Trochlear Morphology Development in Pediatric Patients with Patellofemoral Instability

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INTRODUCTION: Patellofemoral instability (PFI) is a common condition affecting pediatric patients. Trochlear dysplasia has been demonstrated to be the most consistent risk factor for recurrent instability among pediatric patients, but there is limited understanding of how the trochlea develops during adolescent growth. While previous studies have demonstrated growth-related changes in other anatomic risk factors for PFI in asymptomatic individuals, no study has examined the evolution of trochlear morphology among skeletally immature patients with PFI. The aim of this study is to use serial magnetic resonance imaging (MRI) performed in skeletally immature patients with and without PFI to quantitatively measure the changes in trochlear anatomy over time. We hypothesized that patellofemoral maltracking occurring in PFI leads to progressive worsening of trochlear dysplasia with growth.

METHODS: A retrospective review was conducted to identify all patients (<18 yo) with a diagnosis of PFI and treated at our free-standing, tertiary children's hospital. Inclusion criteria included patients with a) open distal femoral physes at the initial MRI examination and b) ≥2 MRI examinations of the same knee, obtained at least 6 months apart and without intervening surgery. Exclusion criteria included prior surgery of the ipsilateral knee or congenital knee deformities. All MRI examinations were retrospectively reviewed to categorize trochlear morphology (using Dejour and Oswestry-Bristol Classifications, OBC, Figure 1) and to measure sulcus angle (SA), medial condylar trochlear offset (MCTO), and lateral trochlear inclination (LTI) using the cranial-most axial MRI image covered by articular cartilage (Table 1). A 1:3 age matched control group with no PFI was also identified for comparison. Descriptive statistics were used and latter morphologic indices were quantified to calculate change per year. ANOVA, Paired student T-tests, chi-squared, and Fisher Exact testing were used to evaluate differences in morphology between MRI examinations and between control groups.

RESULTS: We identified 98 PFI patients (mean age of 12.5 ± 2.2 years) with an average time of 2.4 ± 1.5 years (range; 0.5-6.5 years) between MRIs. Rates of moderate to severe (Dejour B-D, OBC flat or convex) trochlear dysplasia increased from the initial to most recent imaging (67% vs. 88%, p<0.001). Paired T-test analysis revealed statistically significant differences between initial and most recent MRI for LTI and SA (p<0.05). On the other hand, 30 control patients were identified (mean age ± 2.7 years) with an average time of 2.1 ± 1.6 years (range; 0.5-6.5) years between MRIs. Rates of normal trochlear morphology increased from 53% to 87% (p<0.001), while paired T-test analysis revealed statistically significant differences between initial and most recent MRI for TDI, LTI, and SA (p<0.05). When comparing rate of change, trochlear metrics changed toward a more shallow and dysplastic direction in the PFI cohort and toward a deeper, less dysplastic direction in the control group. Statistically significant differences in average change per year were seen for LTIA and SA between the PFI and control groups (p<0.001).

DISCUSSION AND CONCLUSION: Appropriate articular containment and concentricity has been demonstrated to promote normal development and maintain congruity of any joint. Our study found that in skeletally immature patients with untreated PFI trochlear dysplasia progressively worsens over time, while it steadily improves in those without PFI. Future studies should focus on analyzing changes in trochlear morphology between similarly aged patients who do and do not undergo surgical stabilization to determine if these interventions impact trochlear development.

Figure 1: Dejour and Oswestry-Bristol Trochlear Morphology Classifications

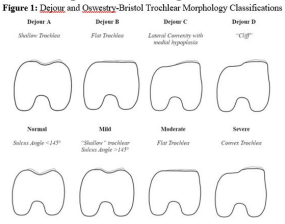

Table 1: Trochlear Morphology Measurements

Measure	Measurement Technique	Figure
Sulcus Angle (SA)	The sulcus angle is measured by finding the angle made by the medial (1-2) and lateral (1-3) trochlear facets.	
Lateral Trochlear Inclination (LTI)	The angle formed by a line drawn parallel to the posterior condylar axis (1) and a line parallel to the articular surface of the lateral trochlear facet (2-3) is measured.	
Trochlear Depth Index (TDI)	A line parallel to the posterior condylar axis was drawn and made to intersect the lowest point of the trochlea. Next, the perpendicular distance from this line to the highest points of the medial (A) and lateral (B) trochlear facets is measured. The average of these distances (C) is then used to find the point of the trochlea and negative if they did below. The TDI is calculated with the equation TDI = (A+B)/2.	
Medial condyle trochlear offset (MCTO)	The perpendicular distance from the deepest point of the trochlea to the highest point of the medial trochlear cartilage (A)	

Table 2: PFI group trochlear dysplasia measurements change per year.

Morphologic Measurement	Mean Initial MRI	Mean Recent MRI	Mean Change per Year (95% CI)	P-value
MCTO (mm)	0.846 ± 1.9	0.569 ± 1.5	-0.22 (-0.56, 0.11)	0.184
TDI	2.27 ± 1.3	2.12 ± 1.3	-0.13 (-0.33, 0.08)	0.242
LTI (degrees)	15.27 ± 5.4	13.91 ± 4.7	-1.71 (-2.53, -0.88)	0.022*
Sulcus Angle (degrees)	159.61 ± 7.8	161.21 ± 7.1	3.15 (2.29, 4.02)	0.047*
Dejour Class				
Normal	3 (3%)	1 (1%)		
A	29 (30%)	11 (11%)		
B	38 (39%)	60 (61%)		<0.001*
C	20 (20%)	17 (17%)		
D	8 (8%)	9 (10%)		
Oswestry Bristol				
Normal	3 (3%)	1 (1%)		
Mild (shallow)	29 (30%)	10 (10%)		<0.001*
Moderate (flat)	38 (39%)	61 (82%)		
Severe (convex)	28 (29%)	26 (27%)		
Statistical significance (p<0.05) indicated by *				

Table 3: Control group trochlear dysplasia measurements change per year.

Morphologic Measurement	Mean Initial MRI	Mean Recent MRI	Mean Change per Year (95% CI)	P-value
MCTO (mm)	2.9 ± 1.3	3.3 ± 1.1	0.14 (-0.04, 0.32)	0.064
TDI	4.4 ± 1.1	4.9 ± 1.7	0.14 (-.04, 0.32)	0.015*
LTI (degrees)	19.5 ± 5.4	22.9 ± 6.3	-0.63 (-1.43, 0.18)	0.003*
Sulcus Angle (degrees)	144.6 ± 9.7	138 ± 8.7	-5.15 (-6.59, -3.70)	<0.001*
Dejour Class				
Normal	16 (53%)	26 (87%)		
A	12 (40%)	4 (13%)		
B	2 (7%)	0 (0%)		<0.001*
Oswestry Bristol				
Normal	16 (53%)	26 (87%)		
Mild (shallow)	12 (40%)	4 (13%)		<0.001*
Moderate (flat)	2 (7%)	0 (0%)		
Statistical significance (p<0.05) indicated by *				