IN VIVO KNEE CARTILAGE CONTACT DURING DOWNHILL RUNNING

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INTRODUCTION

Altered contact mechanics following anterior cruciate ligament (ACL)-reconstruction may increase the risk for long-term joint degeneration[1,2]. Using a high-speed biplane x-ray system, the current study aimed to characterize in vivo knee cartilage contact during the dynamic loading activity of downhill running. Using the contralateral uninjured knee as a control, cartilage contact was measured serially following ACL-reconstruction. It was hypothesized that cartilage in ACL-reconstructed knees would be subjected to increased strain and the location of cartilage contact would be different in comparison to ACL-intact knees.

METHODS

Three subjects had 1.6 mm diameter tantalum beads implanted into their injured and asymptomatic contralateral knees during ACL-reconstructive surgery (3 beads in each femur and each tibia). Following surgery, sagittal 3T MRI scans and axial CT scans were performed on each leg. Cartilage and bones were segmented from the MRI scans and bones were segmented from the CT scans (Mimics Software, Ann Arbor, MI). Three-dimensional MRI and CT models were co-registered (Geomagic, Inc., Research Triangle Park, NC), creating identical anatomical coordinate systems on the left and right bones for each subject.

Subjects were tested within a biplane x-ray system while running downhill (10° slope) at 2.5 m/s three times following surgery (approx. 6, 12 and 24 months). Biplane x-rays were collected at 170 or 250 frames per second for 3 trials per leg for each test session. Implanted beads were tracked within the distortion corrected x-ray images with an accuracy of better than 0.10 mm[3]. Femur and tibia cartilage contact during single-support flexion was determined using this tracked data. Cartilage contact area, average cartilage strain and center of cartilage contact were determined for each compartment (medial/lateral) on each test date.

Cartilage contact areas were averaged within each compartment (i.e. medial contact area = (medial femur contact area + medial tibia contact area)/2) every instant of data collection. Cartilage strain was calculated as the amount of cartilage overlap indicated by the rigid cartilage models divided by the cartilage thickness for each point on the cartilage surface. The center of cartilage contact was determined at each instant by finding the weighted centroid of the contact area, using the amount of cartilage overlap as the weight factor. Joint rotations and translations were also calculated at each instant. All cartilage contact variables were interpolated every 1 degree of flexion. To facilitate analysis, comparisons were made between intact and ACL-reconstructed sides after averaging data across test dates at 5 degree increments of flexion, from 0 to 30 degrees.

RESULTS AND DISCUSSION

Average cartilage contact area in the intact medial compartment remained steady during flexion, ranging between 535 and 601 mm^2, while intact lateral compartment contact area decreased from 445 mm^2 at 0° flexion to 335 mm^2 at 30° flexion. Medial compartment contact area was larger than lateral compartment contact area throughout flexion in the intact knee. Following ACL-reconstruction, medial compartment contact area was generally lower than in the intact knee, while lateral compartment contact area was generally higher than in the intact knee. These differences between ACL-intact and ACL-reconstructed contact areas were most apparent at higher flexion angles. In the ACL-reconstructed knee, medial and lateral compartment contact areas were similar for all flexion angles (except 5°) (Figure 1).

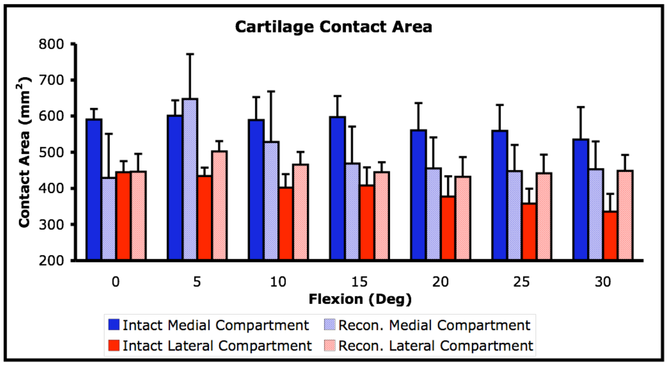

Figure 1: Cartilage contact area in the medial (blue) and lateral (red) compartments for the intact (solid) and ACL-reconstructed (shaded) knees. Standard deviation bars indicate among-day variability.

Medial compartment strain ranged between 14.5 and 18.7 percent, while lateral compartment strain ranged from 15.5 to 19.5 percent in the ACL-intact knees. In the ACL-reconstructed knees, medial compartment strain ranged from 15.0 to 19.3 percent, while lateral compartment strain increased from 14.5 percent at 0° flexion to 29.1 percent at 30° flexion (Figure 2). Increased cartilage strain identified in the lateral compartment may be an indication of increased risk for osteoarthritis (OA) development.

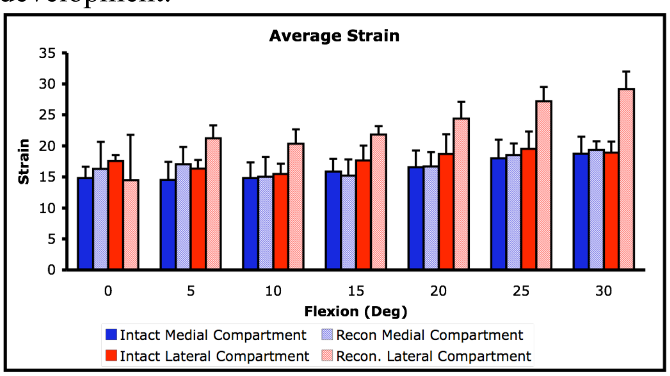

Figure 2: Average cartilage strain in the medial (blue) and lateral (red) compartments for the intact (solid) and ACL-reconstructed (shaded) knees. Standard deviation bars indicate among-day variability.

The path of the center of cartilage contact was more lateral on each cartilage surface following ACL-reconstruction. Additionally, at 0° flexion, the contact point on both the medial and lateral femur cartilage surfaces was more anterior following ACL-reconstruction (Figure 3). These modified contact paths on cartilage surfaces following ACL-reconstruction may increase risk for OA.

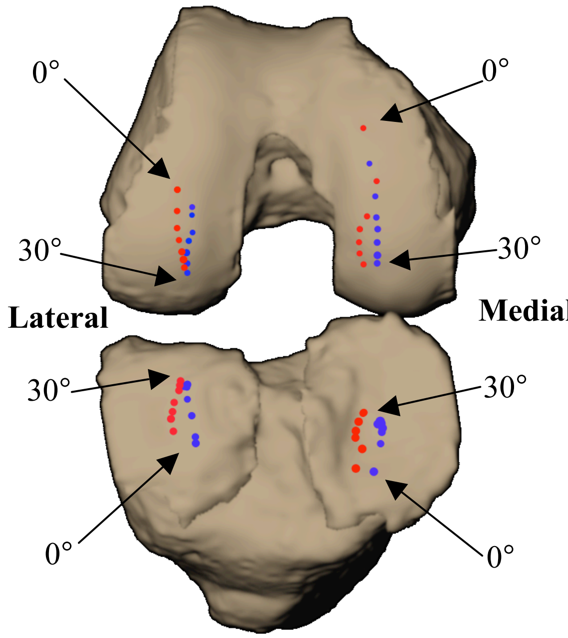

Figure 3: Center of cartilage contact region on the femur and tibia cartilage surfaces every in 5° increments, from 0° to 30° of flexion, during downhill running. Blue is intact contact center, red dots indicate ACL-reconstructed contact center. Figure indicates average contact location at each flexion angle for 6, 12 and 24 months post-surgery test dates.

CONCLUSIONS

This study presented, for the first time, in vivo cartilage contact mechanics during a dynamic loading task. This preliminary evidence indicates cartilage contact mechanics are modified following ACL-reconstruction. However, due to the low sample size, these conclusions should be interpreted with caution.

REFERENCES

1. Brandsson, et al. *Acta Orthop Scand* (2001).
2. Andriacchi, et al. *J. Biomech.* **38**, (2005).
3. Tashman, et al. *J. Biomed. Eng.* **125**, 238-245, 2003.