IN VIVO ASSESSMENT OF CONGRUENCE IN THE PATELLOFEMORAL JOINT OF HEALTHY SUBJECTS

[1]Kim McLaughlin, [1]Janet Ronsky, [2]Richard Frayne
[1]Department of Mechanical and Manufacturing Engineering, University of Calgary, kim@kin.ucalgary.ca
[2]Departments of Radiology and Clinical Neurosciences, University of Calgary

Introduction

Joint congruence indicates how well mating surfaces fit together. A mismatch between contacting surfaces may cause abnormal joint forces and stresses. Joint congruency has been suggested as a potential risk factor in patellofemoral (PF) pain syndrome [1] as well as in the initiation and progression of osteoarthritis [2]. Radiography is the most widely used imaging modality for the clinical assessment of joints. However, this technique is limited for measures of joint congruency. It provides only subchondral bone shape which does not necessarily match the contour of the articulating cartilage [3]. In addition, the joint is typically examined in only one position. The complex 3D geometry of the joint throughout a range of motion may not be adequately characterized by this 2D measurement. Magnetic resonance (MR) imaging overcomes the limitations of current x-ray approaches for assessing joint congruence and has been used to study the knee joint [2]. However, the effect of joint angle and physiological joint loading on knee joint congruency has not been examined. The purpose of this research was to quantify in-vivo PF joint congruence and to examine effects of flexion in a loaded condition.

Methods

MR imaging (3.0T GE unit, 3D FIESTA, 3 mm slice thickness, 2.5 min. data acquisition) was used to quantify the PF joint geometry of 4 healthy female adults (mean age = 25.5 years, height = 160.6 cm, weight = 61.5 kg). Ethics approval for all procedures was provided. The knee was imaged during physiological loading at three alignments (15°, 30° and 45° flexion) using a custom designed loading apparatus. A mathematical joint model was developed through image segmentation, 3D reconstruction of each surface using a thin plate spline and contact determined with a proximity algorithm (Figure 1) [4]. The principal curvatures at each surface point were calculated and averaged over the contact area for the patella and femoral surfaces [5]. Based on the average curvature for each surface, an equivalent surface was created and compared to a flat plane.

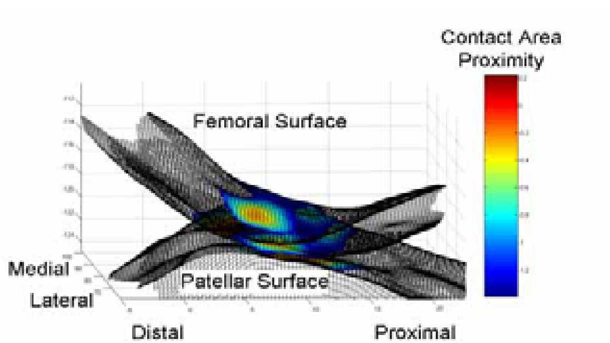

Figure 1: PF joint contact area plotted on the 3D reconstruction of the patellar and femoral surfaces.

The relative curvatures (K^e_{max}, K^e_{min}) were determined for the equivalent surface. A congruence index (CI), zero for perfect congruence, was found using: $CI = K^e_{RMS} = [(K^e_{min})^2 + (K^e_{max})^2 /2]^{½}$ [2]. Changes during flexion in the loaded knee joint were examined. Differences were compared using a paired t-test with a p-value < 0.05 indicating significance.

Results and Discussion

The patellofemoral joint (n=4) became more congruent as the knee joint angle increased (Figure 2). The CI at 30 degrees was found to be significantly different from both 15 degrees (p-value = 0.008) and 45 degrees (p-value = 0.002).

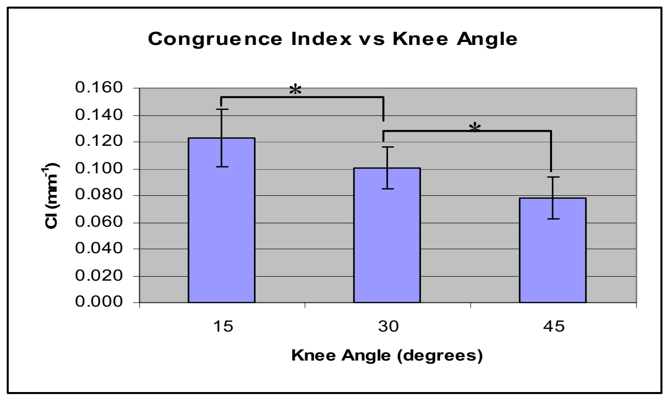

Figure 2: Average CI (mean ± 1 SD) of the loaded PF joint at 15°, 30° and 45°of flexion. (* = p-value<0.05)

The CI enables detailed characterization of subject specific joint congruence over a range of motion. Increased joint congruence can be accomplished by deforming the cartilage, changing the location of the surfaces relative to one another or a combination of both. More congruent joints may allow forces to be better distributed and therefore, minimize potentially deleterious local stress concentrations with increasing flexion angle.

Conclusions

Initial results indicated that the PF joint became more congruent as the angle increased in healthy females. Congruence could potentially be a factor in certain knee joint pathology. On-going work involves investigating the relationship of CI and knee angle in individuals with PFPS.

References: 1: Doucette, S. et al.. *Am. J. of Sport Med*, **20**(4), 434-440, 1992. **2**: Hohe, J. et al.. *Magn. Reson. Imaging*, **47**, 554-561, 2002. **3**: Adam, C. et al.. *J Anat*., **193**, 203-14, 1998. **4**: Baker: *MSc Thesis – U of Calgary*, 2001. **5**: McLaughlin et al. *Proceedings of CSB XIII*, Halifax, Nova Scotia, poster, 2004

Acknowledgements

NSERC, CRC, Calgary Health Region, GEOIDE