Combining static and dynamic MRI to explain the source of patellofemoral pain

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Introduction

Patellofemoral (PF) pain syndrome is one of the most common problems of the knee. Typical symptoms are anterior knee pain, exacerbated by activities such as stair descent, prolonged sitting and squatting. Patellar maltracking is generally accepted as a leading cause of PF pain (PFP). However, effective intervention has been hampered because the mechanical factors related to PFP are poorly understood. Thus, the primary objective of this study was to explore the possibility that numerous maltracking patterns exist within the umbrella term of maltracking in PFP. As an adjunct to this, the correlation between bone shape and PF kinematics was investigated.

Materials and Methods

Two cohorts participated in the IRB approved study. The first consisted of 30 knees (19 subjects) clinically diagnosed with PFP and maltracking ("maltrackers"). The second cohort was an asymptomatic population, consisting of 37 knees (28 subjects). No significant differences in demographics existed between cohorts.

Complete 3D kinematics for the PF and tibiofemoral joints were derived from cine phase contract (cine-PC) MR images. Subjects were placed supine in a MR imager (1.5 T, GE Medical Systems, Milwaukee, WI, USA or 3.0 T, Philips Medical Systems, Best, NL). Kinematics obtained from the two imaging systems were not significantly different. For each knee, a full phase contrast MR image set (24 time frames) was acquired while the subjects cyclically extended/flexed their knee from maximum attainable flexion to full extension and back (~ 2.5 minutes). In addition, 3D static sagittal GRE images were acquired.

Kinematics were defined relative to an anatomical coordinate system embedded in each bone. Coordinate systems identification was completed for a single time frame. Then the tibiofemoral and PF kinematics were tracked throughout the movement through integration of the 3D velocity data. Once the displacement trajectories for a minimum of three non-colinear points were known, the 3D PF kinematics were defined by 3 translations: lateral-medial (LM), inferior-superior (IS) and posterior-anterior (PA) displacement along with 3 rotations: extension-flexion (EF), LM tilt and valgus-varus (VV) rotation. The positive direction of motion is listed last (e.g., medial is positive). Comparisons in kinematics were made based on two variables, value and slope. The magnitude of a kinematic variable at 10º of knee extension was defined as its value. The slope of each kinematic variable was defined by the linear best fit of each variable with knee angle over the full range of motion.

Maltracking subgroups were created by dividing the maltracking cohort into two groups based on PF LM displacement. Patients who were medially displaced relative to the asymptomatic average (≥-0.45mm) with a LM displacement slope ≤ 0.25mm/º were defined as "non-lateral maltrackers". All others were defined as "lateral maltrackers". Three discriminant analyses were used to validate the definition of subgroups. The predicting variable sets included 1) the values and slopes of the variables primarily associated with patellar maltracking (LM displacement and tilt) and 2) the values of LM displacement, IS displacement, EF and VV rotation along with the slopes of LM displacement, LM tilt and VV rotation (these 7 demonstrated significant differences between a maltracking population and asymptomatic controls in a previous study).

Results

Based on a one-way ANOVA distinct kinematics patterns were found between the lateral and non-lateral maltrackers. Although the groups were divided based on LM displacement, the lateral group was 6.2mm laterally displaced, 7.4º laterally tilted and 6.8 mm superior displaced, with increased slopes for lateral displacement (0.22), lateral tilt (0.53) and varus rotation (-.20), compared to the non-lateral maltrackers (Fig 1). The discriminant analyses supported the definition of lateral and non-lateral subgroups with 90% and 93.3% accuracy, respectively. The kinematics of the medial group differed from the normative average for one variable only (increased PF flexion). The lateral group differed from the normative average for all PF value variables except PA displacement.

The non-lateral maltrackers had larger lateral trochlear inclination angle (LTI), as compared to the lateral maltrackers (Fig 2, a 7.3º difference, P=0.000). The LTI was correlated with LM displacement when the two cohorts were pooled (r = .40, P<0.05). This correlation was much stronger for the non-lateral group (0.65, P<0.05), but did not exist for the lateral group (r=.030), when these subgroups were analyzed separately.

Discussion

Quantifying 3D PF kinematics during volitional activity provides new information regarding PF maltracking, which can help in the evaluation of PFP. For example, when a patient does not exhibit the classic clinical markers of PF maltracking (excessive lateral tilt and translation, measured in the axial plane) the pain is often assumed to be from overuse. The 3D knee joint kinematics provide an alternative theory. In the absence of the classic clinical markers of maltracking, shape alterations or other changes in kinematics may result in PF pain. For example, the patients in the non-lateral group do not demonstrate the classic clinical markers of maltracking, but do demonstrate excessive PF flexion. In the absence of patella alta, the patella remains engaged with the sulcus further into terminal extension. Since the lateral edge is higher in this subgroup (larger LTI), the femoral sulcus is more likely to provide the passive force that maintains nearly normative kinematics in the axial plane. The increased use of bony constraints can cause higher bone forces in non-lateral trackers, potentially triggering nociceptors in the subchondral bone. In addition, the increased PF flexion in this group may decrease cartilage contact area, causing increased contact stress. On the other hand, the lateral maltrackers demonstrate the classic markers of maltracking. In this group, the presence of patella alta reduces the overall PF contact area, causing increased stress and may contribute to PFP symptoms. Patella alta creates a situation where the patella leaves the sulcus groove earlier in the extension cycle, resulting in greater tilt and subluxation due to the loss of bony constraints. Pain is likely caused by the high forces required to re-engage the patella into the groove during flexion. Establishing the presence of subgroups within the umbrella diagnosis of PFP with maltracking will likely enhance treatment by allowing by more accurately targeting interventions.

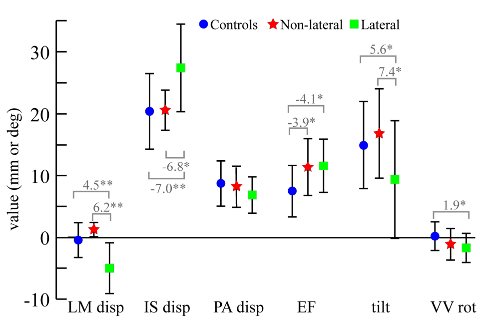

Figure 1: Kinematic values for each group: If significant differences were found in the ANOVA post-hoc analysis, a bar connects the groups and the average difference between the groups was placed above the bar (*P<0.05 & **P<.0.001). LM, IS and PA disp (lateral-medial, inferior-superior and posterior-anterior displacements). EF, tilt, VV rot (extension-flexion, LM tilt and valgus-varus rotation).

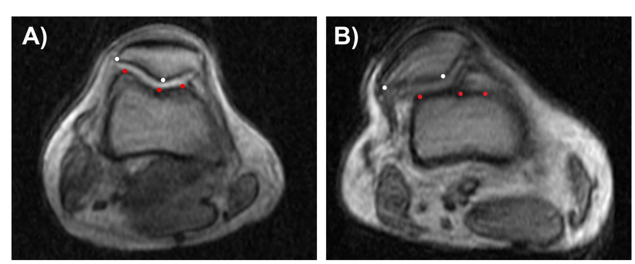

Figure 2: mid-patellar axial image during volitional knee extension (A) Non-lateral trackers. (B) Lateral trackers. In the non-lateral maltrackers, the mid-patella is still engaged with the lateral edge of the femoral sulcus in full extension (A). This is not the case for the lateral maltrackers.