Changes to the Tibial Plateau Articular Cartilage Thickness Profile After an Anterior Cruciate Ligament Injury

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Disclosures:

Introduction: Non-contact injury to the anterior cruciate ligament (ACL) has been associated with the early onset of post-traumatic osteoarthritis (PTOA), regardless of whether surgical or non-surgical treatment is followed\(^5\). Changes in articular cartilage thickness have been shown to occur on the femoral condyle and trochlea at one- and two-year follow-up after an ACL injury, while no changes were reported on the tibial plateau articular cartilage\(^2\,^3\). In contrast, one study reported that differences in the cartilage profile of the tibial plateau were seen in cases that suffered a non-contact ACL injury shortly after injury\(^1\). These data suggest that an ACL injury itself may be causing acute changes in the geometry of the cartilage on the tibial plateau. The objective of this study was to determine if there were differences in tibial cartilage thickness in ACL injured knees compared to their contralateral knee and similarly, if there were side-to-side differences in the tibial cartilage thicknesses of matched control knees. This was done with the use of MRI to measure the medial and lateral compartments of the tibia in an effort to determine the specific regions where change occurs. We hypothesized that cases that had sustained a non-contact ACL injury would demonstrate a difference in cartilage thickness on the tibia of their injured knee, when compared to their normal contralateral knee. Secondly, we hypothesized that the controls would show no side-to-side difference in articular cartilage.

Methods: Approval for this study was granted by the IRB. 92 subjects (31 males, 61 females) with first time non-contact ACL injuries sustained during participation in an organized high school or college sport were recruited. 92 uninjured controls were selected from the case’s sports team and were matched according to subject age and sex. Case and control matching from the same sports team was done to control for the amount, and level of activity. Bilateral MRIs were obtained from both the ACL-injured and control subjects using the Phillips Achivia 3.0T MRI (Fletcher Allen Healthcare, Burlington, VT), with subjects in the supine position with their knee extended. ACL-injured subjects were scanned after injury but prior to surgical reconstruction (median 15 days post-injury, range 1-110 days). DICOM images were viewed and segmented using Osirix Software (Pixmeo, version 3.6.1., open source) and a Cintiq 21 UK Digitizing tablet (Wacom Tech Corp, Vancouver, WA, USA). The cartilage in both the medial and lateral compartments was segmented in the coronal plane, from the peak of the tibial spine to the periphery of the compartment, using the border of the menisci as the end of the peripheral segmentation. The subchondral bone in each compartment was segmented similarly in the sagittal view. The digitized MRI cartilage and bone data was transformed into a coordinate system that was referenced to the tibia.

The tibial cartilage boundary points for the medial and lateral compartment were averaged over the 368 knees by mirroring the right knees to match the left knees. This was done to define a standard geometry for the tibial cartilage surface. Singular value decomposition (SVD) was used to scale and rotate the cartilage and bone in both compartments to fit this standard geometry. Compartment specific cartilage thickness was determined by where the normal vector to the cartilage surface intersected with the underlying subchondral bone at different points (1020 and 802 medial and lateral compartment points respectively) on a 1mm by 1mm grid. Side-to-side differences in these thicknesses were compared between the injured knee of ACL-injured subjects and their uninjured contralateral knee. Side-to-side comparisons were also made within control subjects using the same injured to uninjured side convention as their matched controls. For both the ACL-injured and control groups, the differences (bilaterally) were compared using paired Student’s t-test, which were done for each of the medial (1020) and lateral (802) compartment points where thickness data was collected. The sets of paired Student’s t-tests p-value results were then adjusted for a False Discovery Rate (FDR) using the Benjamini-Hochberg procedure. Analyses were done using SAS, version 9.2 (SAS Institute, Cary, N.C.).

Results: There were significant increases (mean 12.9%, range 6.1%-61.5%) in articular cartilage thickness, located in the medial compartment at the anterior aspect of the tibial spine and tibial plateau of the ACL-injured knees compared to the uninjured contralateral knee (Figure 1). No significant differences in lateral compartment cartilage thickness were seen when making the same comparison to the contralateral side. Additionally there was no significant difference seen in either the medial or lateral compartment of the control group’s knees when knees were compared side-to-side.

Discussion: ACL-injured subjects displayed an increase in the articular cartilage thickness located at the anterior medial portion of the medial compartment of their injured knee, when compared to their uninjured contralateral knee (Figure 1). This finding supports previous research that suggests that changes in cartilage thickness profile occur, which may lead to degenerative changes (PTOA) in the medial compartment after ACL rupture. Notably in this study the case group all underwent MRI scans at a median time of 15 days after injury, with a range of 1 to 110 days. This suggests that changes to the cartilage thickness occur within a short time interval following injury or an inflammatory response to cartilage injury. Changes in the articular cartilage thickness profile could also be a function of the altered joint loading that is produced by the ACL injury. Though these data do
not display a change in the articular cartilage profile of the lateral compartment, it should be noted that the menisci were used as the boundary for segmentation. Because the menisci do not extend as far posteriorly as the cartilage, not all of the medial and lateral compartment cartilage was segmented. Had the segmentation been extended there may have been changes seen in the posterior lateral compartment. Our future work will include segmentation of the entire tibial plateau, in order to capture the entire articular surface.

**Significance:** Results show a significant increase in the thickness of the anteromedial cartilage in the medial compartment of the tibial plateau; this is the same portion of the medial tibial plateau where degenerative changes to the cartilage are seen as a result of PTOA. These changes are seen within a very short time interval between the injury and MRI acquisition, with a median time period of 15 days and a range of 1-110 days.

**Acknowledgments:** NIAMS- 5R01-AR05, Department of Energy SC 00017

Figure 1: There is a significant increase in the anteromedial cartilage thickness in the medial compartment of the tibial plateau of ACL-injured knees when compared to the uninjured contralateral knee.

ORS 2014 Annual Meeting
Poster No: 0087