Subchondral Bone Mismatches In Osteochondral Allograft Transplants For Large Oval Defects Of The Medial Femoral Condyle: Comparison Of Lateral Vs. Medial Femoral Condyle Donors

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All Authors:
Kelly Macklin Rogers MD, M Res UNITED STATES
Connor Shea Locke MS UNITED STATES
Timothy Mologne MD UNITED STATES
William Bugbee MD UNITED STATES
John A. Grant MD, PhD, FRSCS UNITED STATES

Summary:
Using contralateral lateral femoral condyle osteochondral allografts does not significantly change subchondral bone alignment compared to medial femoral condyle (MFC) osteochondral allografts for large osteochondral defects of the MFC.

Data:
Introduction: In order to improve the supply-demand mismatch of medial femoral condyle (MFC) osteochondral allografts (OCA), our previous work has demonstrated that oval contralateral lateral femoral condyle (LFC) OCA can attain an acceptable cartilage surface contour match compared to an oval ipsilateral MFC OCA for large oval defects of the MFC. Additional prior work in the patella demonstrated that differences in underlying subchondral bone contour between homologous and non-homologous OCA may be larger than seen on the cartilage surface. These differences could result in abnormal force attenuation/distribution, possibly leading to earlier allograft failure. The purpose of this study was to use surface contour mapping to determine if using a contralateral LFC vs ipsilateral MFC OCA plays a role in the alignment of donor to native subchondral bone when treating large osteochondral defects of the MFC.

Methods: 30 fresh frozen human femoral condyles were matched by tibial width (±2mm) into 10 groups of three condyles (1 MFC recipient, MFC donor and LFC donor) each for three fellowship-trained cartilage surgeons (90 condyles total). The recipient MFC was initially imaged using nano-CT. Commercially available instruments were used to create 17x36mm “defects” in the recipient MFC and harvest complement donor grafts from each matched donor condyle. Following the first transplant (randomized MFC vs LFC), the recipient condyle was imaged and superimposed on the native condyle nano-CT scan. The donor plug was carefully removed and the process was repeated for the other donor. Drongonlly 3D and Excel were used to determine the root mean square (RMS) of both the surface height deviation and circumferential step-off height deviation between native and donor subchondral bone surfaces for each transplant. Results: There was no statistically significant difference in mean subchondral bone surface deviation between contralateral LFC and ipsilateral MFC plugs (LFC = 0.87 ± 0.22mm, MFC = 0.76 ± 0.24mm, p = 0.07). At the interface between donor plug and the surrounding native subchondral bone, there was no significant difference in circumferential step-off height between the LFC and MFC plugs (LFC = 0.93 ± 0.18mm, MFC = 0.85 ± 0.21mm, p = 0.09). Additionally, when comparing each transplant by quadrant (anterior, posterior, medial, lateral), there were no statistically significant differences in surface deviation and step-off height. There were no significant differences in outcomes between surgeons. Discussion: Using a contralateral LFC or ipsilateral MFC oval donor plug did not lead to statistically significant differences in subchondral bone surface height deviations or circumferential step-off height at the graft/native subchondral bone interface. The acceptable subchondral bone match of LFC allografts to the native MFC surface for oval shaped lesions helps address concerns of donor tissue availability. Finite element analysis is now required to determine how differences in subchondral bone surface height in allograft compared to surrounding native bone may affect local force distribution. Clinical Relevance: Our findings support the use of size-matched non-orthotopic LFC grafts for large oval defects of the MFC. This may promote economic use of available resources without compromising the efficacy of restoring the femoral articular surface.

Development of a Patient Specific Cartilage Graft Using Magnetic Resonance Imaging and 3D Printing

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All Authors:
Matthew Kolevar MD UNITED STATES
Jonathan D. Packer MD UNITED STATES
Jeffrey Hirsch MD UNITED STATES
Jocelyn Wu BS UNITED STATES
Robert Choe DMD, MS UNITED STATES
Michael Rocca MD UNITED STATES
Antoan Koshar MD UNITED STATES
Shannon McLoughlin BS UNITED STATES
Alejandro Venable-Croft BS UNITED STATES
John P Fisher PhD UNITED STATES

Summary:
This study validated the accuracy of a novel process designed to fabricate anatomically correct cartilage grafts in the weight bearing surfaces of human cadaver knees using MRI and 3D printing technology.

Data:
Introduction: Limited treatment strategies exist for large cartilage defects in nonarthritic patients, and the ideal treatment strategy for these defects remains unknown. The specific aim of this project was to develop a patient-specific, anatomically correct graft for cartilage restoration using MRI data and 3D printing technology, and to validate the accuracy of this novel process designed to fit the native contour of the human knee. Our hypothesis was that a custom-made anatomic graft would demonstrate better fit compared to a generic flat graft.

Methods: Four focal cartilage defects (FCDs) were created in paired human cadaver knees age <40 in the weight bearing surface of the 1) trochlea, 2) lateral facet of patella 3) medial femoral condyle, and 4) lateral femoral condyle of each knee. MRIs were obtained of each knee, and anatomic grafts were designed for the left knee as an experimental group, and generic flat grafts were printed for the right knee as a control group. All grafts were 3D printed with poly lactide acid (PLA). Grafts were implanted into corresponding defects and fixed using tissue adhesive. After implantation, repeat MRI was obtained for visualization of graft fit. The primary outcome was accuracy of a novel method for 3D printing individualized, anatomically shaped grafts, as measured on MRI. Graft step-off was measured as the distance between the surface of the graft and the native cartilage surface in a direction perpendicular to the subchondral bone. Graft contour was measured as the gap between the undersurface of the graft and the subchondral bone in a direction perpendicular to the joint surface. Measurements were performed every 1.8mm in two planes (n=18 for each femoral condyle and n=11 each for patella and trochlea) and recorded in millimeters. All patients and test was performed to compare means between groups. Results: Anatomic experimental grafts corresponding to FCDs in the medial femoral condyle, lateral femoral condyle, patella, and trochlea were successfully 3D printed and implanted using MRI data. Graft step-off was significantly better for the anatomic grafts compared to the generic grafts in the medial femoral condyle (0.9+/-0.2 vs. 0.7+/-0.5, p=0.001), lateral femoral condyle (0.1+/-0.3 vs. 1.0+/-0.2, p=0.001), patella (0.2+/-0.3 vs. -1.2+/-0.4, p=0.001), and trochlea (0.4+/-0.3 vs. 0.4+/-0.7, p=0.003). Graft contour was significantly better for the anatomic grafts in the lateral femoral condyle and the trochlea. The anatomic grafts had an observed maximum step-off of -0.9mm and maximum contour mismatch of 0.8mm. The generic grafts had an observed maximum step-off of -1.7mm and maximum contour mismatch of 2.2mm. Conclusions: This study provided validation of a process designed to fabricate an anatomically correct cartilage graft using MRI and 3D printing technology. Anatomic grafts demonstrated superior fit compared to generic flat grafts. Joint incongruity is clinically undesirable, and the mean anatomical graft step-off was less than 1mm in all FCDs. Mean graft contour was also less than 1mm in all FCDs, demonstrating excellent anatomic design and fit. Further research is needed to implement anatomic, biofunctionalized grafts in a large animal model.