The Effect of Irreducible Dislocation on Functional Outcomes in Knees With Multiligament Injuries

A Matched-Cohort Analysis

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Background: Most cases of bicruciate knee dislocation (KD) with associated posteromedial disruption (KD-IIIM) are reducible, but some cannot be reduced by closed reduction because of soft tissue incarceration.

Purpose: To compare the clinical characteristics and functional outcomes of KD-IIIM injuries in patients with or without incarceration of soft tissue requiring open or arthroscopic reduction.

Study Design: Cohort study; Level of evidence, 3.

Methods: This retrospective cohort study of patients with KD was conducted between January 2013 and December 2017 at a single large institution. We applied a 1:2 matching ratio between patients with irreducible KD-IIIM injuries (irreducible group; n = 14) and those with reducible KD-IIIM injuries (control group; n = 28). There were 13 patients in the irreducible group and 25 in the control group who completed follow-up (≥2 years) and were included in our analysis. The efficacy of treatment in patients with KD was evaluated based on range of motion, the Tegner score, the Lysholm score, and the International Knee Documentation Committee (IKDC) score.

Results: At the end of follow-up, the mean Tegner score was 4.5 (range, 4-6), the mean Lysholm score was 79.2 (range, 60-95), and the mean IKDC score was 78.6 (range, 60.9-95.4) in the irreducible group. The respective results in the control group were 4.6 (range, 3-8), 83.1 (range, 39-100), and 80.6 (range, 42.5-96.6). These scores did not differ significantly between the 2 groups. Similarly, mean range of motion was similar between groups (irreducible, 118.1°; control, 124.8°). In the irreducible group, the acute subgroup showed significantly higher Lysholm and IKDC scores than the chronic subgroup, while the acute and chronic subgroups in the control group showed no significant differences in these respective outcome scores.

Conclusion: In the present study, the treatment of irreducible KD led to similar functional outcomes compared with reducible KD. However, the treatment of chronic irreducible KD led to worse outcomes compared with acute irreducible KD, and therefore, urgent reduction is recommended in these patients.

Keywords: posterolateral knee dislocation; dimple sign; irreducibility; arthroscopic surgery

Knee dislocation (KD) is an unusual but serious injury with potential long-term complications; the injury constitutes up to 0.2% of all orthopaedic trauma.4,37 Schenck29 and later Wascher et al37 proposed a practical classification of KD based on the number of injured ligaments. In this classification system, KD-III is the most common type of KD and is further divided into KD-IIIM (dislocation with bicruciate and posteromedial disruption) and KD-IIIL (dislocation with bicruciate and posterolateral disruption).

Approximately 4% of all KD cases are irreducible KD-IIIM injuries, meaning that the knee cannot be reduced with closed manipulation.19 The majority of these irreducible dislocation cases are posterolateral and associated with rotary injury mechanisms.3,8,10,16,17,23 They are often associated with low-energy trauma,13-15 but some cases of high-energy injuries have been reported.16 Various soft tissue structures, including capsuloretinacular structures, the medial collateral ligament (MCL), the vastus medialis muscle, and the gastrocnemius muscle, are
trapped in the medial compartment, preventing closed reduction. The specific “pucker sign” or “dimple sign” is considered a diagnostic feature showing that the skin and soft tissue are invaginated into the joint space.17

In cases of delayed diagnosis and therapy, the functional prognosis of the knee joint and even the lower limb may be seriously compromised, primarily because of the inactivation or even necrosis of interposed structures.12 Most clinicians recommend appropriate initial evaluation and management to maximize clinical success and avoid potential complications associated with these difficult injuries.41,42 Because of the low incidence of this unusual type of dislocation, only scattered case reports and a paucity of follow-up information have been reported in the literature.1-3,8,10,16,34,42 However, our patients came from southwestern China, a farming and industrial area located along multiple interprovincial highways, which creates an environment where multiple ligament injuries and KD, including irreducible cases, occur with some frequency. The diagnosis and treatment of irreducible posterolateral dislocation of the knee remain challenging for most surgeons.

As far as we know, the relationship of KD outcomes to whether the injury is reducible or irreducible has not been evaluated yet. It is also unclear whether delayed treatment of irreducible KD affects functional outcomes. Therefore, the objectives of the present study were to compare the clinical characteristics and midterm postoperative outcomes between KD cases with incarceration of soft tissue requiring arthroscopic or open reduction and a matched group of cases without incarceration. We also compared the clinical outcomes between irreducible KD treated earlier or later. We hypothesized that treating irreducible KD in the acute phase would lead to better outcomes than treating in the chronic phase.

METHODS

Study Population

Ethical approval was obtained from our hospital. On admission, patients provided written informed consent that their anonymized data could be analyzed and published for research purposes. This study was conducted at the Department of Orthopedic Surgery from West China Hospital in Chengdu, Sichuan. Ours is an urban referral center that treats patients from all over southwestern China who have complex trauma, including road traffic accidents and sports injuries.

All patients who underwent surgical intervention by a senior surgeon (J.L.) between January 2013 and December 2017 were identified through a search of the institutional electronic database. The status of the ligaments was recorded and graded according to the modified Schenck classification system of KD, which assesses ligament injury patterns.30,36 Patients were considered eligible for study inclusion if they suffered KD-IIIM injuries involving a rupture of both cruciates and the MCL, underwent ligament reconstruction, and were followed up for at least 2 years. Patients were excluded if they showed an injury of only 2 ligaments, underwent nonoperative treatment, or were followed up for less than 2 years.

All patients with a KD-IIIM injury in which closed reduction could not be performed were included in the irreducible group. They were matched in a 1:2 ratio with patients with reducible dislocation, comprising the control group; the matching was based on age at the time of injury (age within 10 years) and KD grade at the time of injury (Figure 1). Treatment performed within the first 3 weeks after the injury was defined as being administered during the acute phase, while treatment more than 3 weeks after the injury was defined as being administered during the chronic phase.32 The mechanism of injury was classified as low velocity (falling from a height of <3 m or sport-related injury) or high velocity (traffic accident, falling from a height of ≥3 m, crush injury caused by a heavy object, pedestrian struck by a motorcycle, or rotary tiller injury). The MCL injury was categorized based on magnetic resonance imaging (MRI) into 4 types: femoral attachment, tibial attachment, midsurface, or peel-off (Figure 2).

Of 287 consecutive cases, a total of 14 patients with 14 cases of irreducible KD were treated by the same surgical team at our center. They were matched to 28 control patients with reducible dislocation. We collected the following data according to a standardized protocol: age at injury, sex, body mass index, concomitant injuries, type of MCL injury on MRI, surgical reconstruction, and periprocedural or postoperative complications. Despite attempts to contact by telephone or email, 1 patient in the irreducible group and 3 in the control group were lost to follow-up. The remaining 13 study patients and 25 controls were contacted by telephone or through outpatient clinics and were available for a final evaluation.

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Ethical approval for this study was obtained from Sichuan University.
Patients with multiligament knee injury (n = 287) → Medical record review (n = 253) → Enrolled irreducible cases (n = 14) → ≥2-year follow-up (n = 13) -Lost to follow-up (n = 1) → Excluded (n = 34) -vascular lesions or combined other severe traumas → Reducible dislocation (n = 239) → KD grade and age-matched reducible dislocation (n = 28) → ≥2-year follow-up (n = 25) -Lost to follow-up (n = 3) → Clinical characteristics and midterm results between 2 groups were compared

**Figure 1.** Flowchart of patient enrollment. KD, knee dislocation.

**Figure 2.** Magnetic resonance imaging of different types of medial collateral ligament injuries: (A, B) femoral attachment, (C) tibial attachment, (D) midsubstance, and (E) peel-off.
Surgical Technique

At the time of admission, all patients had a detailed clinical history, a physical examination, and imaging such as radiography and MRI. An initial vascular assessment of KD was performed in every patient using the ankle-brachial index.21 The initial assessment of the nerve injury was performed according to clinical manifestations (complete or deficient sensory distribution and/or motor skills) and, if doubt persisted, by electromyography in the medium term.6,23 These examinations were repeated under general anesthesia before surgery. Before open reduction, conventional knee arthroscopic surgery was performed to inspect intra-articular conditions, and arthroscopic reduction of interposed tissue was attempted (Figure 3). If it failed, open reduction through the anteromedial approach was performed during the same surgical procedure. Damaged medial structures were exposed through the skin, and soft tissue was dissected via an anteromedial longitudinal incision. Gentle reduction of incarcerated structures was performed; the injury mechanism of abduction and external rotation of a flexed knee was mimicked to facilitate reduction. The torn medial retinaculum was replaced and repaired, and the medial joint capsule and subcutaneous tissue were meticulously sutured. Then, knee arthroscopic surgery was performed a second time to reconstruct ruptured ligaments. For KD-III injuries with medial structural damage, patients underwent only posterior cruciate ligament (PCL) reconstruction. All-inside reconstruction of the PCL was performed under arthroscopic surgery by utilizing an autogenous hamstring tendon with added suture augmentation (Figure 4).

Injured MCLs were anatomically repaired during the acute stage because of the ligament's excellent healing capability.20,44 MCL reconstruction was performed as described5 when widening of the medial compartment on stress radiographs was ≥10 mm and the injury was chronic.5 During surgery, ligament, meniscal, and cartilage injuries were recorded. All patients were routinely examined by radiography after surgery (Figure 5).

Postoperative Rehabilitation and Assessment

Guided by rehabilitation therapists, isometric quadriceps exercises were started immediately with a hinged knee brace locked in extension for the first 2 weeks postoperatively, then unlocked for other exercises with the aim of improving muscle endurance (Table 1). No weightbearing was recommended for any patients for the first 2 weeks, after which partial weightbearing was permitted as dynamic stability and muscle strength recovered. Starting at 2 months postoperatively, full weightbearing was encouraged with a knee brace. A physical therapy program focusing on the restoration of range of motion (ROM) was initiated at 2 weeks after surgery. Patients were asked to avoid exercises that placed valgus force on the knee for 6 weeks. Once full ROM and functional strength were attained, agility and proprioceptive drills were reintroduced. Normal levels of activity were introduced after 6 months. During this period, the patients were regularly followed up through the outpatient department. The development of knee stiffness necessitated a more rapid and rigid program of rehabilitation. If stiffness still persisted, manipulation under anesthesia or arthroscopic synovectomy was considered between 3 and 6 months after surgery.

The last follow-up consisted of a clinical evaluation and a series of self-administered questionnaires including the Tegner, Lysholm, and International Knee Documentation Committee (IKDC) scores. ROM of the knees was evaluated using standardized goniometry techniques.

Statistical Analysis

Data were reviewed and verified independently before statistical analysis. Data were reported as means with standard deviations. A descriptive analysis was
performed to compare the clinical characteristics as well as functional and radiological outcomes between the irreducible and control groups. Differences in skewed data were analyzed using the Wilcoxon rank-sum test. Differences in categorical variables were assessed using the chi-square or Fisher exact test, as appropriate. Between-group differences were considered statistically significant at \( P < .05 \). Statistical analysis was performed using SPSS 22.0 (IBM).

RESULTS

Demographic and Clinical Characteristics

The mean age was 46.7 years (range, 21-68 years) in the irreducible group and 43.2 years (range, 25-64 years) in the control group. The mean age of patients at the time of injury was 44.4 years (range, 21-68 years). In the irreducible group (n = 13), the mechanisms of injury were a fall in 7 patients, a motor vehicle accident in 2 patients, and a rotary tiller injury in 4 patients. Overall, 6 of the patients

Figure 4. Arthroscopic posterior cruciate ligament (PCL) reconstruction. (A) A PCL guide was placed below and lateral to the posterior edge of the tibial plateau. (B) The guide wire was passed through the tibial tunnel (white arrow). (C) After the graft passed through the femoral tunnel, the tension-reducing suture was tightened. The position of the suture (obscured by soft tissue) is shown as a red dotted line. Then, the other end of the graft was tightened (white arrow). (D) Intraoperative view of the PCL after reconstruction (white arrow).

Figure 5. Postoperative radiograph of a left knee showing a restored joint space and alignment.

in this group suffered from acute dislocation, while 7 presented with chronic dislocation. In the control group (n = 25), the mechanisms of injury were a fall in 10
patients, a motor vehicle accident in 14 patients, and a rotary tiller injury in 1 patient. The control group comprised 10 cases of acute dislocation and 15 cases of chronic dislocation (Table 2).

The mean follow-up period was 38.3 months (range, 25-78 months). No vascular lesions occurred in our patients. The preoperative clinical evaluation and nerve electrophysiological examination revealed partial sensory loss involving the common peroneal nerve in 1 patient in the irreducible group, who experienced complete neurological recovery. The classic dimple sign was identified in 6 acute cases on both the physical examination and coronal or sagittal MRI.

In the chronic subgroup of the irreducible group, only 2 patients suffered from obvious entrapped soft tissue necrosis, which was removed because it was difficult to repair. No skin necrosis or wound healing occurred after surgery. The MCL injury usually involved the femoral attachment in the irreducible group or the midsubstance.

Functional Outcomes

There were no significant differences in functional outcomes between the 2 groups (Table 3). The mean Tegner score for the irreducible group was 4.5 (range, 4-6), similar to the score of 4.6 (range, 3-8) for the control group. There was no significant difference in the mean postoperative

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TABLE 1

| Postoperative Rehabilitation Protocola |
|------------------|------------------|
| 1 wk 2 wk 3 wk 4 wk 5 wk 6 wk 7 wk 8 wk 9 wk 10 wk 11 wk 12 wk 24 wk ≥36 wk |
| **Brace** | **Locked HKB** | **Unlocked HKB** | **Weaning off crutches** |
| **Motion** | 0° | 0°-90° | 90°-110° | >120° | Normal ROM |
| **Exercise** | Isometric and isotonic exercise | Ground walking with brace and crutches | Ground walking without crutches | Jogging | Noncontact activities |

aHKB, hinged knee brace; ROM, range of motion; WB, weightbearing.

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TABLE 2

| Clinical and Demographic Characteristicsa |
|-------------------------------|
| Irreducible Group | Control Group | P |
| Age, y | 46.7 (21-68) | 43.2 (25-64) | .368 |
| Sex, male:female, n | 8:5 | 15:10 | .927 |
| Mechanism of injury, n (%) | | | .016 |
| Motor vehicle accident | 2 (15) | 14 (56) | |
| Fall | 7 (54) | 10 (40) | |
| Rotary tiller injury | 4 (31) | 1 (4) | |
| Body mass index, kg/m² | 23.6 ± 2.1 | 24.9 ± 3.2 | .211 |
| Time to surgery, n (%) | | | |
| Acute | 6 (46) | 10 (40) | .715 |
| Chronic (>3 wk) | 7 (54) | 15 (60) | |
| Injury Severity Score | 12.5 ± 6.1 | 10.1 ± 3.5 | .200 |
| Type of MCL injury on MRI, n (%) | | | .256 |
| Femoral attachment | 9 (69) | 9 (36) | |
| Tibial attachment | 0 (0) | 1 (4) | |
| Midsubstance | 4 (31) | 14 (56) | |
| Peel-off | 0 (0) | 1 (4) | |
| Follow-up, mo | 42.9 (28-78) | 36.0 (25-55) | .157 |
| Patients with ≥2 surgical procedures, n | 3 | 4 | .672 |

aData are shown as mean (range) or mean ± SD unless otherwise indicated. MCL, medial collateral ligament; MRI, magnetic resonance imaging.

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TABLE 3

| Functional Outcomes in Irreducible and Control Groupsa |
|--------------------------------|
| Irreducible Group | Control Group | P |
| **Tegner score** | 4.5 (4-6) | 4.6 (3-8) | .867 |
| **Lysholm score** | 79.2 (60-95) | 83.1 (39-100) | .611 |
| **IKDC score** | 78.6 (60.9-95.4) | 80.6 (42.5-96.6) | .400 |
| **ROM, deg** | 118.1 (90-140) | 124.8 (80-140) | .193 |

aData are shown as mean (range). IKDC, International Knee Documentation Committee; ROM, range of motion.

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TABLE 4

| Functional Outcomes in Acute and Chronic Subgroupsa |
|--------------------------------|
| Irreducible group |
| Acute | 4.8 (3-7) | 84.8 (70-100) | 82.3 (63.2-95.4) | .402 |
| Chronic | 4.5 (3-8) | 79.6 (39-100) | 78.1 (42.5-96.6) | .232 |
| **P value** | .142 | .022 | .002 |
| Control group |
| Acute | 4.7 (3-7) | 84.6 (70-100) | 80.8 (63.2-95.4) | .747 |
| Chronic | 4.5 (3-8) | 82.1 (39-100) | 80.6 (42.5-96.6) | .702 |
| **P value** | .999 |

aData are shown as mean (range). IKDC, International Knee Documentation Committee.

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in the control group. Overall, 3 cases (50%) in the acute subgroup and 1 case (14%) in the chronic subgroup of the irreducible group were reduced arthroscopically. Also, 3 cases (23%) in the irreducible group and 4 cases (16%) in the control group required MCL reconstruction.

Functional Outcomes

There were no significant differences in functional outcomes between the 2 groups (Table 3). The mean Tegner score for the irreducible group was 4.5 (range, 4-6), similar to the score of 4.6 (range, 3-8) for the control group. There was no significant difference in the mean postoperative
Lysholm score between the irreducible group (79.2 [range, 60-95]) and control group (83.1 [range, 39-100]) or in the mean postoperative IKDC score (78.6 [range, 60.9-95.4] and 80.6 [range, 42.5-96.6], respectively). Similarly, there was no significant difference in knee ROM between the 2 groups at final follow-up.

A comparison of postoperative functional scores between patients treated during the acute or chronic phase of injury showed that in the irreducible group, but not the control group, patients in the acute subgroup had significantly higher Lysholm and IKDC scores than patients in the chronic subgroup (Table 4). When the entire patient sample, regardless of KD type, was stratified only by timing of surgery, no significant differences in functional outcomes were observed.

DISCUSSION

The main observation in our study is that the clinical characteristics and midterm functional outcomes of the irreducible group were similar to those of the control group at a minimum 2-year follow-up. Furthermore, patients in the irreducible group who underwent treatment in the acute stage achieved significantly better knee function than those treated in the chronic phase, while no such difference was found in the control group.

Irreducible posterolateral KD, a serious injury with many complications, accounts for nearly 4% of all KD events. Indeed, irreducible cases accounted for 4.9% of the total number of KD cases in our center. Consistent with previous findings, more than half of our irreducible cases (54%) were caused by a low-energy injury. Evidence suggests that the mechanisms of injury in irreducible KD mainly include knee flexion, valgus stress, and external tibial rotation. Under valgus stress on the knee joint, the medial tibial plateau and medial condyle of the femur are separated, and the volume within the knee joint is increased, generating negative pressure. The damaged medial structures are interposed into the medial compartment to fill the expanding volume of the joint, which rapidly renders the dislocation irreducible. Moreover, the injured structure varies according to the knee flexion state at the time of injury, thus causing invagination of various tissue structures. In our study, 46% of irreducible cases showed the classic dimple sign, lower than the 84% reported, suggesting that KD without the dimple sign can also be irreducible. This discrepancy may be primarily caused by the high proportion of chronic cases in our study: The dimple sign may not appear in chronic irreducible KD, even when medial structures are trapped. These considerations indicate that the dimple sign can aid, but not determine, the diagnosis of irreducible KD.

As observed in the MRI analysis of both groups, the femoral attachment and midsubstance were the most frequent sites of an MCL injury, while the tibial attachment was the rarest site of injury. These findings agree with a previous study in which 63% of MCL failures occurred at the femoral attachment and the remainder occurred at the midsubstance. We speculate that the tibial attachment of the MCL is protected from injuries because that part features a larger attachment area involving several muscles.

Although there have been scattered case reports regarding irreducible KD, few studies have compared the clinical effects of this type of dislocation with the corresponding type of reducible dislocation. We found that the mean Tegner, Lysholm, and IKDC scores did not differ significantly between our 2 study groups. Specifically, the mean Lysholm score (79.2 points) in this study was within the range previously reported by some authors, which varies from 79 to 84 points for patients with a mixed type of dislocation but was much higher in patients with polytrauma (62 points) or a neurovascular injury (62.5 points). Similarly, the mean IKDC score (78.6 points) in this study was within the range of previous reports, from 74.5 to 83.8. Because of the small number of patients in the irreducible group, the absence of significant differences between the 2 groups could potentially be attributed to a lack of power.

Subgroup analysis of our patients based on the timing of surgery showed that in the irreducible group, better functional recovery was achieved when ligament reduction and reconstruction were performed during the acute stage (<3 weeks after injury). Although there was no skin necrosis in the chronic irreducible cases, long-term compression can lead to necrosis of entrapped tissue, making repair difficult. No significant difference in outcome quality was observed in patients with reducible dislocation between the acute and chronic subgroups. This contrasts with previous work that showed that even in reducible groups, treatment in the acute phase led to better outcomes than treatment in the chronic phase. This discrepancy may reflect differences in the patient populations, as one of those studies involved patients with a mixed type of dislocation, whereas our sample included only patients classified with a KD-III injury with medial structural damage according to the modified Schenck classification. Future research with a larger sample size should further explore whether treatment in the acute phase of reducible KD leads to significantly better outcomes than treatment during the chronic phase.

Our finding of better outcomes with acute-phase treatment in the case of irreducible KD is consistent with a meta-analysis demonstrating that an early surgical intervention in multiligament injuries yielded better clinical outcomes than chronic-phase reconstruction. In our study, close to half of the irreducible cases were injured in a high-speed accident or while working on farmland. A recent study showed that patients with high-speed injuries presented lower functional scores after surgery than patients with low-speed injuries. In addition, the chronic subgroup showed a slightly higher incidence of rotary tiller injuries, which are often accompanied by multiple injuries that delay surgery. Associated injuries are unlikely to explain the worse outcomes in the chronic subgroup because the 2 subgroups of the irreducible group showed similar mean Injury Severity Scores. Delayed surgical treatment may also be explained by the patient’s condition or by failure of the orthopaedic surgeon to diagnose this
unusual KD, which is not surprising given that such surgeons are typically not knee injury specialists.

Given the limited availability of allogenic grafts for ligament reconstruction, we generally prefer to use autografts for isolated PCL reconstruction and MCL repair or reconstruction for these injuries. Functional outcomes depend on central pivot reconstruction of the PCL. The PCL and posteromedial corner are respectively located in the lateral walls of the medial condyle and medial aspect of the femur, and they are biomechanically antagonistic to each other. When both are damaged, the posteromedial corner should be repaired or reconstructed after PCL reconstruction to avoid increased stress on the reconstructed PCL graft and even subsequent failure.

In our patient population, the mean age was high, and the proportions of farm workers and retired workers were higher than that of athletes. Thus, in many cases, we did not attempt reconstruction of the anterior cruciate ligament (ACL), which is costly for patients and does not reduce trauma or the risk of postoperative joint adhesion. Injuries to the ACL mostly affect young, physically active patients. In a study of middle-aged patients (average age, 42 years) with an ACL injury, nonoperative treatment achieved similar physical outcomes as ACL reconstruction, although the nonoperatively treated patients showed an increase in anterior translation relative to the contralateral side.

Our study presents several limitations. First, unavoidable heterogeneity among patients with regard to age and surgery occurred. However, we collected all possible data about irreducible dislocation and performed analyses of a long-term follow-up. To minimize the influence of potential interfering factors, irreducible lesions were matched to reducible ones in a 1:2 ratio based on KD type. Second, a substantial proportion of patients did not arrive at our center for primary treatment after the injury. In some cases, doctors at lower trauma centers, who are often less familiar with irreducible KD, administered inappropriate treatments, leading to necrosis of entrapped tissue, which may have affected the outcomes of those patients in our study. Third, the retrospective nature of the study design increased the risk of selection bias, similar to that in other case series of KD. Finally, the low incidence of clinically confirmed irreducible KD meant that our sample was small, reducing our statistical power. Despite these limitations, our study provides evidence that the early recognition and appropriate management of patients with irreducible KD can lead to better knee functional outcomes. Further analyses with a larger population are needed to avoid bias and provide more definitive evidence for this unusual type of KD.

CONCLUSION

In the present study, similar clinical outcomes were found between patients with incarceration of soft tissue requiring arthroscopic or open reduction and patients without incarceration. Among patients with irreducible KD, those who received an early diagnosis and appropriate management had significantly better knee functional scores than those who underwent surgery in the chronic stage. Among patients with reducible KD, however, postoperative outcomes were similar regardless of whether treatment occurred in the acute or chronic phase. These results may help to improve the clinical management of KD.

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