Changes in *in vivo* tibiofemoral cartilage-to-cartilage contact area under acute loading; Comparison of two sequences (3D-SPGR vs. T2-weighted FSE)

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INTRODUCTION

Initiation and progression of knee osteoarthritis is affected by mechanical factors including joint loading and joint contact stress.[1] However human *in vivo* articular contact stresses have not been studied systematically. Investigating tibiofemoral (TF) joint contact area is fundamental to understanding stress distribution of the TF articular cartilage and how *in vivo* compressive load is transferred through the TF joint. However, it is unknown how *in vivo* TF cartilage-to-cartilage contact area changes from a non-weight-bearing condition to a weight-bearing condition. Recently, MRI has been suggested as a valid method for quantifying *in vivo* cartilage-to-cartilage contact area and most studies have analyzed patellofemoral contact area using three-dimensional spoiled gradient-recalled (3D-SPGR) images.[2,3] Another commonly used sequence for evaluating cartilage defects clinically is T2-weighted fast spin-echo (FSE) iamges.[4] The purpose of this study is 1) to compare TF cartilage-to-cartilage contact area using 3D-SPGR vs. T2-weighted FSE images; 2) to determine the influence of acute mechanical loading on tibiofemoral cartilage-to-cartilage contact area in the medial and lateral compartment.

METHODS

Nine subjects (age = 53.1 ± 11.08 years; mass = 69.1 ± 5.5 kg) were tested using a 3T GE MR scanner and an 8-channel phased array knee coil. MR images of one knee were taken under both unloaded and loaded conditions. First, subjects were positioned supine on top of a custom-made MRI-compatible loading apparatus with no load applied. Subjects' test lower extremity was positioned in 15° of knee flexion (supported in a transmit-receive knee coil) and 10° of foot external rotation (placed on the loading device footplate and supported in place). For the loaded condition, a compressive load equal to 50% of the subjects' body weight was applied to the bottom of the subject's tested foot (Fig.1). For each condition, two MRI sequences were performed: Coronal 3D-SPGR (FOV=15 cm, slice thickness 1.5mm, 512 ×512 matrix, Flip angle 18°) and coronal fat-saturated T2-weighted FSE (FOV=16cm, slice thickness 2.0mm, TR=3000 ms, TE=13ms, 384 ×192 matrix). The TF cartilage-to-cartilage contact areas were manually segmented using in-house spline-based software written in Matlab. Contact areas were computed by connecting all spline points with a set of triangles and summing the triangle areas. Contact areas calculated in 3D-SPGR and FSE images were compared using Pearson's correlation coefficient. To analyze the effect of acute loading on the cartilage-to-cartilage contact area, average contact area was compared between conditions (unloaded vs. loaded) using paired Student's t-tests ($\alpha = 0.05$). In addition, contact area changes in medial and lateral compartments were compared similarly.

RESULTS

TF cartilage-to-cartilage contact area measured using 3D-SPGR and FSE images showed strong positive correlation (Pearson's correlation coefficient = 0.969, Fig.2). Contact area using FSE images is significantly lower by 27.8(±16.8) % than contact area using 3D-SPGR images (P<0.001). Fig.3 shows a representative MR images under unloaded and loaded conditions. Mean TF contact areas both in medial and lateral compartments significantly increased under *in vivo* acute loading (P<0.05, Table 1, Fig.3). Absolute increase of contact area is significantly larger (P<0.05) in the medial compartment (82.4±46.2mm^2) than lateral compartment (20.6±20.3mm^2). Relative increase is also larger in the medial compartment (46% vs.18%), but not significantly different.

Fig.1 MRI-compatible load-bearing apparatus

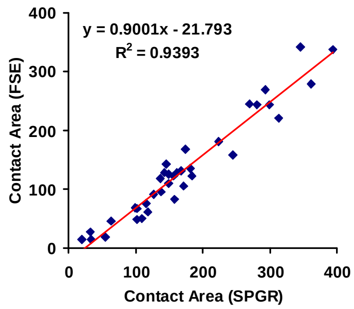

Fig.2 Correlation of measured contact area between SPGR and FSE

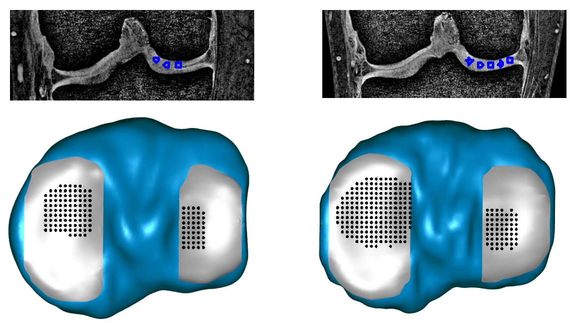

Fig.3 Tibiofemoral contact area under unloaded (Left) and loaded (Right) conditions

Table 1. Mean (±S.D.) TF cartilage-to-cartilage contact areas in the medial/lateral compartments under unloaded and loaded conditions.

	Medial: Unloaded	Medial: Loaded	Lateral: Unloaded	Lateral: Loaded
Contact Area using SPGR [mm^2]	177.2[a] (±72.7)	261.8 (±86.8)	112.8[a] (±66.4)	133.4 (±75.2)
Contact Area using FSE [mm^2]	144.6[a] (±72.8)	221.1 (±85.8)	70.3[a] (±46.2)	98.5 (±67.8)

[a] indicates significant (p<0.05) difference between loaded and unloaded conditions.

DISCUSSION

Results of this study show that TF contact area calculated using 3D-SPGR and FSE sequence are strongly correlated, though measured contact area using FSE images underestimated values by 28% compared to that using 3D-SPGR. These results suggest that both imaging sequences could be used to measure cartilage-to-cartilage contact area but the direct comparison of cartilage contact from different sequences should consider the fact that FSE images lead to underestimation of cartilage-to-cartilage contact compared to 3D-SPGR images. This study has shown that acute loading on the tibiofemoral joint resulted in significant increase of TF contact area both at the medial and lateral compartments. It is also interesting to note that the contact area in the medial compartment was twice as large as that in the lateral compartment under loaded condition. These results suggest that the *in vivo* articular contact environment in the medial compartment changes dramatically under acute loading and may actively transmit larger amounts of compressive load. This sensitive contact environment change to loading in the medial compartment may be associated with higher prevalence of osteoarthritis in the medial compartment. *In vivo* contact area changes under acute loading in this study may provide valuable information to *in vivo* contact stress analysis in the future. The different relative changes in the medial and lateral compartments may be associated with the individual alignment of the lower extremity and warrants further study.

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