Long Patellofemoral Cartilage T1ρ Relaxation Times in Healthy Knees Are Associated with Medial Alignment and Depth of Patella within Trochlear Groove

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INTRODUCTION: Onset of patellofemoral pain and patellar dislocations are initiating events that can lead to progressive cartilage degradation and osteoarthritis. Pathologic anatomy and patellofemoral malalignment are common features of these disorders and also have been linked to patellofemoral cartilage degradation following injury. Cartilage degradation progressing to patellofemoral osteoarthritis can also occur without an initiating injury. To improve understanding of factors that contribute to progressive patellofemoral cartilage degradation in the absence of injury, the current study related patellofemoral alignment and anatomy to cartilage properties for healthy knees.

METHODS: MRI-based T1ρ relaxation times were quantified to characterize cartilage properties. Long T1ρ relaxation times indicate a low concentration of proteoglycans related to degradation of the cartilage matrix. With IRB approval, 16 subjects (17 ± 3 years old; 7 females; BMI: 23 ± 3 kg/m^2) with no prior knee injuries participated in MRI scans. Each MRI scanning session (Prisma, Siemens) included a 3D water excitation double echo steady state (DESS) scan of the knee for segmentation of the cartilage surfaces (slice thickness of 0.7 mm), a 3D non-fat saturated Sampling Perfection with Application optimized Contrasts using different flip angle Evolution (SPACE) scan for measurements of anatomy and alignment, and a T1ρ relaxation time scan (fat saturated scan, slice thickness = 4 mm, spin lock times = 0, 10, 30, and 70 ms, spin-lock frequency = 500 Hz). Cartilage was automatically segmented from the DESS scan and divided into medial, lateral and central regions on the patella and within the trochlear groove. T1ρ relaxation times were mapped to the reconstructed cartilage surfaces (Fig. 1) [1]. Mean T1ρ relaxation time was quantified for each region of cartilage.

Figure 1: T1ρ relaxation times mapped to patellofemoral cartilage.

Parameters of anatomy and alignment were measured from the SPACE scan (Fig. 2). Anatomical measurements characterized trochlear depth (lateral trochlear inclination), patellar height (Caton-Deschamps index), and position of the tibial tuberosity (tibial tuberosity to trochlear groove, TT-TG, distance). Measurements of patellofemoral alignment included patellar shift (bisect offset index) and patellar tilt. Multi-variable linear regressions, including variations in age and body mass index (BMI), were used to correlate measures of anatomy and alignment with T1ρ relaxation times for each region of cartilage. Statistical significance was set at $p < 0.05$.

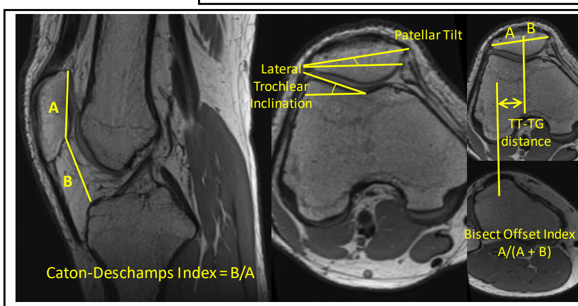

Figure 2: Measures of patellofemoral anatomy and alignment.

RESULTS SECTION: T1ρ relaxation times became significantly longer as bisect offset index (central patella) and Caton-Deschamps index (lateral patella and lateral trochlear groove) decreased. Decreasing bisect offset index represents medial alignment of the patella within the trochlear groove. Decreasing Caton-Deschamps index represents decreasing patellar height. For each significant correlation, T1ρ relaxation times also became significantly longer with increasing BMI. Upper quartile T1ρ relaxation times exceeded 40 ms.

DISCUSSION: Based on the current results, for healthy knees, the primary anatomical characteristics that are detrimental to cartilage are a medially positioned and low patella. These characteristics represent a patella that is well engaged with the trochlear groove during function. The significant relationships occurred for central and lateral regions of the patellofemoral joint, where patellofemoral contact is typically concentrated. Increasing BMI was also detrimental to cartilage, further showing an adverse response to elevated patellofemoral cartilage loads. Upper quartile T1ρ relaxation times were in the range of the acute phase following patellar dislocation [1].

Table 1: Significant multivariable linear regressions relating T1ρ relaxation times to anatomy and alignment, age and BMI, plus upper quartile T1ρ relaxation times.

	r^2	p-value	Standardized β	Upper Quartile T1ρ (ms)
Central Patella				42.5
Bisect offset	0.33	0.013	-0.45	
BMI (kg/m^2)	0.51	0.002	0.62	
Lateral Patella				41.6
Caton-Deschamps	0.25	0.042	-0.43	
BMI (kg/m^2)	0.37	0.011	0.56	
Lateral Trochlea				46.3
Caton-Deschamps	0.27	0.036	-0.46	
BMI (kg/m^2)	0.30	0.029	0.48	

In contrast, lateral patellar alignment and patellar height are related to cartilage degradation for patients being treated for pain or instability [2,3]. The current population lacks an inflammatory response to injury. An inflammatory biochemical environment could alter how cartilage responds to biomechanical loading. The current population also lacks pathologic anatomy that contributes to lateral patellar maltracking. Lateral maltracking can reduce patellofemoral contact area during function. Cartilage degradation related to over constraint of the patella could be a relevant contributor to patellofemoral pain with normal patellar tracking, accounting for approximately 40% of the patellofemoral pain population [4]. Follow up studies are needed to further characterize biomechanical factors instigating progressive cartilage degradation to osteoarthritis in the absence of a specific injury.

SIGNIFICANCE/CLINICAL RELEVANCE: For healthy knees, medial alignment and depth of the patella within the trochlear groove are associated with reduced integrity of the cartilage matrix. While patellar instability and maltracking have been established as factors that can contribute to patellofemoral pain and osteoarthritis, over constraint of the patella may also be a risk factor.

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