Anatomic Drivers of J-Sign Presence and Severity

If There Is a Jump, Look for a Bump

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Background: Medial patellofemoral ligament reconstruction is frequently indicated for recurrent lateral patellar instability. The preoperative presence and severity of a J-sign have been associated with poorer postoperative outcomes.

Purpose: To determine the underlying anatomic factors that contribute to the presence, severity, and jumping quality of the J-sign.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: All patients undergoing evaluation for patellar instability at a single institution between 2013 and 2023 and healthy controls without patellar instability were included. Patients with a history of knee osteotomies were excluded. The presence of a jumping J-sign and its relationship to patellofemoral measures including the Caton-Deschamps Index (CDI), trochlear dysplasia (Dejour grade), tibial tubercle–trochlear groove (TT-TG) distance, tibial tubercle lateralization, trochlear bump height, mechanical alignment, femoral anteversion, tibial torsion, trochlear medialization, patellar width, axial patellar/trochlear overlap, patellar height, trochlear height, and knee rotation angle (KRA) were measured using standardized 1.5-T magnetic resonance imaging (MRI). Univariate pairwise and multivariable analyses were performed to determine the factors associated with J-sign presence, severity, and quality.

Results: Of the 130 knees with patellar instability, 89 (68.5%) demonstrated a J-sign on physical examination. In total, 44 (33.8%) patients demonstrated a 1-quadrant J-sign, 32 (24.6%) demonstrated a 2-quadrant smooth J-sign, and 13 (10.0%) demonstrated a jumping J-sign. A total of 22 control, noninstability cases were included. On multivariable analysis, increasing TT-TG distance (OR, 1.1 increase per millimeter; P = .04), external KRA (OR, 1.1 increase per degree; P = .02), and increasing CDI (OR, 1.3 increase per 0.1 increase in CDI; P = .02) were associated with J-sign presence. Increasing bump height (OR, 1.72 increase per millimeter; P = .007) and decreasing patellar width (OR, 0.89 decrease per millimeter; P = .076) were associated with a larger J-sign, when present. Increasing bump height (OR, 1.80 increase per millimeter; P = .018), increasing patellar width (OR, 1.33 increase per millimeter; P = .047), and decreasing CDI (OR, 0.009 decrease per 0.01 increase in ratio; P = .008) were associated with a jumping J-sign in comparison with a smooth 2-quadrant J-sign. A KRA of 10° (AUC, 0.70) and a cartilaginous bump height of 6.6 mm (AUC, 0.73) were thresholds associated with jumping J-sign presence.

Conclusion: The presence of a J-sign is associated with MRI findings of relatively greater external tibiofemoral rotation, increased TT-TG distance, and increased patellar height, while J-sign severity and jumping quality are associated with the presence of additional underlying trochlear factors such as increased bump height. The anatomic drivers identified in this study should be further evaluated as possible factors associated with suboptimal outcomes after surgical management.

Keywords: patellar instability; J-sign; trochlear bump; dysplasia; pathoanatomy

The pathophysiology of lateral patellar instability involves a complex interaction between static anatomic factors of the trochlea and patella, such as trochlear dysplasia and patellar height, and dynamic elements such as quadriceps activation during knee flexion.[3,10] Patellar maltracking, measured clinically as a J-sign, is observed on physical examination at the terminal degrees of active knee extension. The lateral deviation of the patella in active extension often traces an inverted J shape. This is largely a subjective measurement with only fair interrater reliability and is typically graded ordinally in quadrants (grades 1-4), or may also be qualified by quality of transition, such as "gradual" or "jumping."[5,8] Separately, there is also the Donell classification system, which qualitatively describes patellar tracking in 8 patterns.[8]

The American Journal of Sports Medicine
2025;53(5):1119–1126
DOI: 10.1177/03635465251322788

Several studies have provided growing evidence for the clinical relevance of a J-sign. Preoperatively, Milinkovic et al[7] demonstrated that the presence of a high-grade J-sign had a significant negative effect on quality of life in patients with patellar instability, as measured by the Banff Patellofemoral Instability Instrument 2.0 (BPII 2.0). Sappey-Marinier et al[9] and Zhao et al[15] identified a preoperative J-sign as a predictor of failure of isolated medial patellofemoral ligament (MPFL) reconstruction. Similarly, patients with a high-grade J-sign demonstrated inferior clinical outcomes, graft laxity, and residual maltracking after derotational distal femoral osteotomy with MPFL reconstruction (MPFLR).[13] Previously, Zhao et al[15] performed a limited analysis of factors driving the presence of a J-sign, citing patellar height and trochlear dysplasia. However, given the growing evidence of the clinical relevance of a J-sign, a comprehensive evaluation of the underlying anatomic factors contributing to a high-grade J-sign is relevant for optimizing clinical and surgical outcomes.

Therefore, the objective of this study was to investigate the anatomic factors associated with the presence, severity, and quality of a J-sign. We hypothesized that both trochlear factors and patellar factors contribute to this common physical examination finding.

METHODS

Patient Selection

After institutional review board approval from Rush University Medical Center, a retrospective review of patients undergoing clinical evaluation for patellar instability between 2013 and 2023 by the senior author (A.B.Y.) at a single institution was performed. Images were acquired on a 1.5-T MAGNETOM Altea MRI scanner (Siemens Healthineers). The imaging protocol consisted of proton density–weighted axial, sagittal, and coronal views with fat suppression; T1-weighted coronal view; T2-weighted sagittal view with fat suppression; and T2-weighted coronal oblique anterior cruciate ligament view. The indication for magnetic resonance imaging (MRI) of the affected knee was a (1) history of suspected first-time patellar dislocation event, (2) chronic history of subluxation events, or (3) chronic history of multiple confirmed recurrent patellar dislocations. Inclusion criteria for the study were (1) a history of patellar instability, (2) a referral for MRI of the affected knee, and (3) available MRI scans for review at the initiation of the study, even if obtained at an outside institution. Patients were excluded if they did not have available preoperative perfect lateral radiographs or if they had a history of a surgery involving osteotomy of the affected knee (eg, tibial tubercle osteotomy or trochleoplasty). A prospective arm was conducted for the recruitment of healthy controls for comparison (A.B.Y.). Healthy volunteers underwent MRI of the knee utilizing the same protocol as patients with patellar instability. Inclusion criteria consisted of age 18 to 30 years, and exclusion criteria consisted of (1) a self-reported history of patellar dislocation or subluxation events, (2) previous surgery to the index knee, and (3) recent or ongoing mechanical symptoms, recurrent swelling, or anterior knee pain. MRI in this cohort was performed on a volunteer basis based on self-reported history, and no formal physical examination was performed. All volunteers were presumed to have no J-sign.

Clinical and Radiographic Measurements

Physical examination was performed by the senior author most commonly after reviewing the MRI scans. All patients with patellar instability were examined seated upright (Figure 1). During active open-chain extension of the knee from 90° of flexion, patellar tracking was assessed from this position to terminal extension. Lateral deviation was characterized by quadrants, and additionally characterized based on the clinical experience of the senior author as abrupt, jumping, severe, or, conversely, gradual or mild. This was a qualitative, binary description of the J-sign to capture a facet of the intensity of this maltracking pattern. The authors did not find this to be well described in the existing literature. For this study, the J-sign was characterized as either 1 or 2 patellar quadrants of deviation. Two-quadrant J-signs were further characterized as gradual or jumping. Mechanical axis was measured on anteroposterior leg-length radiographs for patients with patellar instability. Full leg-length radiographs were not available for healthy controls.

On MRI, the following measurements were performed by 2 authors (N.D. and A.R.P.) who were trained by the senior author and blinded to the physical examination: Caton-Deschamps Index (CDI), Dejour dysplasia grade,

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Submitted December 20, 2023; accepted November 27, 2024.

One or more of the authors has declared the following potential conflict of interest or source of funding: M.H. has received consulting fees from DJO–Enovis, Moximed, and Vericel; support for education from Smith & Nephew, Arthrex, Foundation Medical, and Medwest Associates; honoraria from Encore Medical; and hospitality payments from Stryker and Medical Device Business Services. N.T. has received speaking fees from DJ Orthopedics; hospitality payments from Piedmont Plus Innovation, Encore Medical, and Stryker; support for education from Arthrex, SouthTech Orthopedics, and Smith & Nephew; and a grant from Medical Device Business Services. A.B.Y. has received honoraria from JRF Ortho; consulting fees from Stryker, AlloSource, CONMED Linvatec, JRF Ortho, and Olympus; research support from Arthrex, Organogenesis, and Vericel; is an unpaid consultant for Patient IQ, Smith & Nephew, and Sparta Biomedical; and holds stock or stock options in Patient IQ. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

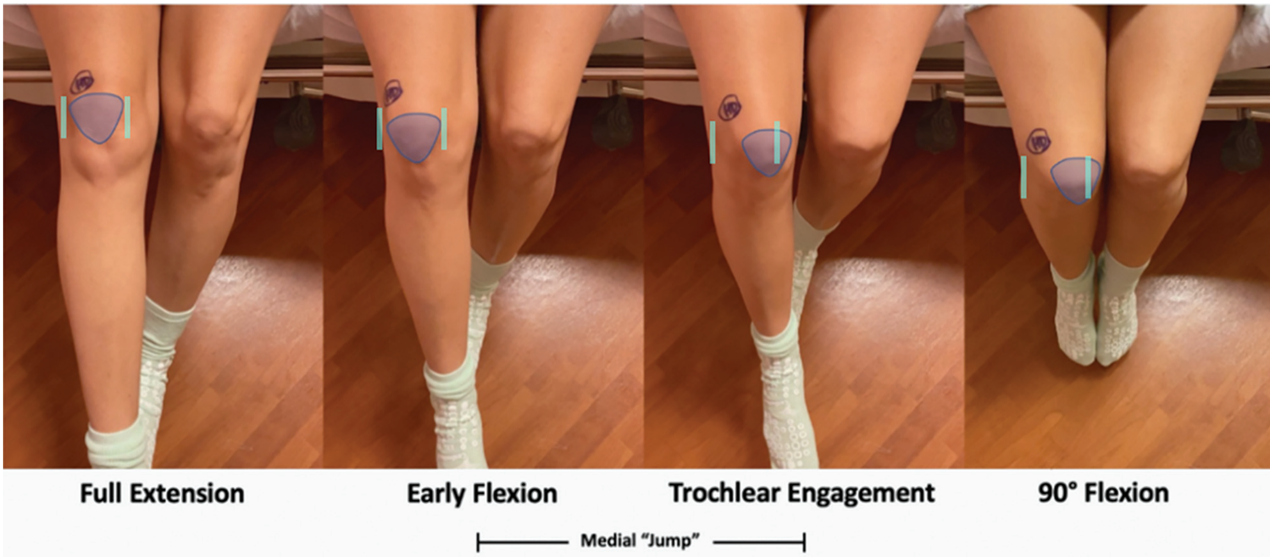

Figure 1. Clinical examination of the J-sign. Lines indicate the borders of the patellar position at full extension.

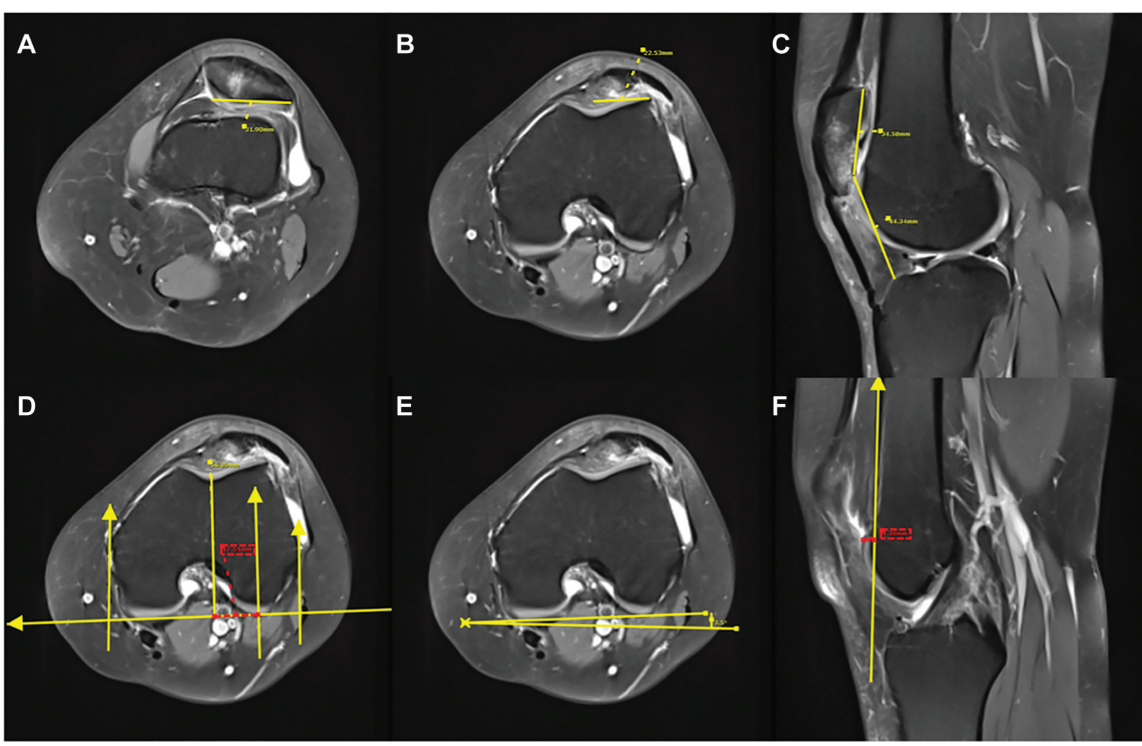

Figure 2. Selected magnetic resonance imaging measurements with descriptions adapted from Hevesi et al[2]: (A) patellar width, the widest distance of the articular surface of the patella along a line parallel to the posterior femoral condylar axis; (B) axial patellar/trochlear overlap, the distance from the most medial aspect of the patella to the most lateral aspect of the trochlea along a line parallel to the posterior femoral condylar axis; (C) Caton-Deschamps Index; (D) tibial tubercle–trochlear groove distance; (E) knee rotation angle, the angle between a line parallel to the posterior femoral condylar axis and a line parallel to the posterior tibial condyles; and (F) bump height to cartilage.

femoral anteversion, tibial torsion, tibial tubercle–trochlear groove (TT-TG) distance, tibial tubercle lateralization, trochlear medialization, patellar width, axial patellar/trochlear overlap, patellar length, trochlear length, trochlear cartilaginous bump height, and knee rotation angle (KRA). Selected example measurements are shown in Figure 2, while all measurement examples can be found in the Appendix (available in the online version of this article). In summary, femoral anteversion was measured on axial MRI slices as the angle between the femoral neck and the posterior femoral condylar reference line. Tibial torsion was measured as the angle between the posterior tibial condylar line and the bimalleolar axis. TT-TG distance was measured from the deepest point of the cartilaginous groove to the center of the tibial tubercle on a line parallel to a posterior femoral condylar reference.[2] Tubercle lateralization and trochlear medialization were measured as percentages of the total tibial or femoral width, respectively, from a medial boundary reference line. Patellar width and axial patellar/trochlear overlap were defined as the patellar width and trochlear width measurements demonstrated by Hevesi et al[2] and Heidenreich et al.[1] Briefly, patellar width was measured as the distance between the medial and lateral articulating surfaces of the patella and recorded on the axial slice with the greatest patellar width, and axial patellar/trochlear overlap was measured as the distance between the medial articulating surface of the patella and the lateral edge of the trochlear cartilage. Trochlear length was measured as the femoral distance from the most proximal aspect of trochlear cartilage to the intersection of the most distal aspect of the patella on the sagittal MRI slice that included the most proximal aspect of the trochlea. KRA was measured as the angle between a posterior tibial condylar reference line and a posterior femoral condylar reference line on the axial slice that best depicted the proximal trochlea. The trochlear bump was defined as the proximal trochlear prominence anterior to the cortical reference line composed of both bone and cartilage. Cartilaginous bump height was measured as a perpendicular line from an anterior cortical reference line measuring to the apex of the cartilaginous supratrochlear bump. This was performed on the sagittal view, in which both the Blumensaat line and apex of the bump were visualized. Additionally, each knee was assigned a Dejour dysplasia grade based on a perfect lateral radiograph by the senior author.[6]

Statistical Analysis

All descriptive statistics were reported as mean ± standard deviation or number (percentage), where appropriate. Normality of the data was determined using the Shapiro-Wilk test. Given the presence of nonnormal data, nonparametric tests were utilized for univariate analysis. Groups were compared using Wilcoxon rank-sum or chi-square tests. Pairwise analyses were performed using Kruskal-Wallis tests with post hoc Dunn test. Bonferroni corrections were performed in the setting of multiplate comparisons. For multivariable analysis, stepwise Akaike information criterion-driven regressions were utilized for variable selection. Lastly, cutpoint optimization with receiver operating characteristic (ROC) curve analysis was utilized to determine thresholds of continuous variables associated with binary outcomes. An associated area under the curve (AUC) $\geq$0.70 was determined to be adequate. All testing was 2-sided, and significance was established as a P value <.05. All testing was performed in R Version 4.1.0 (R Core Team) and Stata Version 16.1 (StataCorp).

RESULTS

Patient Characteristics

A total of 130 knees in patients with patellar instability and 22 knees in healthy controls were included for analysis. All characteristics are presented in Table 1.

Of the 130 patellar instability knees, 89 (68.5%) demonstrated a J-sign on physical examination. Of the patients who had a J-sign, 44 (33.8%) demonstrated a 1-quadrant J-sign, 32 (24.6%) demonstrated a 2-quadrant smooth J-sign, and 13 (10.0%) demonstrated a jumping J-sign.

On univariate pairwise analysis, there were significant intergroup differences across all measures except patellar length, tibial torsion, and mechanical axis valgus (Figure 3). Compared with the healthy controls, patients with a jumping J-sign demonstrated greater bump height ($P <$ .001), KRA ($P <$ .001), and TT-TG distance ($P <$ .001), as well as lower patellar width (P = .003) and axial patellar/trochlear overlap ($P <$ .001). Within the patients with instability, patients with a jumping J-sign had the greatest mean bump height of all groups ($P <$ .05 for all comparisons), as well more external KRA (P = .01) and lower axial patellar/trochlear overlap (P = .002) relative to patients with instability without a J-sign. Mean anatomic measures across all groups are listed in Appendix Table A1 (available online).

Presence of a J-Sign

Given the significant collinearity of KRA, tibial tubercle lateralization, and TT-TG distance demonstrated by Hevesi et al,[2] KRA and tibial tubercle lateralization were included as the individual components of TT-TG distance, and a separate regression was performed using overall TT-TG distance in lieu of KRA and tubercle lateralization.

When included in multivariable analysis, increasing TT-TG distance (OR, 1.1 increase per millimeter; P = .04) and increasing CDI (OR, 1.3 increase per 0.1 increase in CDI; P = .02) were associated with the presence of a J-sign (Figure 4). Larger patellar width values were associated with a decreased J-sign presence (OR, 0.80 decrease per millimeter; $P <$ .001). By ROC analysis, a TT-TG distance >11.27 mm (AUC, 0.68) and CDI >1.27 (AUC, 0.66) were associated with the presence of a J-sign.

In a separate multivariable analysis, increasing KRA (OR, 1.1 increase per degree; P = .02) and increasing CDI (OR, 1.4 increase per 0.1 increase in CDI; P = .01) were associated with the presence of a J-sign (Figure 5). In contrast, larger patellar width values were associated with a decreased risk of a J-sign (OR, 0.81 decrease per millimeter; $P <$ .001). A KRA of at least 0.5° (AUC, 0.72) and CDI of 1.27 (AUC, 0.66) were associated with a present J-sign.

TABLE 1
Group Characteristics[a]

Characteristic	Patellar Instability Cohort (n = 130)	Control Cohort (n = 22)	P Value
Age, y	21.4 ± 9.3	27.8 ± 4.2	<.001
Sex			.98
Male	41	7	
Female	89	15	
Dejour dysplasia grade			<.001
A	41		
B	27		
C	10		
D	16		
Normal	36	22	
J-sign[b]			<.001
None	41	22	
1-quadrant smooth	44		
2-quadrant smooth	32		
2-quadrant jumping	13		
Imaging characteristics			
Knee rotation angle, deg	2.8 ± 6.9 (−11.7 to 24.7)	−4.8 ± 4.0 (−10.2 to 3.2)	<.001
Femoral anteversion, deg	19.3 ± 11.4 (−12.5 to 46.7)	13.8 ± 8.5 (2.0 to 25.8)	.014
Tibial torsion, deg	36.7 ± 10.2 (6.4 to 69.0)	36.7 ± 7.8 (20.8 to 48.9)	.27
Mechanical axis valgus, deg	1.1 ± 2.8 (−7.2 to 8.7)		
Patellar length, mm	30.5 ± 2.9 (22.7 to 37.5)	30.6 ± 2.8 (23.5 to 36.3)	.85
Trochlear length, mm	10.2 ± 5.3 (0 to 24)	11.9 ± 4.6 (1.6 to 19.7)	.12
Patellar width, mm	35.2 ± 4.6 (16.7 to 48.8)	40.2 ± 5.2 (33.8 to 53.7)	<.001
Axial patellar/trochlear overlap, mm	27.0 ± 7.6 (2.9 to 45.82)	31.7 ± 3.2 (27.6 to 37.6)	<.001
TT-TG distance, mm	16.4 ± 4.5 (6.1 to 29.4)	10.4 ± 4.0 (2.6 to 18.8)	<.001
CDI	1.3 ± 0.2 (0.8 to 1.7)	1.1 ± 0.1 (0.9 to 1.3)	<.001
Tubercle lateralization, % of tibial width	0.7 ± 0.1 (0.3 to 0.8)	0.7 ± 0.03 (0.6 to 0.7)	.66
Trochlear medialization, % of femoral width	0.5 ± 0.04 (0.4 to 0.7)	0.5 ± 0.04 (0.4 to 0.6)	.18
Bump height, mm)	5.8 ± 1.6 (2.5 to 11.9)	4.7 ± 1.0 (2.7 to 6.3)	<.001

[a]Data are presented as n or mean ± SD (range). CDI, Caton-Deschamps Index; TT-TG, tibial tubercle–trochlear groove.
[b]Presumed negative J-sign in the control cohort.

J-Sign Severity in Quadrants

Among all patients with patellar instability, 76 had a smooth J-sign (44 with 1 quadrant, 32 with 2 quadrants). On multivariable analysis, larger cartilaginous bump height (OR, 1.72 increase per millimeter; P = .007) and smaller patellar width (OR, 0.89 decrease per millimeter; P = .076) were associated with a 2-quadrant sign (Figure 6). A bump height >5.63 mm (AUC, 0.71) was associated with any 2-quadrant J-sign (smooth or jumping).

Jumping J-Sign

Among 45 knees with a 2-quadrant J-sign, 13 (28.9%) knees demonstrated a jumping J-sign. On multivariable analysis, compared with patients with a 2-quadrant smooth J-sign, large cartilaginous bump height (OR, 1.80 increase per millimeter; P = .018) was associated with a jumping J-sign. In this setting, a relatively lower CDI (OR, 0.009 decrease per 0.01 increase in ratio; P = .008) was associated with a jumping J-sign. Additionally, a larger relative patellar width (OR, 1.33 increase per millimeter; P = .047) was associated with a jumping J-sign, while more external knee rotation (OR, 1.20 increase per degree; P = .052) and smaller axial patellar/trochlear overlap (OR, 0.86 decrease per millimeter; P = .058) trended toward association with a jumping J-sign.

A KRA of 10° (AUC, 0.70) and a cartilaginous bump height of 6.6 mm (AUC, 0.73) were thresholds associated with the presence of a jumping J-sign (Figure 7). Three patients with a jumping J-sign had a cartilaginous bump height <6 mm. Two of these patients with bump heights of 2.73 mm and 5.66 mm had KRAs >10°, at 14.5° and 12.3°, respectively. The third had a bump height of 5.76 mm and KRA of 6.4°.

DISCUSSION

This study sought to identify anatomic factors associated with the presence of a jumping J-sign on physical examination in patients with patellar instability. Overall, a jumping J-sign was observed in 10% of the study population. On multivariable analysis, trochlear bump height (6.6 mm) and external KRA (10°) were independent predictors for a jumping J-sign. This analysis suggests that the presence

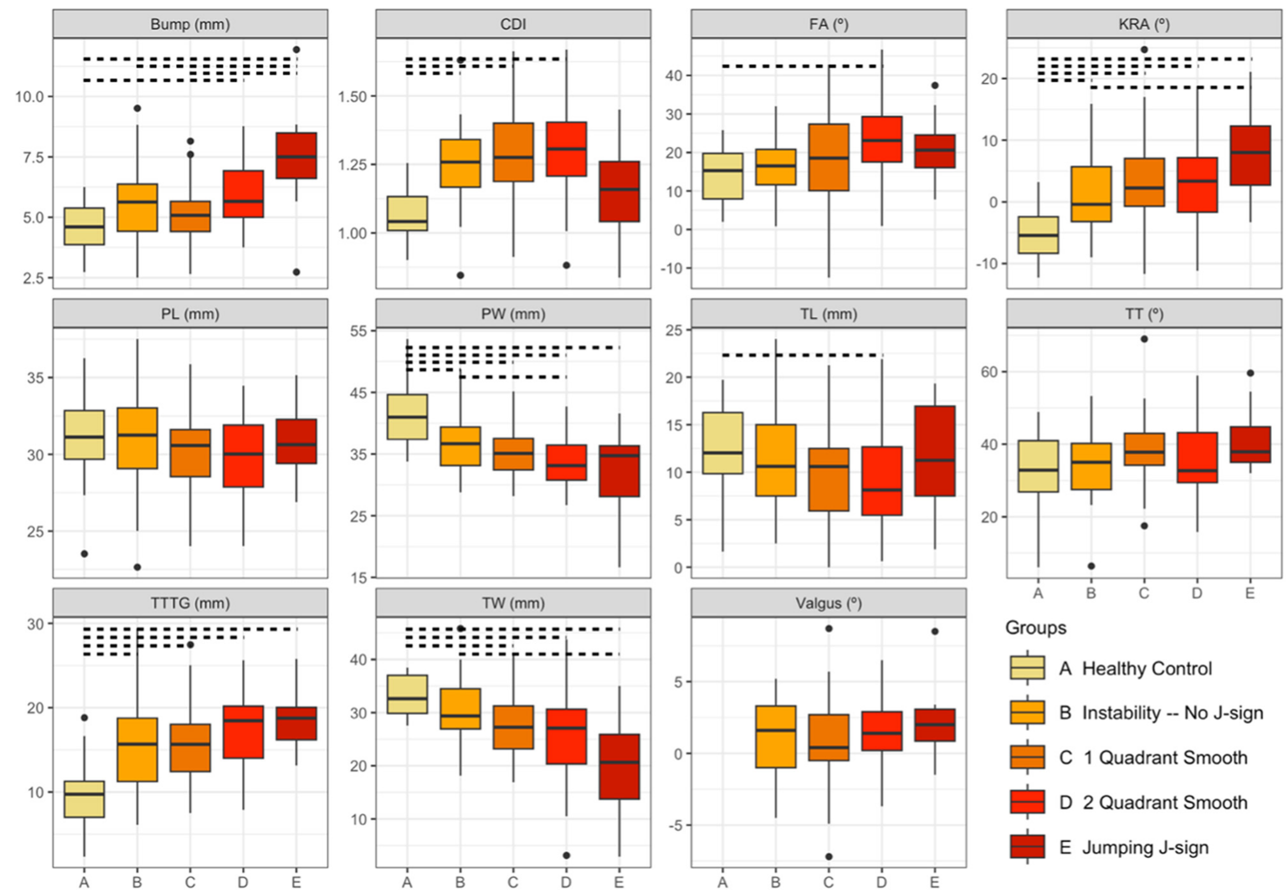

Figure 3. Pairwise comparisons demonstrate significant differences across measures except for patellar length (PL), trochlear length (TL), tibial torsion (TT), and mechanical axis valgus between healthy controls and patients with patellar instability (mechanical valgus measured only for patients with patellar instability). CDI, Caton-Deschamps Index; FA, femoral anteversion; KRA, knee rotation angle; PW, patellar width; TTTG, tibial tubercle–trochlear groove; TW, trochlear width.

of a jumping J-sign is driven by anatomic trochlear factors and tibiofemoral rotation, as opposed to patellar factors.

Past studies investigating predisposing risk factors for the presence of a jumping J-sign on physical examination have cited a wide range of anatomic factors, without a clear consensus. These include trochlear dysplasia, femoral and tibial torsion, increased CDI, and an increased TT-TG distance.[9,14] In a study evaluating risk factors for failure of MPFLR, Sappey-Marinier et al[9] found a significant relationship between Dejour grade B and D trochlear dysplasia and the presence of a jumping J-sign. Unlike the present study, the authors did not assess the effect of trochlear bump height in their analysis, which could have confounded the results because both Dejour grades found to be significant (grades B and D) include the presence of a trochlear bump. Another study by Zhang et al[14] found that patella alta was significantly associated with the presence of a grade 3 jumping J-sign, although the authors did not factor trochlear bump height into the analysis. Our study found that when accounting for trochlear bump height and tibiofemoral rotation, patellar height may both influence the presence of a J-sign and contribute to the jumping quality. In our analysis, we found that increased patellar height may predispose a patient to a J-sign, although in patients with a J-sign the patella must be low enough to interact with the trochlear bump to produce a jump. Additionally, a larger patellar width was associated with a jumping J-sign, which may be indicative of a patella with lower patellar tilt to interact with the bump and produce a jump. Furthermore, by including the drivers of TT-TG distance, this study further discerned that the rotational component of the relationship between the tibial tubercle and trochlear groove may carry more significance than the pure lateralization of the tubercle on the tibia.

To our knowledge, a study on patellar kinematics after MPFLR in the setting of trochlear dysplastic features, focused on the trochlear bump, has not been a published. Van Haver et al[12] demonstrated abnormal patellar kinematics (increased internal rotation, lateral tilt, and translation) in a cadaveric model with simulated trochlear dysplasia, most severely abnormal in the Dejour grade D group. However, no specific metrics were provided on the morphology of the trochlear implants used in the study. Future investigation will be required to evaluate the effect of trochlear bump morphology on patellar tracking, length changes of the native MPFL, and effect on MPFLR.

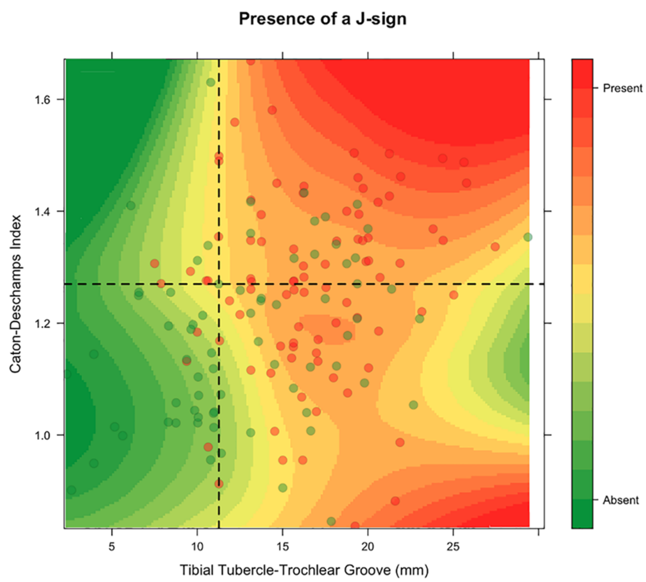

Figure 4. The presence of a J-sign driven by tibial tubercle–trochlear groove (TT-TG) distance and Caton-Deschamps Index (CDI). By receiver operating characteristic analysis, a TT-TG distance >11.27 mm and a CDI >1.27 were associated with the presence of a J-sign.

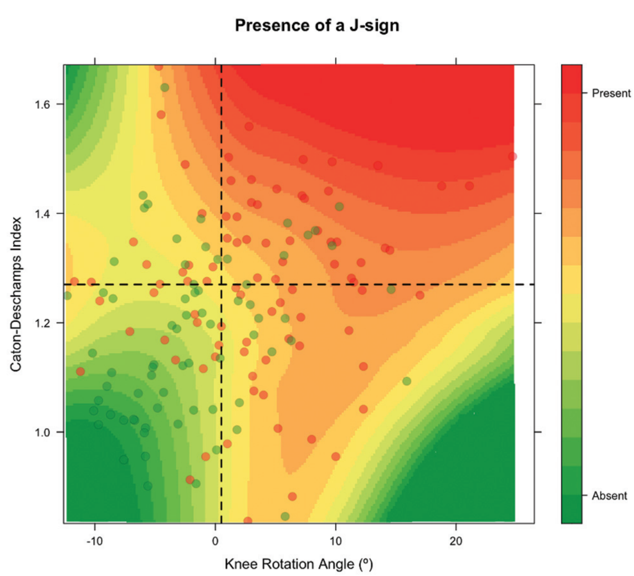

Figure 5. The presence of a J-sign is driven by the Caton-Deschamps Index and knee rotation angle.

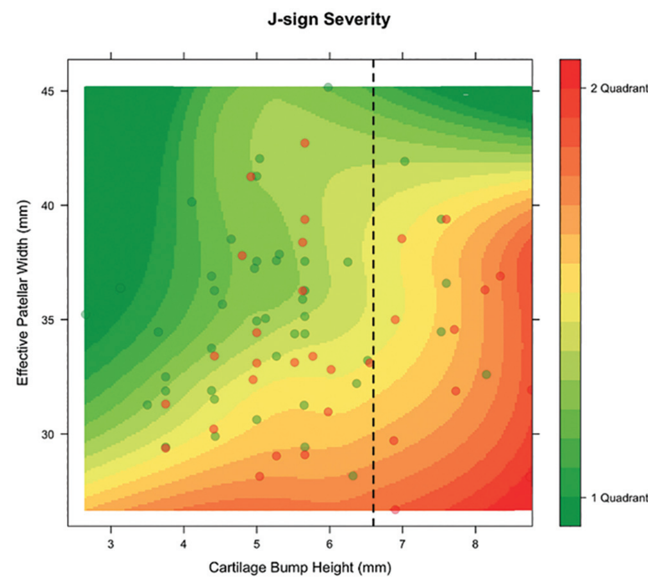

Figure 6. J-sign severity is driven by bump height and patellar width measurements.

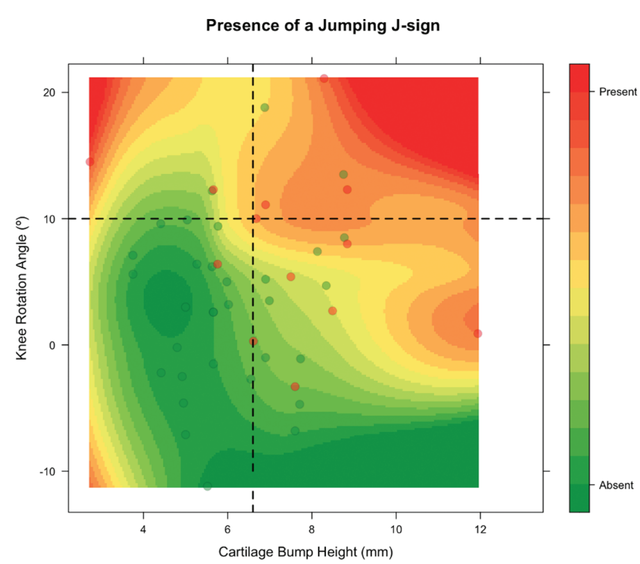

Figure 7. The presence of a jumping J-sign is driven by bump height and knee rotation angle (KRA). In the setting of a low bump height, a high knee rotation angle is needed to produce the jump. However, as bump height increases, a lower knee rotation angle is required to produce the jump. By receiver operating characteristic analysis, a bump height of 6.6 mm and KRA of 10° are associated with the jumping J-sign.

In terms of clinical outcomes, Hiemstra et al[4] previously established a trochlear bump threshold of 5 mm, above which patients had significantly lower postoperative BPII scores after isolated MPFLR. This is the only previous study, to the authors' knowledge, that establishes a threshold of trochlear bump height that may be considered concerning. Physical examination findings, however, were not included in their study, making it difficult to directly compare the 2 thresholds. Within this study, trochlear bump was measured as any trochlear prominence anterior to a cortical reference line. This was measured in all patients, including control patients, to establish a statistical threshold associated with abnormal physical examination findings. Therefore, all controls and patients with instability did have some trochlear prominence that could be considered normal, and the results from the present study could be utilized to justify that bump height >6 mm is associated with pathology. Separately, the presence of a J-sign has been identified as an independent risk factor for isolated MPFL failure by Sappey-Marinier et al.[9] Within the study, the authors did not qualify the J-sign beyond presence; therefore, severity could not be correlated with outcomes. Previous literature in combination with the present findings strongly supports the role of the trochlear bump in the J-sign. Therefore, based on the findings of the present study, identification of a J-sign on physical examination should prompt evaluation of tibiofemoral rotation, trochlear bump height, and axial patellar/trochlear overlap.

Limitations

There are several limitations to this retrospective study. Despite the use of a single surgeon's database, variability in J-sign grading may have occurred with experience, as the database spanned several years of practice. Measurements and physical examination were also performed by 1 grader only, and therefore assessment of interrater reliability could not be performed in this analysis. This is a possible source of bias. There was also no minimum number of attempts or assessments for J-sign, and therefore all available preoperative visit notes were reviewed. A patient with at least 1 demonstrated J-sign was recorded as being positive, but intermittently positive findings were not noted. Because this was not specifically analyzed, this suggests a possible confounding variable in the categorization process. Also, given the retrospective nature of this study, J-sign grading could not be standardized for this study. Therefore, there were a few cases in which the description was incomplete, such as missing quadrants of translation. These cases were included for analyses of patellar instability and J-sign presence but were removed for J-sign severity and jumping J-sign analyses. This study did benefit from the addition of a cohort of healthy controls, allowing for a more robust comparison of factors that may contribute to the presence of a J-sign. Although a control cohort was included, its demographic composition differed from that of the instability group, with significantly older age and a relatively greater proportion of male patients; however, this was nonsignificant. The relatively younger age of the control cohort may potentially influence trochlear anatomy; however, trochlear morphology has been determined to be mostly complete around age 12.[11] Additionally, the healthy controls were assumed to have no J-sign, although this was not confirmed by formal physical examination.

CONCLUSION

The presence of a J-sign is associated with MRI findings of a relatively greater external tibiofemoral rotation, increased TT-TG distance, and increased patellar height, while J-sign severity and jumping quality are associated with the presence of additional underlying trochlear factors such as increased bump height and external knee rotation. Identification of this physical examination finding suggests the presence of multiple interacting anatomic factors that may increase the risk of poor postoperative outcome. Further investigation is required to determine the effects of these anatomic risk factors on outcomes of MPFLR.

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