Does Ligamentous Laxity Protect Against Chondral and Osteochondral Injuries in Patients With Patellofemoral Instability?

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Background: Many patients undergoing medial patellofemoral ligament (MPFL) reconstruction for patellofemoral instability have chondral or osteochondral injuries requiring treatment.

Hypothesis: In patients undergoing MPFL reconstruction for patellofemoral instability, those with ligamentous laxity (LAX) would be less likely to have chondral or osteochondral defects requiring surgical intervention compared with those with no laxity (NLX).

Study Design: Cohort study; Level of evidence, 2.

Methods: Included were 171 patients with patellofemoral instability (32 men, 139 women; mean age, 22 years [range, 11-57 years]) who underwent MPFL reconstruction between 2005 and 2015. Patients with a Beighton-Horan score $\geq$5 were considered LAX (n = 96), while patients with scores <5 were considered NLX (n = 75). Preoperative magnetic resonance images were evaluated to determine the presence, size, and location of chondral or osteochondral injury as well as the grade according to the Outerbridge classification. Documented anatomic measurements included tibial tubercle–trochlear groove (TT-TG) distance, Caton-Deschamps Index (CDI) for patellar height, and the Dejour classification for trochlear dysplasia.

Results: Of the 171 patients, 58 (34%) required a surgical intervention for a chondral or osteochondral defect: chondroplasty (29/58; 50%), particulated juvenile cartilage implantation (18/58; 31%), microfracture (16/58; 28%), osteochondral fracture fixation (2/58; 3.4%), and osteochondral allograft (2/58; 3.4%). While there was no statistical difference in the proportion of patellar chondral or osteochondral injuries between patients with NLX (58%) versus LAX (67%) (P = .271), there was a significantly higher rate of patellar grade 3 or 4 injuries in the NLX (74%) versus LAX (45%) group (P = .004). Similarly, there was no difference in femoral chondral or osteochondral injury rates between groups (P = .132); however, femoral grade 3 or 4 injuries were significantly higher in the NLX (67%) versus the LAX (13%) group (P = .050). After adjusting for age, sex, radiographic parameters (TT-TG distance and CDI), and trochlear morphology, patients with LAX were 75% less likely to have had a grade 3 or 4 patellar cartilage injury compared with patients with NLX (P = .006).

Conclusion: For patients who sustained patellar or femoral chondral or osteochondral injuries, compared with their counterparts with NLX, patients with LAX were less likely to have severe (grade 3 or 4) injuries requiring surgical intervention.

Keywords: patellar instability; chondral injury; osteochondral injury; ligamentous laxity

Many studies have found that hypermobility may be a risk factor for musculoskeletal injuries when participating in sports. However, we have seen a low incidence of a need for surgical intervention for patellar or femoral chondral or osteochondral defects in patients undergoing medial patellofemoral ligament (MPFL) reconstruction for patellofemoral instability. This has led us to ask: Are patients with ligamentous laxity (LAX), who are therefore at an increased risk of patellofemoral instability, somewhat protected from concomitant chondral or osteochondral injuries?

Generalized hypermobility has a prevalence between 10% and 20%.[22] Hypermobility is more common among patients with recurrent patellar instability,[23] and patients with a greater than 5-year history of patellofemoral instability have a significantly increased risk for patellofemoral chondral injuries.[6] Hypermobile players had a higher incidence of injuries and were more likely to sustain at least 1 injury, a reinjury, or a severe injury compared with nonhypermobile participants.[11]

In addition to hypermobility, other risk factors that have been identified in association with patellofemoral instability

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include patella alta, an elevated tibial tubercle–trochlear groove (TT-TG) distance, and trochlear dysplasia.[11,22] Patella alta is thought to prevent the patella from engaging the trochlea in knee flexion. An elevated TT-TG represents a lateralized tibial tubercle that may increase the lateral pull on the patella. Finally, a shallow or dysplastic trochlea may predispose individuals to instability events.

There are conflicting data on whether hypermobility is protective of patellar chondral injury. Studies have found that hypermobility may be a risk factor for injuries when participating in soccer.[18] In a study by Konopinski et al[11] of 54 English Premier League soccer players, there were 9 severe knee injuries in hypermobile patients, 6 of which were cartilage injuries. Other studies have failed to detect a difference in the incidence of injuries between hypermobile and nonhypermobile lacrosse players[3] and netball players.[25] A recent systematic review with meta-analysis concluded that there was an increased risk of knee injury in sports participants with generalized joint hypermobility.[20] Interestingly, al-Rawi and Nessan[2] prospectively evaluated 115 patients with chondromalacia patella, or runner's knee, versus 110 healthy individuals without chondromalacia patella and found that the number of patients with hypermobile joints was significantly higher in patients with chondromalacia patella compared with the control group.

Nomura and Inoue[14] showed that cartilage lesions of the patella in recurrent patellar dislocations (RPDs) are common, with fissuring most commonly observed in the central dome and fibrillation/erosions observed mostly on the medial facet. Similar to the study of Nomura and Inoue[14], Lording et al[12] noted that the central and medial aspects of the patella are most commonly affected. The authors state that these injuries are likely to occur because of shear forces at the time of dislocation, as the patella moves over the lateral femoral condyle or by impact against the femur once dislocated.[12] However, neither study mentions the Beighton-Horan (BH) scale for their patients to assess whether hypermobility plays a role in protecting or predisposing toward chondral or osteochondral injuries. Damage of the articular cartilage due to recurrent dislocation has been documented in patients with hypermobility.[16] The range of effect size varies greatly. Stanitski[26] reported that 15 patients without hypermobility had a 2.5 times increased frequency (80% vs 33%) of articular cartilage lesions when compared with 15 patients with hypermobility. Conversely, Howells and Eldridge[9] showed that the prevalence of lesions affecting the articular cartilage of the patellofemoral joint identified intraoperatively was comparable between hypermobile patients and controls ($P = .516$).

In this study, we sought to determine whether LAX was protective of concomitant chondral or osteochondral damage requiring surgical intervention in patients with recurrent patellofemoral instability.

METHODS

After receiving institutional review board approval, we prospectively collected data on patients who underwent MPFL reconstruction between 2005 and 2015 for symptoms of recurrent lateral patellofemoral instability. All surgeries were performed by 2 fellowship-trained surgeons with expertise in patellofemoral instability (B.E.S.S. and S.M.S.). Patients were excluded if they had a previous surgical procedure on the operative knee. A total of 171 patients were enrolled in this study.

For all patients, constitutional laxity of the ligaments was rated using the BH scale, in which 1 point is awarded for each fifth-finger metacarpophalangeal hyperextension $>90°$; passive thumb-forearm apposition, elbow, and knee hyperextension $>10°$; and the ability to place palms flat on the floor with the knees fully extended[19]—for a total of 9 possible points. LAX was defined as BH ≥ 5. The number of prior dislocations and mechanism of injury (contact vs noncontact) were recorded for each patient. Preoperative magnetic resonance images were evaluated for chondral or osteochondral injuries, and their size and Outerbridge grade were noted. The Outerbridge classification was utilized as described: grade 0, normal cartilage; grade 1, abnormal signal with an intact cartilage surface; grade 2, partial-thickness ulceration or fissuring (affecting $<50\%$ of the cartilage depth); grade 3, ulceration or fissuring affecting deeper than 50% of the cartilage thickness; and grade 4, full-thickness defect with osteochondral defect.[19,28] Anatomic measurements were documented for each patient and included TT-TG distance (abnormal if >20 mm), Caton-Deschamps Index for patellar height (abnormal if >1.2), and the Dejour classification for trochlear dysplasia (type A, shallow trochlea with a sulcus angle $>145°$; type B, flattened trochlea; type C, lateral convexity with medial hypoplasia; and type D, cliff sign or trochlear "bump").[4]

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Ethical approval for this study was obtained from the Hospital for Special Surgery (study No. 2015-014).

TABLE 1
Comparison of Patient and Clinical Characteristics of Study Population[a]

	Overall		NLX Group (BH <5)		LAX Group (BH ≥5)		
Characteristic	n	Value	n	Value	n	Value	*P*
Age at time of surgery, y	170	22.5 ± 8.4	75	22.6 ± 9.6	95	22.4 ± 7.4	.931
Sex: female (vs male)	171	139 (81)	75	53 (71)	96	86 (90)	**.002**
No. of instability events	170	8.5 ± 19.3	74	9.2 ± 20.9	96	8 ± 18.2	.694
TT-TG distance, mm	133	14.3 ± 4.9	63	14.4 ± 5.2	70	14.1 ± 4.7	.682
TT-TG ≥20 mm (vs <20 mm)	133	13 (10)	63	7 (11)	70	6 (9)	.622
Patellar height (CDI)	134	1.2 ± 0.2	63	1.2 ± 0.2	71	1.2 ± 0.2	.484
CDI >1.2 (vs ≤1.2)	134	63 (47)	63	27 (43)	71	36 (51)	.364
Injury mechanism: contact (vs noncontact)	159	14 (9)	70	6 (9)	89	8 (9)	.927
Trochlear dysplasia: present (vs absent)	133	121 (91)	63	57 (90)	70	64 (91)	.848
Additional surgery: yes (vs no)	171	58 (34)	75	29 (39)	96	29 (30)	.246
Articular cartilage injury	163	142 (87)	72	64 (89)	91	78 (86)	.548
Grade 3-4 (vs grade 1-2)	142	95 (67)	64	42 (66)	78	53 (68)	.770
Patellar cartilage injury	165	104 (63)	72	42 (58)	93	62 (67)	.271
Grade 3-4 (vs grade 1-2)	104	59 (57)	42	31 (74)	62	28 (45)	**.004**
Femoral cartilage injury	114	22 (19)	51	13 (25)	63	9 (14)	.132
Grade 3-4 (vs grade 1-2)	20	9 (45)	12	8 (67)	8	1 (13)	**.050**

[a]Data are reported as mean ± SD or n (%). Boldface *P* values indicate a statistically significant difference between the NLX and LAX groups ($P \leq .05$). BH, Beighton-Horan; CDI, Caton-Deschamps Index; LAX, ligamentous laxity; NLX, no ligamentous laxity; TT-TG, tibial tubercle–trochlear groove.

Intraoperatively, chondral and osteochondral injuries were measured, graded, and surgically addressed as necessary. Surgical interventions included chondroplasty, particulated juvenile cartilage implantation (DeNovo; Zimmer), microfracture, osteochondral fracture fixation, or osteochondral allograft (OCA).

Descriptive statistics of continuous variables were reported using means and standard deviations. Discrete variables were reported using frequencies and percentages. Independent-samples *t* tests were used to compare continuous variables between patients who had a preoperative BH score <5 (no laxity [NLX] group) versus ≥5 (LAX group). Continuous variables that were found to be in violation of the assumption of normality from Shapiro-Wilks tests were assessed using Mann-Whitney *U* tests. Chi-square tests were used to compare discrete variables between the LAX and NLX groups. Multivariable logistic regression analysis was performed to adjust for any potential confounding from variables such as age, sex, patellar translation, patellar height, and trochlear dysplasia. Statistical significance was defined as $P \leq .05$. All analyses were conducted using SPSS Version 22.0 (IBM).

Before the initiation of the study, we estimated a clinical difference of 20% in the incidence of chondral defects between our study populations and defined that as a clinically meaningful difference. Previous studies have reported differences in the incidence of chondral injuries ranging from 4% to 63%.[8,26] Our assumption presumed a more conservative estimate of a 20% difference in chondral injury incidence between patients with LAX and NLX. With that estimate, our a priori power analysis determined that sample sizes of 80 patients in each group would achieve 80% power to detect a 20% difference in the incidence of chondral defect in patients undergoing MPFL reconstruction for patellar instability, with statistical significance set at alpha ≤.05.

RESULTS

The 171 study patients consisted of 32 men and 139 women, with a mean age of 22 years (range, 11-57 years). There were 96 patients in the LAX group and 75 patients in the NLX group. In this study population, the LAX group had a higher proportion of women than the NLX group (90% vs 71%; $P = .002$). No group differences were found with respect to trochlear morphology ($P = .848$), patellar height ($P = .484$), or patellar translation ($P = .682$). A complete description of the demographic and clinical data of the patient population is summarized in Table 1.

Of the 171 patients in the study population, 58 (34%) required a surgical intervention for a chondral or osteochondral defect at the time of MPFL reconstruction. Of the 58 defects, 29 (50%) were chondroplasty, 18 (31%) were particulated juvenile cartilage implantation, 16 (28%) were microfracture, 2 (3.4%) were osteochondral fracture fixation, and 2 (3.4%) were OCA (Figure 1).

Patellar Chondral or Osteochondral Injuries

There was no statistically significant difference in the percentage of patients with patellar chondral or osteochondral injuries in the LAX group (67%) compared with the NLX group (58%) ($P = .271$). Of those patients with patellar chondral or osteochondral injuries, the LAX group was found to have a lower rate of more severe (Outerbridge grade 3 or 4) injury (45%) compared with the NLX group (74%) ($P = .004$) (Table 1).

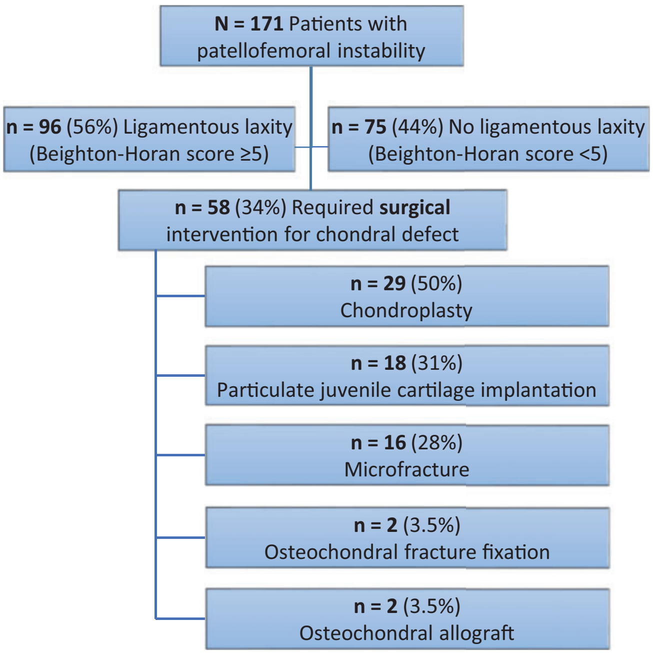

Figure 1. Breakdown of treatment for chondral or osteochondral injuries requiring surgical intervention.

Femoral Chondral or Osteochondral Injuries

Patients with LAX were found to have a lower proportion of femoral chondral or osteochondral injuries (14%) compared with the NLX group (25%), although this difference was not significant ($P = .132$). In patients with femoral chondral or osteochondral injuries, patients with LAX had significantly fewer grade 3 or 4 injuries (13%) versus patients in the NLX group (67%) ($P = .050$).

Risk Factors for Chondral or Osteochondral Injuries

There was no difference in the grade or required surgical intervention for chondral or osteochondral lesions in relationship to the number of instability events ($P = .878$) or mechanism of injury (contact vs noncontact [$P = .772$]). Our study also found no association with chondral or osteochondral injury with trochlear morphology ($P = .843$), patellar height ($P = .303$), TT-TG ($P = .874$), or age at time of surgery ($P = .482$).

Risk Factors for Severe Patellar Chondral or Osteochondral Injuries

A multivariable logistic regression model was built to assess the association of LAX on grade 3 or 4 patellar chondral or osteochondral injury in patients with patellar chondral or osteochondral injury while controlling for the potential confounding effects of patient and clinical variables. Variables that were included in the regression model were age, sex, patellar translation (TT-TG ≥20 mm), patellar height (patellar alta vs normal), trochlear dysplasia (Dejour type A, B, C, or D vs normal), and BH score (≥5 vs <5). Results from the regression analysis indicated that after adjusting for all other variables in the model, patients with LAX were 75% less likely to have had grade 3 or 4 patellar chondral or osteochondral pathology compared with the NLX group (odds ratio, 0.24; 95% CI, 0.09-0.66; $P = .006$) (Table 2). Regression modeling for the outcome of femoral chondral or osteochondral injuries was not performed because of the limited number of femoral chondral or osteochondral injuries in our cohort.

TABLE 2
Results of Multivariable Logistic Regression Model for Grade 3 or 4 Patellar Chondral or Osteochondral Injuries[a]

Parameter	OR (95% CI)	*P*
Age at time of surgery	1.06 (1.00 -1.13)	.070
Female sex (vs male)	2.46 (0.66-9.12)	.178
TT-TG ≥20 mm	3.07 (0.50-18.96)	.228
Patella alta (CDI >1.2)	1.50 (0.58-3.91)	.405
Trochlear dysplasia	2.52 (0.46-13.77)	.287
Beighton-Horan score ≥5	0.24 (0.09-0.66)	**.006**

[a]Boldface *P* value indicates statistical significance ($P \le .05$). CDI, Caton-Deschamps Index; OR, odds ratio; TT-TG, tibial tubercle–trochlear groove.

DISCUSSION

While the results of this analysis did not show a statistically significant difference in the number of chondral or osteochondral defects between LAX and NLX, several important results can be taken away from these data. Our study demonstrated that in patients with cartilage injury, there are significant differences in the severity of chondral damage between patients with LAX and those with NLX. While there was no difference in the absolute number of chondral injuries seen, patients with LAX were much less likely to have high-grade lesions requiring surgical intervention at the time of MPFL reconstruction. When this was broken down by location of lesion, patients with LAX had fewer patellar (Figure 2) and femoral condyle (Figure 3) grade 4 chondral or osteochondral injuries when compared with their counterparts with NLX.

As an example, Figure 4 shows a case of a patient with NLX with patellofemoral instability and a focal patellar osteochondral injury with an associated loose body. This patient underwent fixation of the osteochondral fracture at the time of MPFL reconstruction. A second-look arthroscopy shows a healing chondral surface, despite the widespread fissuring seen at the index procedure.

Interestingly, despite their known contribution to the risk of recurrent patellar instability, factors including trochlear dysplasia, patella alta, elevated TT-TG, and young age did not have an impact on the severity of chondral or osteochondral injuries.

The results of this study may help surgeons counsel patients after their first dislocation regarding their potential for severe chondral or osteochondral injury in the event of RPDs going forward. Surgeons may be inclined to

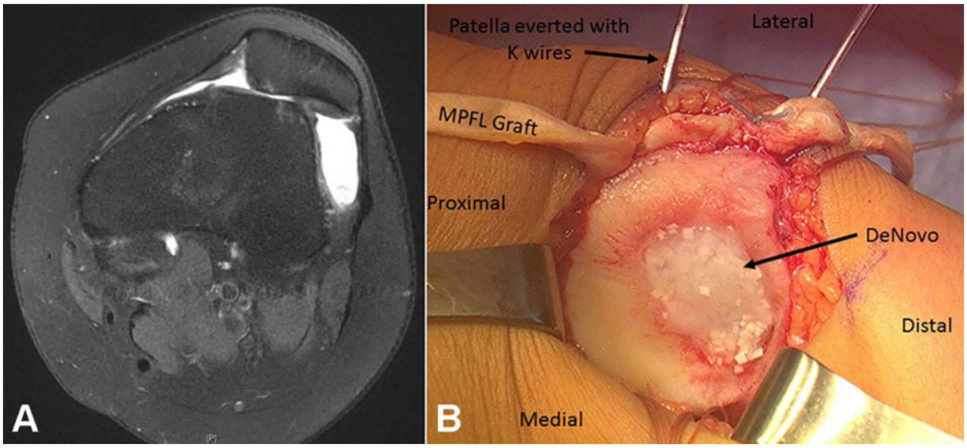

Figure 2. (A) Axial magnetic resonance image showing a focal patellar chondral defect from a lateral patellar dislocation. (B) Intraoperative photo of particulated juvenile chondral allograft (DeNovo) to the patellar chondral defect. MPFL, medial patellofemoral ligament.

Figure 3. Sagittal magnetic resonance image showing a focal chondral defect on the lateral femoral condyle from a lateral patellar dislocation.

stabilize patients with NLX sooner than their counterparts with LAX because of their increased risk of developing grade 4 chondral lesions requiring surgical intervention with recurrent dislocations.

First-Time Versus Recurrent Patellar Instability

The rate of chondral or osteochondral injury associated with patellar instability and acute dislocation has ranged from 5% to 95% in the literature.[††] This is in line with our study, which had an articular cartilage injury rate of 87.1%.

[††]References 5, 7, 10, 13, 14, 17, 21, 24, 26–28.

There has been conflicting evidence regarding whether the incidence, severity, and natural history of chondral and osteochondral lesions vary in the setting of acute versus chronic patellar instability. Nomura and Inoue,[15] in their second-look analysis of 60 knees—30 with acute patellar dislocation (APD) and 30 with RPD, found that in most APD knees, cracking in the central dome did not have remarkable change 16.7 months after MPFL reconstruction. In RPD, fissuring (which was hypothesized to be the worsening of previous cracking) did not change. However, the authors reported that the cartilage changes in RPD were far more complicated than those seen in APD. Unfortunately, the authors did not relate these data to the BH score for their patients. Our study adds the effect of LAX and thus helps clinicians counsel their patients on the potential for future severe cartilage injuries requiring treatment.

Vollnberg et al[28] reported on 129 knees with acute, recurrent (<10 dislocations), and chronic (>10 dislocations) dislocators and found increasing cartilage lesions and signs of early osteoarthritis as the frequency of dislocation increased. The prevalence rates of cartilage lesions were 71%, 82%, and 97% in the 3 groups, respectively. In contrast, our data showed no difference in the grade or required surgical intervention for chondral lesions in relationship to number of instability events (P = .878) or mechanism of injury (contact vs noncontact [P = .772]). Our study also found no association of chondral injury with trochlear morphology (P = .843), patellar height (P = .303), TT-TG (P = .874), or age at time of surgery (P = .482).

Hypermobility

As previously mentioned, there has been some literature exploring the role of hypermobility with respect to the natural history of chondral lesions in the setting of patellar instability. In 1965, Ahstrom[1] was the first to suggest that hypermobility may play a role in patellar dislocation. He

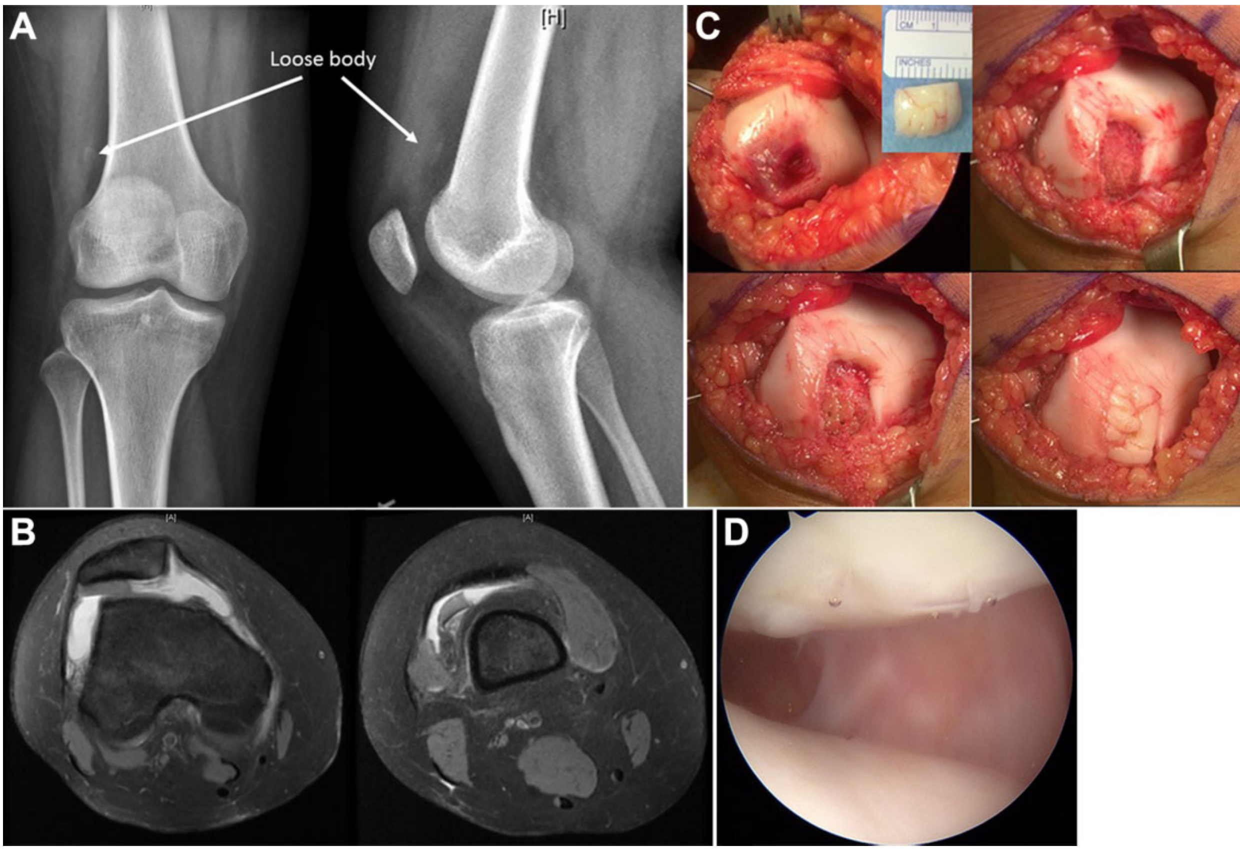

Figure 4. (A) Anteroposterior and lateral radiographs showing a suprapatellar loose body. (B) Axial magnetic resonance image showing a focal osteochondral defect with an intra-articular loose body. (C) Intraoperative photo of patellar osteochondral defect and sequential steps to prepare the lesion for fixation and final fixation of the osteochondral fracture. (D) Appearance of osteochondral fracture at second-look arthroscopy showing a healed chondral surface despite extensive fissuring seen at the index procedure.

reported on 18 cases of APD in the setting of hypermobility in which patients sustained osteochondral fractures. In 1983, Runow[23] looked at 104 patients with patellar dislocation, two-thirds of whom were classified as hypermobile. He noted that osteochondral fractures were seen twice as often in those dislocators who were not hypermobile.[23] More recently, Stanitski[26] looked at hypermobility in 30 children aged 12 to 16 years with acute primary patellar dislocation and found those who were not hypermobile had a 2.5 times greater incidence of articular lesions than those who were hypermobile. Most recently, Howells and Eldridge[9] looked at 25 hypermobile patients with 50 matched controls who underwent MPFL reconstruction for RPD. They found that atraumatic dislocation was the most common type of dislocation, with 18 hypermobile patients (72%) and 35 controls (70%). They also reported no chondral damage in 21 hypermobile (84%) patients and 40 controls (80%). Three hypermobile patients (12%) and 6 controls (12%) had osteochondral defect, 1 hypermobile patient (4%) and 3 controls (6%) had Outerbridge grade 2 to 3 defects, and 1 control (2%) had Outerbridge grade 4. Unlike the current study, these data do not support a trend toward a difference in the amount or severity of chondral damage between hypermobile and nonhypermobile patients.

CONCLUSION

For patients who sustained patellar or femoral chondral or osteochondral injuries, compared with their counterparts with NLX, patients with LAX were less likely to have severe (grade 3 or 4) injuries requiring surgical intervention.

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