; $p < 0.001$).

Range of Motion

Average Range of Motion

No significant differences were found in terms of mean range of motion when the groups were compared on the basis of surgical timing or rehabilitation. Range-of-motion values were reported for only eight patients in the chronic treatment group. The standard deviation for the average range of motion for these eight patients was not reported and therefore a statistical comparison could not be performed.

Flexion Loss of ≥10°

Significantly more patients in the acute treatment group (31%; 95% confidence interval, 25.1% to 38.0%) were found to have flexion loss of ≥10° when compared with patients in the chronic treatment group (8%; 95% confidence interval, 2.8%

TABLE III (*continued*)

Extension Loss ≥5°	Excellent/Good Scores	Severely Abnormal/ Poor Scores	Average Lysholm Score	Return to Work	Return to Athletics	Manipulation/ Arthrolysis
14.8 (7.7 to 26.6)†	50.7 (39.6 to 61.7)	16.0 (9.4 to 25.9)†	87.5 points	77.4 (60.2 to 88.6)‡	NR§	10.7 (5.5 to 19.7)
8 of 54	38 of 75	12 of 75	42	24 of 31	—	8 of 75
4.9 (2.3 to 10.2)	52.0 (43.3 to 60.7)	6.5 (3.3 to 12.3)	82.0 points	93.9 (87.3 to 97.2)	43.6 (34.3 to 53.3)	20.1 (14.8 to 26.6)
6 of 123	64 of 123	8 of 123	146	92 of 98	44 of 101	34 of 169

TABLE IV Results of Chronic Treatment Based on Rehabilitation Protocol

Postoperative Rehabilitation	N	Anterior Instability	Posterior Instability	Varus Laxity	Valgus Laxity	Average Range of Motion	Flexion Loss ≥10°
Immobilization	86						
Percentage (95% confidence interval)*		9.3 (4.8 to 17.3)	10.5 (5.6 to 18.7)	1.4 (0.2 to 7.5)	5.6 (2.2 to 13.4)	NR†	11.8 (3.3 to 34.3)
No. of patients		8 of 86	9 of 86	1 of 72	4 of 72	—	2 of 17
Early mobility	20						
Percentage (95% confidence interval)*		0.0 (0.0 to 16.1)	25.0 (11.2 to 46.9)	20.0 (8.1 to 41.6)‡	0.0 (0.0 to 16.1)	130.5°	5.0 (0.9 to 23.6)
No. of patients		0 of 20	5 of 20	4 of 20	0 of 20	8	1 of 20

*Applies to all values except for the average range of motion, which is expressed in degrees, and the average Lysholm score, which is expressed in points. †NR = not reported. ‡Significantly greater than the immobilization group (p = 0.001).

to 21.3%) (odds ratio, 5.18; 95% confidence interval, 1.5 to 17.5; p = 0.004). Significantly fewer patients also were found to have flexion loss when managed in stages (0% [zero of eighteen]; 95% confidence interval, 0.0% to 17.6%; p = 0.005) when compared with those who were managed acutely. A significant difference also was found among patients in the acute treatment group when they were compared on the basis of rehabilitation. Within the acute treatment group, flexion loss of ≥10° was reported in 48% of those who were immobilized, compared with 28% of those who were allowed early mobilization (odds ratio, 3.3; 95% confidence interval, 1.8 to 6.4; p < 0.001).

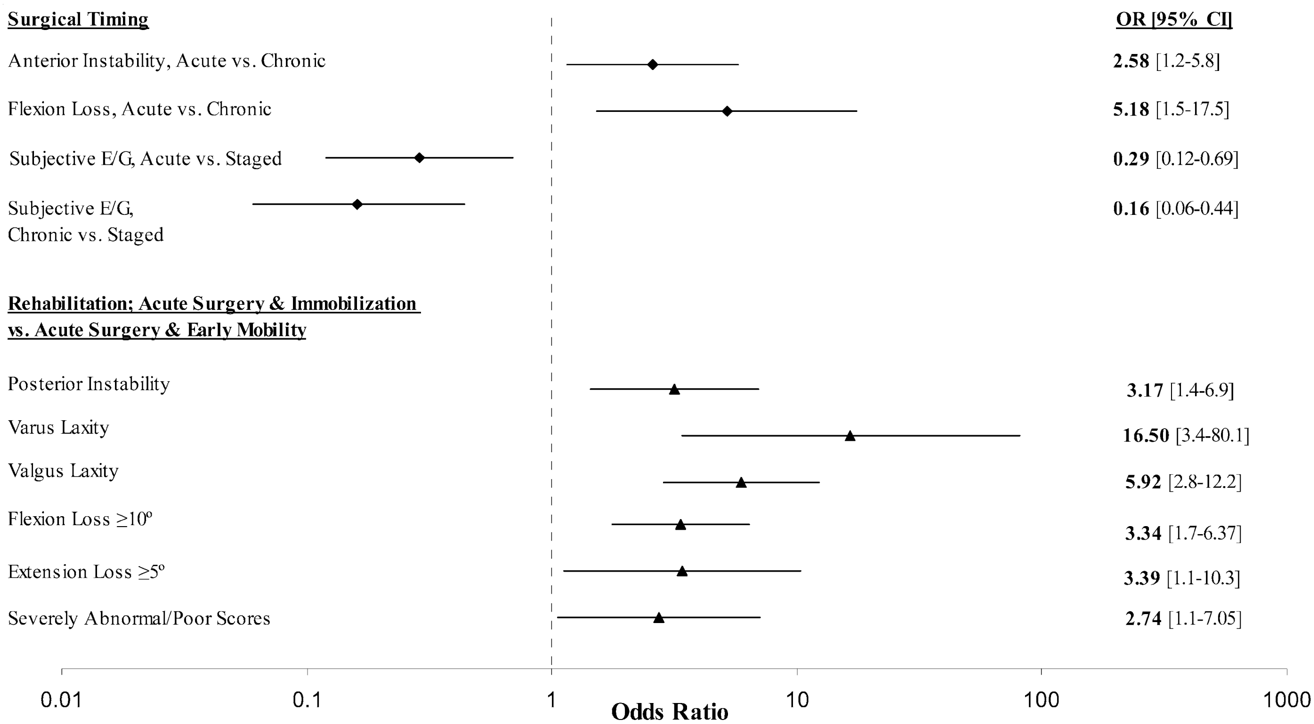

Fig. 2

Odds ratios are illustrated relative to 1. The comparisons being made are labeled to the left of the figure with the odds ratio (OR) and 95% confidence interval (CI) listed to the right of the figure. They are plotted on a logarithmic scale. In the surgical timing comparisons, values of >1 indicate that the variable is more likely to occur in the acute treatment group. Values of <1 indicate that excellent/good outcomes (E/G) were less likely to occur in both the acute and chronic treatment groups when compared with staged treatments. In the rehabilitation comparison of acutely managed patients, all of the variables listed were more likely to occur (odds ratio, >1) if the patients were immobilized rather than if they were permitted early range of motion postoperatively. All listed comparisons showed significant differences.

TABLE IV (*continued*)

Extension Loss ≥5°	Excellent/Good Scores	Severely Abnormal/ Poor Scores	Average Lysholm Score	Return to Work	Return to Athletics	Manipulation/ Arthrolysis
0.0 (0.0 to 18.4)	32.3 (18.6 to 49.9)	11.8 (3.3 to 34.3)	85.7 points	NR†	NR†	0.0 (0.0 to 7.0)
0 of 17	10 of 31	2 of 17	69	—	—	0 of 51
10.8 (2.8 to 30.1)	45.0 (25.8 to 65.8)	10.0 (2.8 to 30.1)	79.3 points	100 (51.0 to 100.0)	68.8 (44.4 to 85.8)	0.0 (0.0 to 16.1)
2 of 20	9 of 20	2 of 20	4	4 of 4	11 of 16	0 of 20

Extension Loss of ≥5°

There were no differences in terms of the percentage with reported extension loss when the comparison was based on surgical timing. A significant difference was found on the basis of rehabilitation within the acute treatment group. Extension loss was reported in 15% of patients who were immobilized, compared with 5% of those who were permitted early mobilization (odds ratio, 3.4; 95% confidence interval, 1.1 to 10.3; $p = 0.024$).

Subjective Outcomes

Patients with Excellent or Good Subjective Outcome Scores

The percentage of patients who had excellent or good subjective outcomes in the staged treatment group (79%; 95% confidence interval, 62.2% to 89.3%) was significantly greater than that in the chronic treatment group (37%; 95% confidence interval, 25.3% to 51.0%) (odds ratio, 6.25; 95% confidence interval, 2.3 to 16.7; $p < 0.001$) and than in the acute treatment group (52%; 95% confidence interval, 44.6% to 58.4%) (odds ratio, 3.44; 95% confidence interval, 1.4 to 8.3; $p = 0.004$). No differences were seen on the basis of rehabilitation.

Patients with Severely Abnormal or Poor Subjective Outcome Scores

Within the acute treatment group, significantly more severely abnormal/poor outcomes were found among patients who were managed with immobilization (16%; 95% confidence interval, 9.4% to 25.9%) than among those who were permitted early mobilization (7%; 95% confidence interval, 3.3% to 12.3%) (odds ratio, 2.7; 95% confidence interval, 1.1 to 7.1; $p = 0.031$). No differences were found on the basis of surgical timing.

Average Lysholm Score

No significant differences in the average Lysholm score were found between any of the groups when compared on the basis of surgical timing or rehabilitation.

Return to Work

Acutely managed patients who were immobilized early were significantly less likely to return to work than those who were mobilized early (odds ratio, 0.22; 95% confidence interval, 0.07 to 0.73; $p = 0.008$). No differences were found on the basis of surgical timing.

Return to Athletics

Patients who were managed acutely were significantly less likely to return to athletics than those who were managed in stages (odds ratio, 0.09; 95% confidence interval, 0.02 to 0.39; $p < 0.001$). However, data pertaining to this outcome were reported for only sixteen and twenty patients in the chronic and staged treatment groups, respectively.

Patients Requiring Manipulation Under Anesthesia or Operative Arthrolysis

Significantly fewer patients (0% [zero of seventy-one]; 95% confidence interval, 0.0% to 5.1%) in the chronic treatment group underwent follow-up manipulation or arthrolysis when compared with both the acute treatment group (17%; 95% confidence interval, 13.0% to 22.4%; $p < 0.001$) and the staged treatment group (15%; 95% confidence interval, 7.6% to 28.2%; $p = 0.001$).

Discussion

To our knowledge, this is the first systematic review that has analyzed the timing of surgery and postoperative treatment of multiple-ligament knee injuries. The results demonstrate that anterior knee instability was more likely to be a complication following the acute treatment of multiple-ligament knee injuries. Severe flexion losses as well as the need to undergo a second operation or manipulation under anesthesia for the treatment of knee stiffness were also more likely for patients who were managed acutely. Conversely, patients who were managed chronically had a significantly lower proportion of excellent/good subjective outcomes in comparison with those who were managed acutely. There was no difference in Lysholm scores between acutely and chronically managed patients. Postoperative immobilization resulted in significantly poorer outcomes for almost all variables in patients who were managed acutely. Finally, early motion only seemed to have a deleterious effect in patients who had delayed (chronic) treatment.

Joint Stability

The present review indicates that valgus laxity was more prevalent in patients who were managed acutely in comparison with those who were managed with delayed (chronic) surgery, although this difference was not significant. Therefore, complete knee dislocations with multidirectional instability may require reconstruction of the medial collateral ligament to restore satisfactory valgus stability. Grade-I and II medial collateral ligament injuries have been shown to heal with satisfactory stability following nonoperative treatment if found in isolation[40-43] or with concomitant cruciate ligament injury[44]. Less severe medial collateral ligament injuries with bicruciate injury may benefit from four to eight weeks of nonoperative treatment, allowing the medial collateral ligament to heal prior to cruciate reconstruction[27,28,45,46]. However, when bicruciate injuries are associated with grade-III medial collateral ligament tears, as is often the case with knee dislocations[47], treatment options are less clear. Some authors have advocated that these injuries be repaired primarily with simultaneous cruciate ligament reconstruction[5,18,48,49]. Primary repair of the medial collateral ligament is more difficult when delayed past the initial weeks following the injury because of scar formation and tissue retraction. Conversely, when the anterior cruciate ligament is reconstructed acutely, postoperative motion limitations have been encountered[50-52]. Concomitant medial collateral ligament repair also may increase the risk of range-of-motion complications[53-55].

The current review also indicates that varus laxity has been reported most often in patients who have been managed acutely. Many of the same issues that pertain to the timing of the surgical treatment of the medial collateral ligament in patients with multiple-ligament knee injuries also arise when addressing injuries involving the posterolateral corner. Chronic repair of the posterolateral corner is often complicated by scar tissue, poorly defined anatomic landmarks, and changes in limb alignment. Early repair has been recommended to avoid these complications[9,46,56,57]. However, increased tensile stress has been measured in the cruciate ligaments of knees that lack the secondary support of the posterolateral corner structures[58,59]. Therefore, it has been recommended that all concomitant posterolateral corner and bicruciate injuries be addressed simultaneously to protect the cruciate ligaments[60]. However, the current review indicated that patients in the acute treatment group were >2.5 times more likely to have residual anterior instability in comparison with those in the chronic treatment group (odds ratio, 2.6; 95% confidence interval, 1.2 to 5.8). In the studies that were included in our review, fewer patients who were managed acutely (21%; three of fourteen) underwent posterolateral corner reconstruction in comparison with patients who were managed chronically (50%; four of eight). Early anatomic repair of the posterolateral corner may be insufficient to protect the anterior cruciate ligament from excessive stress following multiple-ligament knee injuries; reconstruction may be better suited to restore stability whether surgery is acute or delayed. However, the extent to which the posterolateral corner is disrupted as well as the chronicity of the injury are two factors that have been shown to be important determinants of outcome in making this treatment decision[61].

Joint Stiffness

Patients undergoing staged procedures and those managed acutely demonstrated a similar need for additional treatment secondary to arthrofibrosis. The average number of patients undergoing manipulation or arthrolysis for the treatment of joint stiffness was greater in both the staged and acute treatment groups when compared with the chronic treatment group. In fact, no patient in the chronic treatment group required additional surgery or manipulation because of loss of range of motion (0% [zero of seventy-one]; 95% confidence interval, 0.0% to 51.0%). Nevertheless, final range of motion was preserved best in the patients undergoing staged treatment. This finding suggests that simultaneous repair and reconstruction of the cruciate ligaments acutely can lead to substantial range-of-motion deficits that are unresponsive even to follow-up surgery.

The likelihood of encountering a cruciate ligament avulsion fracture increases substantially in the pediatric population[62,63] and in cases of traumatic knee dislocations[47]. If cruciate ligament disruption occurs in the form of an avulsion fracture, it is reparable through acute direct fixation. However, contracture of the ligament can occur if treatment is delayed[64]. Acute fixation of avulsion fractures also has been shown to be highly associated with restriction of postoperative motion[62,65]. Seventy-one percent (ten) of the fourteen acute treatment studies and 13% (one) of the eight chronic treatment studies that we analyzed involved the use of transosseous fixation of avulsed ligaments for the management of some of the subjects. This may explain the high percentage of patients in the acute treatment group who required follow-up arthrolysis or manipulation.

Postoperative Rehabilitation

Early postoperative range of motion has been proposed to help to reduce arthrofibrosis[18,19,21]. Although immediate postoperative immobilization typically is expected to help patients to achieve greater joint stability[35], the current review indicates that the mean range of motion was not significantly different between patients managed with early immobilization and those managed with early mobility. However, in patients who were managed acutely, more severe flexion and extension deficits were observed in those who were immobilized. There were no differences in the need for arthrolysis according to postoperative rehabilitation (mobility or immobilization). Additional intervention (manipulation) may explain why the current review showed that patients who were managed acutely and mobilized postoperatively had better range-of-motion outcomes. Interestingly, there was less joint instability in all directions in patients who were allowed early postoperative mobility in the acute treatment group. Early postoperative mobilization also resulted in a greater percentage of patients returning to work. This finding indicates that more aggressive rehabilitation after acute surgery may be associated with less severe final range-of-motion deficits, which is similar to what has been previously shown in the literature[66].

Among patients who were managed chronically, the difference in rehabilitation protocols only yielded a difference in varus laxity. Varus laxity was significantly less among patients who were immobilized. It is difficult to assess the importance of these findings because of the small sample size of the chronically treated early mobility group. These findings contradict those seen in the acute treatment group. It has been noted in the literature that the results for patients who are managed chronically are less predictable than those for patients who are managed acutely[22]. This observation, coupled with the small sample size and the greater chance for random error in this comparison, likely contributed to this result. Only 19% (twenty) of 106 patients in the chronic treatment group underwent early range of motion as part of their rehabilitation. This low number of patients undergoing a more aggressive rehabilitation is not consistent with what was observed in the acute treatment group. Sixty-nine percent (169) of 244 patients who underwent acute surgery underwent early postoperative mobility. Thus, surgeons may be more concerned about range-of-motion complications in patients who are managed acutely.

Subjective Outcomes

A significant difference was observed in the percentage of excellent and good subjective outcomes between all groups with at least two years of follow-up. Staged treatment demonstrated the highest percentage of excellent and good outcomes, followed by acute treatment and finally by chronic treatment. The significantly lower number of the best outcomes in patients in the chronic treatment group is consistent with findings in the literature[10,13,18,39]; however, this seemed to contradict the objective findings of the current review.

An obvious limitation to this comparison is that multiple rating scales were pooled. The outcome scales included in this comparison were the IKDC system, the Meyers ratings[1,2], the Taylor outcome criteria[37], and the Cincinnati knee-rating system[38]. As there is no subjective outcomes instrument designed for patients with multiple-ligament knee injuries, multiple scales may be needed to provide a comprehensive picture. We cannot know for certain until the utility of these tests is examined specifically in the setting of multiple-ligament knee injuries as it has been for other knee injuries. Until then, several authors[13,67] have explicitly advocated the use of multiple knee-rating scales to provide the most comprehensive evaluation and reporting.

Limitations

To our knowledge, the present study is the first to systematically review the operative and postoperative treatment of multiple-ligament knee injuries. This review is limited by the paucity of high-level-of-evidence studies in the literature comparing treatment strategies for these injuries. As no prospective, randomized clinical trials have been reported in the literature, evidence-based treatment recommendations are lacking. We included studies that described outcomes in patients with more severe knee dislocations; therefore, it may be difficult to generalize the findings of the current review to all patients with a knee dislocation. Despite this effort to keep our study population more homogeneous, we acknowledge the high variability in study sample size, injury severity, concomitant injuries, and treatment techniques reported in the studies that we did include. In addition, the overall quality of the review suffers from the same problems of the data that are currently available in the literature, including publication bias and the potential for higher study attrition rates. It is possible that the inherent nature of the populations of patients who are managed acutely, chronically, and in stages may introduce bias due to attrition. However, we are unaware of any published evidence indicating that attrition bias is different among different patient groups. Therefore, instead of making treatment recommendations, we have summarized our primary observations from the available data in the literature. It should also be noted that the subjective outcomes of this review corroborate those of the two studies that directly compared acute and chronic intervention within their own retrospective series[13,22].

Orthopaedic surgeons must consider the following observations with an awareness of the aforementioned limitations.

First, regardless of the rehabilitation protocol, surgical repair and reconstruction of multiple-ligament knee injuries within three weeks after the injury is associated with more cases of anterior joint instability and of severe range-of-motion complications as well as the need for additional surgery for manipulation or arthrolysis.

Second, patients who are managed in stages report the highest percentage of excellent and good subjective outcomes and also report the least number of range-of-motion deficits.

Third, although final range of motion was preserved best in patients undergoing staged treatment, a high percentage of those patients needed follow-up surgery secondary to arthrofibrosis. This finding suggests that simultaneous repair and reconstruction of the cruciate ligaments acutely may lead to substantial range-of-motion deficits that are unresponsive even to follow-up surgery.

Fourth, acute treatment combined with more aggressive postoperative rehabilitation may decrease range-of-motion complications and may increase the likelihood of returning to work. Additionally, aggressive postoperative rehabilitation does not seem to be associated with an increase in joint instability when compared with immobilization after surgery.

Fifth, the type of rehabilitation following delayed surgical treatment of multiple-ligament knee injuries does not seem to affect range of motion to the extent that was observed following acute treatment.

In conclusion, the present review of the available literature suggests that delayed reconstruction of multiple-ligament knee injuries (KDIII or higher) could potentially yield equivalent stability outcomes when compared with acute surgery. Staged procedures may produce better subjective outcomes and a lower number of severe range-of-motion deficits but are still associated with the need for additional treatment because of joint stiffness. Patients who are managed acutely are as likely as those who are managed in stages to require additional treatment of range-of-motion deficits, but these deficits may be more refractory to intervention. However, for the acutely managed patient, early mobility may yield better outcomes in comparison with immobilization. The type of rehabilitation in patients for whom surgery is delayed may not affect the outcome as greatly as it does for those who undergo operative treatment immediately. Until a subjective outcome-scoring system has been validated in the context of multiple-ligament knee injuries, it is best to evaluate the surgical outcomes of multiple-ligament knee injuries with multiple scoring systems because subjective outcomes may differ from the objective findings and the interpretations of the examiner.

Appendix

eA Tables listing the articles reviewed in this study are available with the electronic versions of this article, on our web site at jbjs.org (go to the article citation and click on "Supplementary Material") and on our quarterly CD/DVD (call our subscription department, at 781-449-9780, to order the CD or DVD). ■

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