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Injuries to the Posterolateral Aspect of the Knee

Association of Anatomic Injury Patterns with Clinical Instability*

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ABSTRACT

Seventy-one consecutive patients with posterolateral knee injuries had clinical stability testing abnormalities documented prospectively. We compared these findings with the incidence and patterns of their injuries documented at surgery. An abnormal reverse pivot shift test was associated with injury to the fibular collateral ligament ($P = 0.01$), popliteal components ($P = 0.01$), and midthird lateral capsular ligament ($P = 0.02$). An abnormal posterolateral external-rotation test at 30° of flexion was associated with injury to the fibular collateral ligament ($P = 0.0001$) and lateral gastrocnemius tendon ($P = 0.01$). An abnormal adduction test at 30° of flexion was associated with injury to the posterior arcuate ligament ($P = 0.02$). The results of this study should alert the clinician to the possibility of injury to a specific anatomic structure when the corresponding clinical stability test is abnormal. Because the fibular collateral ligament was injured in only 23% of the knees in this large series of patients, we recommend that an injury to the fibular collateral ligament not be the sole determining factor in making the diagnosis of posterolateral injuries. The wide array of injuries to many individual anatomic components that we found indicates the complexity of injuries to the posterolateral aspect of the knee.

Hughston et al.[4] provided the first surgical description of injuries to the posterolateral aspect of the knee, but their report did not describe the injured components in detail. Baker et al.[2] described the surgical findings in 17 patients with acute posterolateral rotatory instability. While their report is more detailed regarding specific anatomic injuries, no association of the injuries with abnormal clinical limits-of-motion testing was provided. The purpose of our paper is to report the association we found between clinical examination tests demonstrating abnormal limits of joint motion and specific anatomic injury patterns in a group of patients who had injuries to the posterolateral structures of their knees.

MATERIALS AND METHODS

Our prospective study population comprised 71 consecutive patients who had surgery to treat posterolateral knee injuries between 1985 and 1993. There were 49 male and 22 female patients in our series. Twenty-one of the injuries were acute (<6 weeks from time of injury) and 50 were chronic. Based on their preoperative examinations and examinations under anesthesia, patients were included in the study if they had a clinical diagnosis of posterolateral instability (injuries to posterolateral knee structures with an intact PCL [$N = 67$]) or straight lateral instability (injuries to posterolateral knee ligaments with a torn PCL [$N = 4$]) of the affected knee. All of these knees were operated on because of the patient's reduced activity level or profound sense of knee disability and instability. The patients' abnormal symptoms were reproduced by a sequence of limits-of-motion examination tests. The reproduction of abnormal motion and the symptoms noted on their initial preanesthesia physical examinations established the diagnosis. In the case of an acute injury, surgical repair was recommended only for patients who had grade 3 injuries to the posterolateral knee structures causing posterolateral tibial subluxation that could be demonstrated clinically.

The most common mechanisms of injury were twisting

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(N = 21), noncontact hyperextension (N = 15), contact hyperextension (N = 11), an anterior blow to a flexed knee (N = 7), and a valgus force on a flexed knee (N = 5). At the time of examination, the most common symptom was pain (70 patients), with the most frequent locations being along the medial joint line (N = 31), the lateral joint line (N = 23), and the posterolateral aspect of the knee (N = 11). Fifty-eight patients also complained of symptoms related to clinical episodes of instability.

The clinical examination, performed by a single examiner (GCT) with the patient under anesthesia, comprised the following joint stability tests: the anterior drawer test with the knee at 90° of flexion in both neutral and slight external tibial rotation, the posterolateral external-rotation test with the knee at 90° of flexion in both neutral and external tibial rotation (Fig. 1), adduction (Fig. 2) and abduction with the knee at 30° of flexion, the posterolateral external-rotation test with the knee at 30° of flexion (Fig. 3), the pivot shift test, the reverse pivot shift test (Fig. 4), and the external rotation-recurvatum test (Fig. 5). Abnormalities in limits-of-motion testing were compared with the results in the normal contralateral knee. Limits-of-motion tests specific for posterolateral instability included the posterolateral external-rotation test at 30° and 90° of knee flexion, adduction at 30° of flexion, the reverse pivot shift test, and the external rotation-recurvatum test.

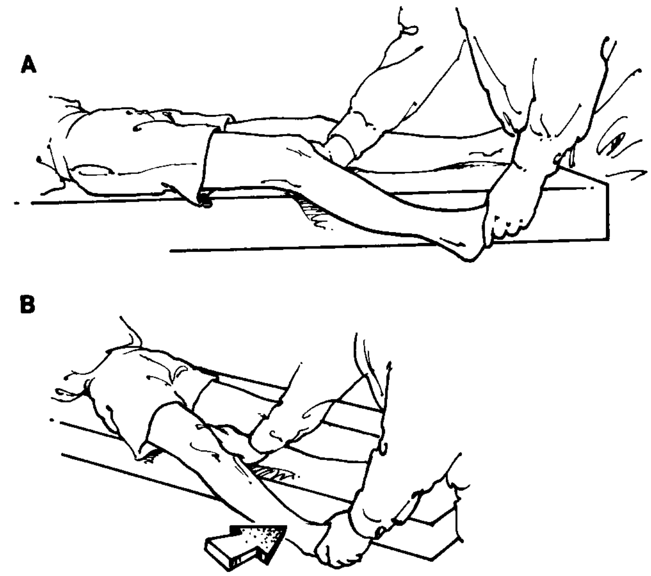

Figure 2. Adduction stability test at 30°. A, patient is supine with the knee flexed to approximately 30° and the thigh is supported on the examining table. B, examiner grasps the patient's foot and applies a force of adduction (arrow) and gentle internal rotation of the tibia to detect opening of the lateral compartment.

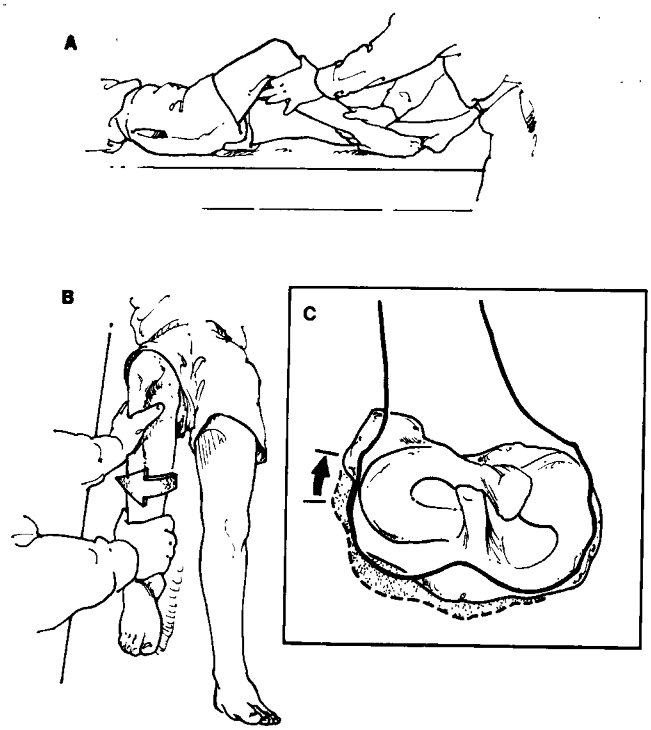

Figure 1. Posterolateral external-rotation test at 90°. A, patient is supine with the knee flexed to 90°. B, examiner applies a coupled force of posterior translation and external rotation of the tibia. With a finger on the posterolateral aspect of the knee, the examiner can feel posterolateral subluxation of the tibia as it occurs. C, arrow indicates abnormal posterolateral subluxation of the tibia in relation to the femur.

The status of the PCL was assessed with the posterolateral external tibial rotation test with the knee at 90° of flexion, and the posterior tibial translation test with the knee at 90° and the tibia in neutral and internal rotation. The motion produced by these tests was graded 0 to 3, according to guidelines established by the American Medical Association[1] and criteria in previously published works.[3,4,15,17] In addition, radiographs were reviewed to determine whether the patient had an osseous injury.

The same surgical approach was used in every knee and has been described in the published results of a concurrent study.[16] The following individual anatomic components of the posterolateral aspect of the knee were examined for injury at the time of surgery and were compared with abnormal limits-of-motion test results: the superficial, capsuloosseous, and deep layers of the iliotibial tract; the long head of the biceps femoris muscle (anterior, direct, and reflected arms; anterior and lateral aponeurosis); the short head of the biceps femoris muscle (proximal attachment to the biceps tendon, capsular arm, biceps-capsuloosseous layer of the iliotibial tract confluens, anterior and direct arms, and lateral aponeurotic expansion); the fibular collateral ligament; the midthird lateral capsular ligament; the fabellofibular ligament; the posterior arcuate ligament (medial and lateral limbs); the popliteus complex (muscle; tendon; anteroinferior, posterosuperior, and posteroinferior popliteomeniscal fascicles; and popliteofibular ligament); the coronary ligament; the posterior capsule; and the lateral gastrocnemius tendon.[16] All grade 3 (complete) injuries, as determined by visual examination and probing, were recorded. We did not find it difficult to

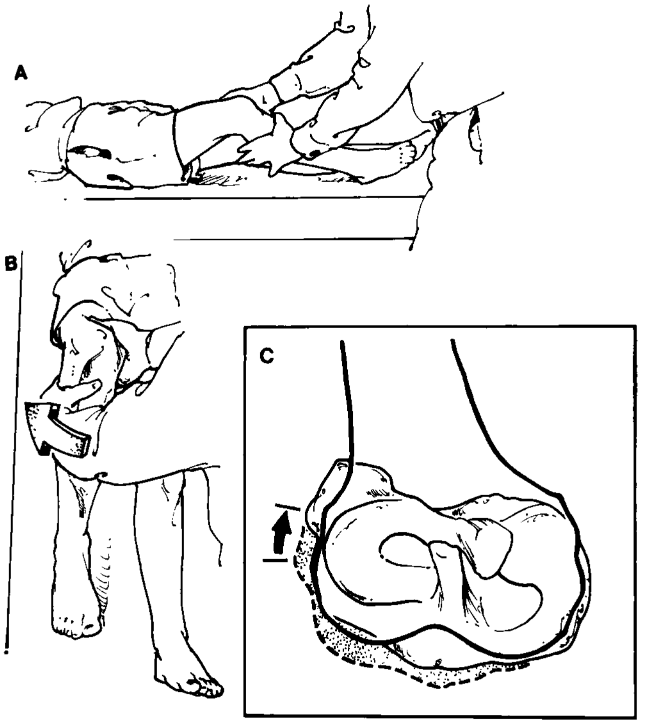

Figure 3. Posterolateral external-rotation test at 30° of flexion. A, patient is supine with the knee flexed to 30° and in neutral rotation (essentially the same starting position as for a Lachman test). B, examiner applies a coupled force of posterior translation and external rotation of the tibia (arrow). With a finger on the posterolateral aspect of the knee, the examiner can feel posterolateral subluxation of the tibia. C, arrow indicates abnormal posterolateral subluxation of the tibia in relation to the femur.

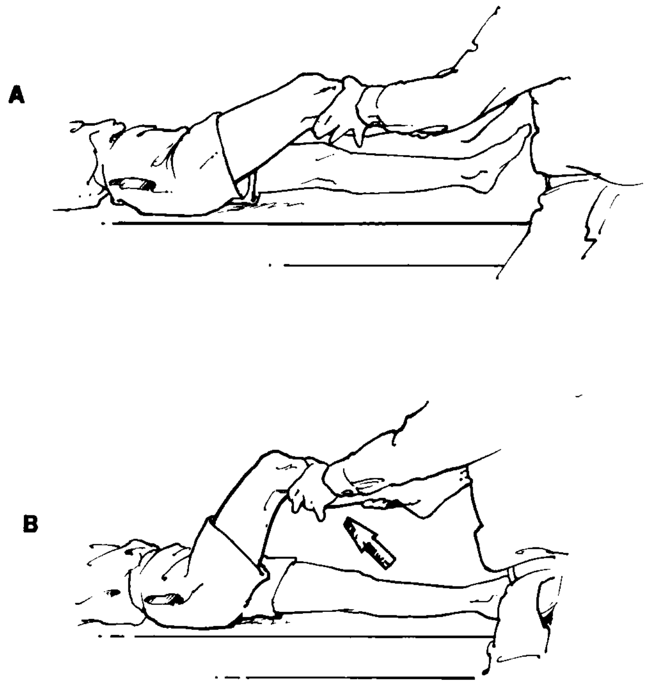

Figure 4. Reverse pivot shift test. A, examiner lifts the supine patient's leg by grasping it at the ankle and gently applying abduction and an axial load. B, this motion flexes the knee while allowing external rotation of the tibia as a posterior translation force is applied (arrow). As the knee goes into flexion, posterolateral subluxation of the tibia can be palpated. This is in contrast to the pivot shift maneuver, in which the subluxation is anterior and occurs near extension.

distinguish between normal tissue planes and their relationships and injured tissue planes in chronic cases, which were scarred and lax.

In addition to recording the patterns of injury to the anatomic components of the posterolateral aspect of the knee, we also recorded injuries to the ACL, the PCL, the menisci, the midthird medial capsular ligament, chondral and osseous surfaces, and other structures approached surgically. These injuries are not reported in this study.

Multiple logistic regression analysis was used to determine the ability of the clinical examination to predict specific anatomic injuries. In addition, a diagnostic test utility analysis was performed to determine the positive and negative predictive values of clinical limits-of-motion testing in forecasting whether a posterolateral anatomic structure was injured.

As mentioned, the injuries were divided into acute (<6 weeks from injury to surgery) and chronic (≥6 weeks from injury to surgery) groups. The Pearson product moment correlation coefficients were calculated to look for potential relationships between the examination parameters and, specifically, acute or chronic injuries.

RESULTS

Tears found in individual anatomic structures at the time of surgery are summarized in Table 1. In addition, 9 of the 71 patients (12.7%) had peroneal nerve injuries. Of these, six patients had combined motor and sensory loss of peroneal nerve functions, two patients had only sensory loss, and one patient had only motor weakness. Three knees had avulsion fractures of the proximal fibula (arcuate fracture[14]) and one knee had an avulsion fracture of the lateral tibial tubercle (Segond fracture[13]).

Table 2 lists the stability tests that demonstrated a statistically significant positive association between specific anatomic injuries and abnormal test results. A positive posterolateral external-rotation test with the knee at 90° of flexion was observed in 54 patients (76%), and 52 patients (73%) had a positive external rotation-recurvatum test.[5] However, neither of these tests was associated with any specific posterolateral ligament or tendon injury ($P > 0.05$).

An analysis of the positive and negative predictive values for specific injured anatomic components was also performed for specific posterolateral instability tests with abnormalities in limits-of-motion tests (reverse pivot shift, posterolateral drawer tests at 30° and 90° of knee flexion, adduction at 30° of knee flexion, and the external rotation-

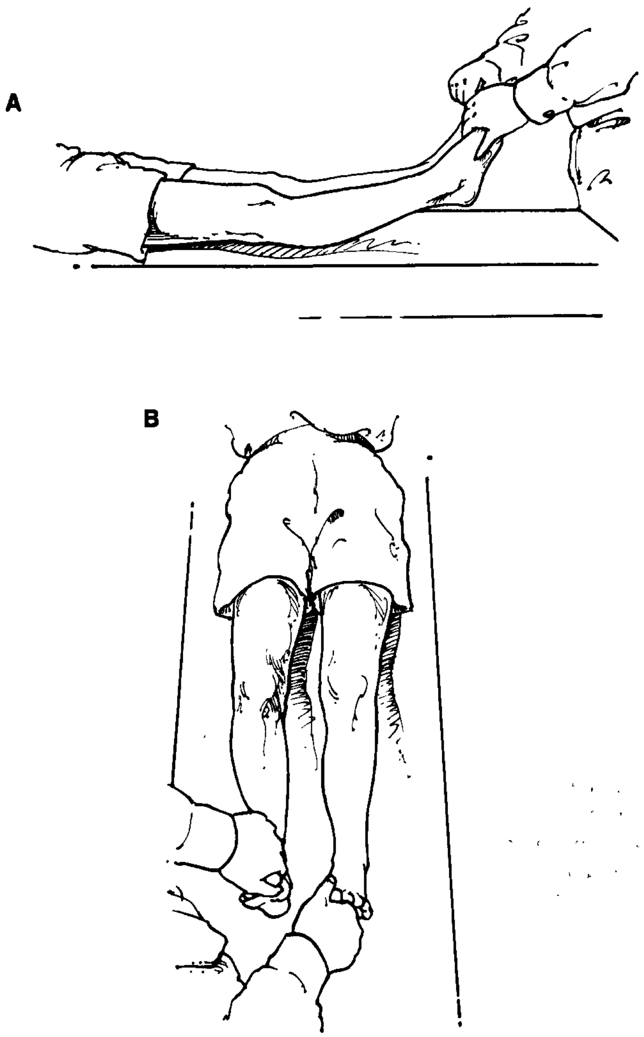

Figure 5. External rotation-recurvatum test. A, patient is supine with both legs extended. The examiner grasps the great toes of both feet and simultaneously lifts both legs. B, a positive test is indicated by increased recurvatum, varus, and apparent internal rotation of the tibia on the injured leg caused by posterolateral opening of the joint.

recurvatum tests). Because of the wide array and large percentage of individual structures injured, it was difficult to isolate the individual anatomic components, or even groups of components, for specific posterolateral instability tests. However, we were able to identify some trends. The highest positive predictive values (PPVs) were seen for the capsuloosseous layer of the iliotibial tract for both the reverse pivot shift (PPV = 0.68) and the posterolateral drawer at 90° (PPV = 0.69), the deep layer of the iliotibial tract and the posterolateral external-rotation test at 30° (PPV = 0.70), the posterior arcuate complex and adduction at 30° (PPV = 0.67), and the lateral gastrocnemius tendon and the external-rotation recurvatum test (PPV = 0.71). High negative predictive values (NPVs) were seen for the reverse pivot shift test and the fibular collateral

TABLE 1
Tears Found in Posterolateral Knee Anatomic Structures During Surgical Exploration

Anatomic structure	No. of tears	Percentage of patients
Capsuloosseous layer of ITT[a]	**53**	75
Deep layer of ITT	**51**	72
Components of posterior arcuate ligament	**47**	66
Components of short head of biceps femoris muscle[b]	**45**	63
Lateral aponeurotic components of biceps femoris muscle	41	58
Midthird lateral capsular ligament	**37**	52
Fabellofibular ligament	**28**	39
Popliteal components	**25**	35
Fibular collateral ligament	**16**	23
Components of long head of biceps femoris muscle[b]	**9**	13
Superficial layer of ITT	**4**	**6**
Lateral gastrocnemius tendon	3	**4**
Arciform layer of ITT	2	3

[a] Iliotibial tract.
[b] Excluding lateral aponeurotic components.

TABLE 2
Positive Associations Between Stability Tests and Specific Anatomic Injuries for the Posterolateral Knee

Stability test	Injured anatomic component
Reverse pivot shift	Fibular collateral ligament (P = 0.01) Popliteal components (P = 0.01) Midthird lateral capsular ligament (P = 0.02)
Posterolateral external rotation at 30° of flexion	Fibular collateral ligament (P = 0.0001) Lateral gastrocnemius tendon (P = 0.01)
Adduction at 30° of flexion	Posterior arcuate ligament (P = 0.02)

ligament (NPV = 0.89) and popliteus complex (NPV = 0.78), the posterolateral drawer at 90° and the fibular collateral ligament (NPV = 1.00) and popliteus complex (NPV = 0.86), abnormal limits of motion for adduction testing at 30° and the posterior arcuate complex (NPV = 1.00), and the external rotation-recurvatum test and the lateral gastrocnemius tendon (NPV = 0.94).

A comparison of abnormalities in limits-of-motion testing for the posterolateral instability provocative tests (posterolateral external-rotation test at 30° and 90°, adduction at 30° flexion, reverse pivot shift, and the external rotation-recurvatum test) by time of injury (acute or chronic) revealed no significant difference between the two groups.

DISCUSSION

As a result of an anatomic study done in conjunction with this report,[16] we divided the anatomy of the posterolateral aspect of the knee into its specific anatomic components.

By using the same surgical approach for each knee, we were able to identify a wide array of injured anatomic structures. By further grouping the structures into three regions—lateral, fibular head, and posterior—based on their origin, insertion, proximity, and perceived interactions with other anatomic structures, the multiregional complexity of the injury patterns was illustrated. There were 54 (76%) injuries in the lateral region, 35 (49%) in the fibular head region, and 53 (75%) in the posterior region. In 53 (75%) of the knees, at least two regions were involved simultaneously. We believe that any reconstructive procedure to correct posterolateral instability must address all three regions of the posterolateral aspect of the knee.

The associations described here between anatomic injuries and limits-of-motion examinations, as demonstrated with clinical stability tests, provide an in vivo comparison with the in vitro static testing performed by others.[6,7,9–12] We found that posterolateral knee injuries often involved a number of different anatomic structures that, when combined, caused variations in the outcome of stability testing. The associations were the same in patients who had acute injuries as in those who had chronic injuries. By examining the association between abnormalities in the clinical limits-of-motion testing and the anatomic injuries documented at surgery, this study demonstrated that injured structures can be identified in patients with either acute or chronic injuries.

In our study, a positive reverse pivot shift test was associated with injuries to the fibular collateral ligament, the popliteus components, and the midthird lateral capsular ligament. Our findings were predicted by Jakob et al.,[8] who first described the reverse pivot shift test and found that sectioning of the fibular collateral ligament, popliteal tendon, or the arcuate ligament produced a positive reverse pivot shift in cadaveric knees. However, the midthird lateral capsular ligament was not studied and, to date, no static in vitro cutting studies have been performed to correlate the effect of sectioning the midthird lateral capsular ligament with the results of the reverse pivot shift test.

According to our data, a positive posterolateral external-rotation test with the knee at 30° of flexion correlated strongly with injuries to the fibular collateral ligament. We also found a correlation with the lateral gastrocnemius tendon (and hence the fabellofibular ligament), but there were only three injuries to this structure—too few to allow statistically significant analysis. Our in vivo findings are similar to the in vitro findings of Gollehon et al.,[6] who demonstrated an increase of external rotation at 30° of flexion after sectioning the fibular collateral ligament. They demonstrated a much greater increase in the amount of posterolateral rotation with a combined sectioning of the fibular collateral ligament and the posterolateral capsular structures. Other in vitro studies have also revealed that sectioning the posterolateral capsular structures alone[7] or in combination with the fibular collateral ligament[11,12] is necessary to produce these results.

In our study, injuries to the posterior arcuate ligament complex were associated with increased varus instability. In vitro selective static cutting studies report that sectioning of the fibular collateral ligament,[6,7] the fibular collateral ligament and posterolateral capsule,[6,11] or the popliteal tendon[9] is necessary to produce varus instability at 30° of flexion. In our in vivo study, combined injuries to the fibular collateral ligament, the posterior arcuate complex, and the posterior capsule produced marked abnormal translation and varus tibial rotation (lateral joint line opening).

The results of this in vivo study with regard to abnormal limits-of-motion testing should help the clinician to determine preoperatively the probability of anatomic injury to specific structures. In particular, the reverse pivot shift test correlated with injuries to the fibular collateral ligament, popliteus components, and midthird lateral capsular ligament; the posterolateral external-rotation test at 30° of flexion correlated with injuries to the fibular collateral ligament and lateral gastrocnemius tendon; and the adduction test at 30° of flexion correlated with injuries to the posterior arcuate ligament.

We believe our data provide information for an improved clinical perception. For example, earlier in vitro studies have reported on the importance of the fibular collateral ligament in preventing posterolateral rotation of the tibia on the femur in static testing conditions.[6,7,11] However, in our study, only 16 (23%) injured knees had grade 3 tears of the fibular collateral ligament. This information is of special importance to the clinician who suspects an injury to the posterolateral aspect of the knee, orders a magnetic resonance imaging scan, and receives a report that the fibular collateral ligament is intact. If only the in vitro studied relationship between the fibular collateral ligament and abnormal posterolateral tibial external rotation is kept in mind,[6,7,11] many patients with posterolateral instability who lack obvious injury to the fibular collateral ligament would receive misdiagnoses. This limited interpretation could lead to incorrect treatment based on the results of magnetic resonance imaging.

We also believe that our in vivo analysis of the complex association between injured anatomic structures of the posterolateral aspect of the knee should stimulate more extensive in vitro studies. These studies should examine more of the individual anatomic structures to assess the effect of injury to these structures on posterolateral instability of the knee.

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