Regional Variation In Lateral Compartment Articular Cartilage to Augment Guidelines For Unicompartimental Knee Replacement

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INTRODUCTION:
Unicondylar knee arthroplasty (UKA) is a controversial treatment for medial knee osteoarthritis. While clinical studies have demonstrated survival rates from 73-98% at 10 years; revision surgery – which consists of converting to a total knee replacement – is complex. The current Kozinn and Scott criteria for identifying patients most likely to benefit from a UKA include age, weight, flexion angles, angular deformity, and intact cruciate ligaments. The quality of articular cartilage in the lateral compartment is not typically assessed, and this omission may in part explain the high variability in survivorship of UKAs.

The objective of this study was to characterize the regional variation in mechanical properties of lateral compartment articular cartilage in patients undergoing total knee replacement. Our hypothesis was that the mechanical properties would correlate with the ICRS Cartilage Assessment score.

METHODS:
This study was approved by our Institutional Review Board, and all participants signed informed consent. Inclusion criteria were patients within 20-90 years of age undergoing primary total knee replacements for primary osteoarthritis. Patients with rheumatoid arthritis, inflammatory osteoarthritis, valgus or neutral alignment on hip to ankle standing films, or a history of infection or fracture were excluded.

Sample Collection: 8mm osteochondral plugs were removed from patients undergoing primary total knee replacements for osteoarthritis with varus alignment. Samples were identified from three locations: the center of the lateral tibial plateau, the center of the lateral distal femoral condyle, and the center of the trochlea. Prior to removal, the severity of osteoarthritic lesions in plug locations was evaluated using an ICRS cartilage assessment score based on the Outerbridge score. The score ranged from 0-4 with healthy cartilage scoring zero and a lesion with bone completely exposed scoring a 4.

Once removed, samples were placed in protease inhibitor (Sigma Aldrich, St Louis, MO) and stored at -20°C.

Method of Testing: Each osteochondral sample was oriented so that the center of the sample was parallel to the surface of a porous indenter (diameter 1.25 mm) that was attached to the upper actuator of an Enduratec testing machine (ELF 3200, BOSE). (Fig 1) A compressive load of 20g was applied at a rate of 5 g/s and held for 1 hr. A saline drip was applied to keep tissue moist throughout testing. After testing was completed the indenter fixture was replaced with a needle fixture to measure cartilage thickness. The needle was positioned at the top surface and advanced at a rate of 0.05mm/s until a rapid increase in stiffness was observed, indicating that bone had been pierced.

Data Extraction and Analysis: Displacement-time data were numerically fit to the biphasic indentation creep solution to determine two intrinsic material coefficients at each test site: aggregate modulus (Ha) and hydraulic permeability (k). Differences in outcome measures as a function of sample location were tested for using a Kruskal-Wallis One Way Analysis of Variance followed by Pairwise Multiple Comparison Procedures using Dunn's Method (SigmaStat, v. 3.2, Systat Inc.). A Spearman Rank Order Correlation test was run to explore for associations between the ICRS Cartilage Assessment score and all other outcomes.

RESULTS:
A total of 44 osteochondral samples were tested from 32 different patients: 15 samples from the lateral tibial plateau, 11 samples from the distal lateral femoral condyle, and 18 samples from the trochlea. Aggregate modulus, permeability, cartilage thickness and an ICRS score were determined for each plug. Aggregate Modulus of the distal lateral femoral condyle was significantly higher than that of the lateral tibial plateau region (p<0.05). (Fig 2) Permeability ranged from 5.18E16 - 7.66E-15 mN/s and was not significantly affected by sample location. Of note, the distribution of ICRS cartilage assessment score was affected by region (Table 1), with a higher number of specimens from the trochlea having scores of 3 or greater relative to specimens taken from all other regions.

DISCUSSION:
The mechanical properties of lateral compartment articular cartilage in patients undergoing total knee replacement were found to be within the range of that previously reported for specimens taken from normal human cadaveric knees. A regional variation in modulus was found with the lateral femoral condyle having a significantly higher Aggregate Modulus than that of the lateral tibial plateau. This finding has also been reported for normal human cadaveric knees. A regional variation in the ICRS Cartilage Assessment score was found in this study with specimens from the trochlea exhibiting higher scores (more damage) than all other sites. However, the variation in modulus was not explained by the variation in the cartilage assessment score, leading us to reject our hypothesis. The exact link between the pre-op condition of articular cartilage in the lateral plateau and the survivorship of UKA remains unclear. Nonetheless, our study suggests that any efforts to augment the current guidelines for identifying patients most likely to benefit from a medial compartment UKA should consider a non-destructive measurement of cartilage mechanical properties, which may provide additional information about cartilage health that is not captured by the ICRS Cartilage Assessment score alone.

SIGNIFICANCE:
Patients with primary osteoarthritis are currently being evaluated for TKA or UKA with a set of predefined criteria. These criteria, while inclusive of many osteoarthritic symptoms, fail to include potential compartmental variations. By studying the integrity of the lateral compartment and examining the cartilage biomechanical properties these criteria could be updated to fit patient needs better.

ACKNOWLEDGEMENTS: This study was funded through an Institutional Grant provided by Smith&Nephew. Additional funding was received from NIH grant AR046121. We would like to acknowledge the assistance of Samantha Lee and Scott Tucker with data analysis. We also thank the Clark & Kirby Foundations.

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