INTRODUCTION: Static patellofemoral (PF) malalignment, dynamic PF maltracking and pathological femoral shape are related to PF pain. PF malalignment and maltracking are likely symptoms of imbalanced forces on the patella, which may partially arise from pathological femoral shape. Yet, no studies have explored the relationships between femoral shape and PF kinematics ("tracking") in subjects with PF pain and PF maltracking. Thus, the effects of the femoral shape on patellar kinematics are unknown.

The primary objective of this study was to relate femoral trochlear shape to PF kinematics in patients with PF maltracking and in healthy subjects. A second objective was to identify properties of femoral shape that may be predictive of PF kinematics. Specifically, three hypotheses were tested: 1) differences in femoral shape exist between healthy subjects and patients with PF pain and suspected maltracking, 2) femoral shape differences are predictive of pathological kinematic patterns, and 3) measures of femoral shape are correlated with PF kinematics.

METHODS: MRIs of 26 (33) knees with PF pain and maltracking (asymptomatic controls) were retrospectively evaluated in this IRB-approved study. Patients had PF pain with maltracking as diagnosed by a clinician and healthy subjects had no history of lower leg pathology, surgery or major injury. No significant differences were found in demographics between the maltracking and asymptomatic groups [1].

After obtaining informed consent for all subjects, two sets of MRIs were acquired. 1) A high resolution 3D sagittal Gradient Recalled Echo Image series. The resolution varied from (0.547 mm x 1.0 mm) to (1.172 mm x 1.5 mm). 2) Full dynamic sagittal-oblique fast-PC series (x,y,z velocity and anatomic images over 24 time frames) and an axial fastcard image series (anatomic images only). All dynamic images were acquired while subjects cyclically extended/flexed their knee [2].

Seven measures of femoral trochlear geometry (lateral trochlear inclination (LTI), sulcus angle, articular cartilage depth (ACD), sulcus groove length, trochlear bump, trochlear groove width, and trochlear depth) and one measure of patellar geometry (patellar height (PH)) were quantified from the 3D static image sets using ImageJ (NIH, Bethesda, MD). All distance measures were scaled by the ratio of the average epicondylar width across all able-bodied subjects to the individual subject’s epicondylar width. PF kinematics were obtained for each subject through integration of the fast-PC velocity data [2]. Maltrackers with a value of Lateral-Medial (LM) patellar displacement ≥ 0.3 mm (medial) at 10° knee extension and a LM displacement slope ≥ 0.25 mm/° were defined as “medial maltrackers”. All other maltrackers were defined as lateral maltrackers.

Statistical comparisons were made between controls and maltrackers, and controls, medial maltrackers, and lateral maltrackers using Student’s t-test and ANOVA with Tukey’s post-hoc, respectively (α=0.05). Femoral shape measures significant between the three cohorts were correlated with values of PF displacement and orientation.

RESULTS: Differences in femoral shape between patients with PF maltracking and controls were found for two variables (Table 1): ACD and PH were significantly greater for maltracking subjects (p=0.005, p=0.008, respectively) compared to controls. There were no significant differences between the two groups for the six other shape parameters.

Only LTI was predictive of the type of maltracking pattern (medial versus lateral maltracker). LTI was significantly greater in medial maltrackers compared to both lateral maltrackers and controls (p=0.01). In addition, sulcus angle was significantly larger in lateral maltrackers compared to medial maltrackers (p=0.047). However, there was no significant difference for either maltracking group compared to controls. ACD was significantly higher in medial maltrackers compared to controls (p=0.01). However, no significant differences were present for any other group-pair. PH was significantly greater in medial maltrackers compared to controls (p=0.026). No significant differences were present between lateral maltrackers and the other groups. Trochlear bump, groove width, depth, condyle asymmetry, facet asymmetry and sulcus groove length were not significantly different between any of the groups.

LTI was significantly correlated with PF LM displacement and PF tilt (Figure 1) for all subjects combined (combined asymptomatic controls and maltrackers). Correlations did not exist for the lateral maltrackers as a subgroup. For medial maltrackers, the correlation of LTI with PF lateral-medial displacement was strong, but LTI was not correlated with PF tilt. For controls, the correlation of LTI with PF tilt was moderate and with LM displacement was weak.

DISCUSSION: This was the first study to correlate femoral shape parameters with PF kinematics in patients with PF pain and suspected maltracking. This study not only defines femoral shape parameters, it begins to explain observed maltracking patterns and potential sources of PF pain. The correlations between patellar kinematics and femoral shape measures in medial maltrackers likely indicate that a soft tissue imbalance causes this cohort to rely on the lateral edge of the femur to prevent lateral subluxation. The increase in patellar height furthers this dependency. Pain likely arises from increased contact forces.

Unfortunately, the maltracking sub-populations could not be defined based purely on clinical measures (e.g. Q-angle, J-sign, lateral hypermobility) [1]. Thus, the LTI provides a simple measure that can be added to the clinician’s toolbox when diagnosing patellar maltracking problems. Based on these results, the presence of PF pain combined with a Q-angle ≥15° and a large LTI likely indicates a medial maltracking pattern. Development of predictive models incorporating both femoral shape measures and patellar kinematics may result in a more reliable determination of etiology of pain in patients with patellofemoral pain.