Patellar Engagement within the Trochlear Groove is Correlated with Long Cartilage T1ρ Relaxation Times Following Medial Patellofemoral Ligament Reconstruction

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INTRODUCTION: Medial patellofemoral ligament (MPFL) reconstruction is currently the most common approach for surgical patellar stabilization following patellar dislocation, but the influence on patellofemoral cartilage has not been well established. Preventing additional dislocations spares the cartilage ongoing traumatic impact, but progressive cartilage degradation has been identified for more than 40% of patients following MPFL reconstruction [1]. One risk of MPFL reconstruction is over constraint of the patella elevating patellofemoral contact pressures [2]. Pathologic anatomy that contributes to patellar dislocations can also continue to adversely influence cartilage following MPFL reconstruction [3]. The current study was performed to determine if patellofemoral post-operative alignment and anatomy influence cartilage properties following MPFL reconstruction.

METHODS: Patellofemoral anatomy, alignment and cartilage properties were quantified from 3T MRI scans following MPFL reconstruction. With IRB approval, seventeen patients with unilateral MPFL reconstruction were evaluated 0.5 to 5.7 years following surgery (10 females, 18.3 ± 2.6 years old, BMI = 26.5 ± 7.4 kg/m^2, 15 treated for multiple dislocations).

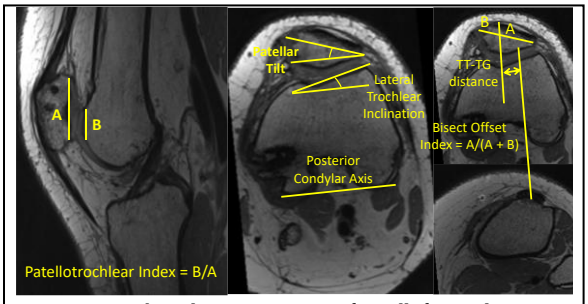

Figure 1: MRI-based measurements of patellofemoral anatomy and alignment.

Parameters of anatomy and alignment were measured from a 3D non-fat saturated scan with a 0.5 mm slice thickness (Fig. 1). Anatomical landmarks were selected on MRI slices to quantify trochlear depth (lateral trochlear inclination), position of the tibial tuberosity (tibial tuberosity to trochlear groove, TT-TG, distance), patellar depth within the trochlear groove (patellotrochlear index), patellar lateral shift (bisect offset index) and patellar tilt.

Cartilage properties were quantified based on T1ρ relaxation times. Long T1ρ relaxation times indicate a low concentration of proteoglycans within cartilage. Using automated deep learning algorithms, cartilage was segmented from a 3D fat saturated scan (slice thickness = 0.7 mm) and separated into compartments representing the patella and trochlear groove. T1ρ relaxation times (fat saturated scan, slice thickness = 4 mm, spin lock times = 0, 10, 30, and 70 ms, spin-lock frequency = 500 Hz) were quantified throughout the cartilage [4]. To map T1ρ relaxation times to the cartilage, images from the DESS scan were rigidly registered with the first echo of the T1ρ images. Following non-rigid registration between the first echo and a template mask covering the knee joint, the resulting transformation was applied to a rigid registration of the later echoes of the T1ρ images to the first echo. T1ρ relaxation times were fit to cartilage pixel by pixel by relating image signal to exponential decay based on time of spin lock to T1ρ relaxation time. T1ρ relaxation times were averaged for each compartment. Linear regressions were used to correlate measures of anatomy and alignment with T1ρ relaxation times for both regions of cartilage. Demographic parameters were also correlated against T1ρ relaxation times, and T1ρ relaxation times were compared between males and females. Statistical significance was set at $p < 0.05$.

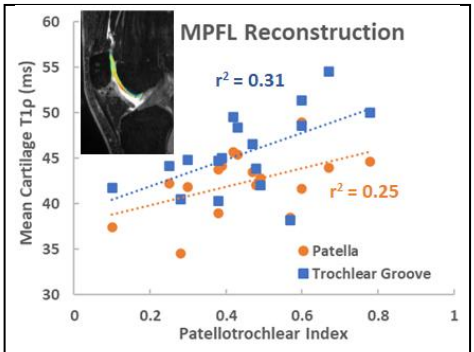

Figure 2: T1ρ relaxation time vs. patellotrochlear index for the patella and trochlear groove, plus relaxation times mapped to cartilage (insert).

RESULTS SECTION: T1ρ relaxation time tended to increase with increasing engagement of the patella within the trochlear groove. Large values for patellotrochlear index were significantly correlated with long T1ρ relaxation times for the patella and trochlear groove (Table 1, Figure 2). Small values for bisect offset index were significantly correlated with long T1ρ relaxation times for the patella. No other significant correlations were identified for anatomy or alignment ($p > 0.15$). No significant correlations were identified between T1ρ relaxation times and time from surgery, age or BMI ($p > 0.3$). There were no significant differences between males and females ($p > 0.3$).

Table 1: Significant linear regressions relating T1ρ relaxation times to patellofemoral alignment

	r^2	p-value	Standardized β
Patella			
Bisect offset	0.30	0.022	-0.55
Patellotrochlear index	0.25	0.043	0.50
Trochlear Groove			
Patellotrochlear index	0.31	0.020	0.56

DISCUSSION: Based on the current results, following MPFL reconstruction, patellar engagement with the trochlear groove in an axial (low bisect offset index) and sagittal (high patellotrochlear index) plane is detrimental to cartilage. Long T1ρ relaxation times indicate early degradation of the cartilage matrix that could lead to progressive cartilage degradation and post-traumatic osteoarthritis. T1ρ relaxation times were generally elevated compared to average values for healthy knees (38 ms for the patella, 43 ms for the trochlear groove) [4]. A low bisect offset index and high patellotrochlear index are likely related to surgery influencing patellofemoral alignment. Post-operative articular constraint applied to the patella by the trochlear groove could be generally elevating patellofemoral contact pressures, loading areas of patellofemoral cartilage damaged by traumatic injury, or altering the region of contact.

SIGNIFICANCE/CLINICAL RELEVANCE: During MPFL reconstruction, surgeons set the resting length of the graft and release or tighten surrounding soft tissues in order to stabilize, but not over constrain, the patella. The current results provide evidence in patients of the potential detrimental influence of over constraint on cartilage. Early cartilage degradation places the patellofemoral joint at risk for post-traumatic osteoarthritis.

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