### Title

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# Osteochondral Allograft Transplant to the Medial Femoral Condyle Using a Medial or Lateral Femoral Condyle Allograft: Is There a Difference in Graft Sources?

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## Abstract

**Background—**Osteochondral allograft (OCA) transplantation is an effective treatment for defects in the medial femoral condyle (MFC), but the procedure is limited by a shortage of grafts. Lateral femoral condyles (LFCs) differ in geometry from MFCs but may be a suitable graft source. The difference between articular surface locations of the knee can be evaluated with μCT imaging and 3D image analysis.

**Hypothesis/Purpose—**We tested the hypothesis that LFC OCAs inserted into MFC lesions can provide a cartilage surface match comparable to those provided by MFC allografts by comparing the surgical placement of human MFC and LFC allografts into MFC defects ex-vivo.

**Study Design—**Controlled laboratory study

**Methods—**20 MFC and 10 LFC were divided into three groups, 10 MFC recipients (MFCr), 10 MFC donors (MFCd) and 10 LFC donors (LFCd). A 20 mm defect was created in the weight-bearing portion of the MFCr. Two grafts, one MFCd and one LFCd, were implanted sequentially into each MFCr recipient condyle. Images of the MFCr using a Skyscan 1076 μCT at 18 μm voxel size were acquired and analyzed to compare the surface contours of the original recipient site with the MFCd- and LFCd-repaired sites. 3D transformations were defined to localize the defect site in the three scans of each MFCr condyle. Vertical heights from each cartilage surface voxel to a plane were determined to delineate the contour of each image. Vertical deviations from each voxel of the graft cartilage surface, relative to the intact recipient cartilage surface, were calculated and assessed as root mean square deviation (sRMS), percent graft area that was proud, sunk, and within the “acceptable” (±1.00mm) distance. The effect of repair (with MFC versus with LFC) on each of the surface match parameters (ARMS, Aacc, A unacc,proud, Aunacc,sunk, hRMS, hacc, h unacc,proud, and hunacc,sunk,) is presented as mean±StDev and was assessed by t-test.

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Percentage data were arcsin transformed before statistical testing. An alpha level of 0.05 was used to conclude if variations were statistically significant.

**Results—**MFCr defects were filled using both orthotopic MFCd and non-orthotopic LFCd. Registered μCT images of the MFCr illustrate the cartilage surface contour in the sagittal and coronal planes, in the original intact condyle as well as after OCA repairs. Specimen-specific surface color-maps for the MFCr after implant of the MFCd and after implant of LFCd were generally similar with some deviation near the edges. On average, the MFCr site exhibited a typical contour, and the MFCd and LFCd were slightly elevated. Both types of OCA, MFCd and LFCd, matched well, with overall height deviations of 0.63mm and 0.0.47 for area and stepoff, respectively, with no difference between MFCd and LFCd ($p=0.92$ and $p=0.57$, respectively) and acceptable deviation based on area (87.6% overall) and stepoff (96.7% overall) with no significant difference between MFCd and LFCd ($p=0.87$ and $p=0.22$, respectively). A small portion of the implant was proud, (12.1% of area and 2.6% of circumference stepoff height) with no significant difference between MFCd and LFCd ($p=0.26$ and $p=0.27$, respectively). A very small portion of the implant area and edge was sunk (0.3% of area and 0.6% of circumference) with no significant difference between MFCd and LFCd ($p=0.29$ and $p=0.86$, respectively).

**Conclusion—**The achievement of excellent OCA surface match with either an MFC or LFC donor graft into the common MFC recipient site suggests that non-orthotopic LFC OCA are acceptable graft options for MFC defects.

## Introduction

Articular cartilage lesions in the knee are a relatively common finding in young patients that present with knee pain and swelling.[9,14,20,49] As articular cartilage lacks the ability to heal, articular cartilage defects can lead to degenerative arthritis and knee dysfunction. There are many different treatment options for full thickness articular cartilage defects, including microfracture,[16,18,34,47] osteoarticular autograft transplant,[5,18,31] autologous chondrocyte implantation,[1,2,40,53] and osteochondral allograft transplant.

Fresh osteochondral allograft transplantation was first described in the early 19th century[28,29] and has been a viable treatment option for over twenty-five years.[3,6,8,12,15,17,22,27,32,33,44,50] In the past, the availability of suitable grafts and the need to implant the grafts on an urgent basis, once harvested, limited their use. However, with newer technology and storage media, chondrocyte viability can be maintained for several weeks, allowing surgeons to implant grafts on more of an elective basis.[51] Articular cartilage lesions of the medial femoral condyle (MFC) account for the majority of cartilage lesions in the knee, outnumbering lateral femoral condyle (LFC) lesions as much as 6-fold. [9,14,20,49] As a result, MFC allografts are in most demand. 2012 Joint Restoration Foundation (JRF) statistics indicate that 97% of osteochondral allografts requested were for medial femoral condyle grafts. In contrast, 75% of the JRF grafts that are suitable and made available to surgeons are LFCs (data on file, Joint Restoration Foundation, Denver, CO)

When performing an osteochondral allograft transplant, most surgeons demand that the graft being used match the site of the defect (i.e., right MFC allograft for a right MFC lesion), although some degree of mismatch in geometry appears acceptable. While finite element

models of resultant biomechanics predict general trends on the effects of articular geometry,[10] assumptions about actual tissue structure and properties for individual cases necessitates experimental studies. Osteochondral grafts with articular surface recessed by 1 mm or less in human knees appear to lead to acceptable outcomes.[35] Computer simulation, cadaveric, and animal specimen studies indicate that slightly recessed grafts could still restore contact pressure to nearly normal levels whereas elevated grafts 0.5-1mm proud lead to as much as a 50% increase in contact pressure.[19,23,24,25,52] Elevated osteochondral grafts can have deleterious effects, leading to the development of degenerative changes in the knee.[21] Thus, it appears that a geometrical match within 1 mm recession and 0.5-1 mm elevation is acceptable.

The geometries of LFCs and MFCs have been studied extensively and have been shown to differ in shape, curvature, and size.[11,36,42,43,46] In addition, articular cartilage thickness on femoral condyles has also been studied extensively, with studies showing differences between LFCs and MFCs, as well as variations with gender, race, weight, height, and applied stress during weight-bearing.[4,7,13,30,38,39,41,45] However, there are several characteristics of LFCs that make them a potentially suitable graft source for osteochondral lesions in the MFC. The articular cartilage on the LFC, except in the area of the sulcus terminalis, is as thick or thicker than corresponding areas on the MFC.[30] The LFC is wider than the MFC, which can provide the needed tissue for lesions that are larger than 25 mm in the medial-lateral width. Approximately 75% of the grafts that are larger than 2.6 cm in the medial to lateral dimension are LFC (data on file, Joint Restoration Foundation, Centennial, CO). The LFC has a superficial zone with better function than the corresponding region of the medial side with normal aging, as indicated by a higher tensile modulus and strength.[37,48]

The present study tested the hypothesis that LFC allografts inserted into MFC lesions can provide a cartilage surface match that is equivalent to that provided by MFC allografts and within geometrical acceptability. To address this aim, the surface geometries of intact human MFC recipient condyles and those repaired with MFC and LFC allografts *ex vivo* were compared.

## Materials and Methods

We designed a study to determine whether a LFC allograft can favorably compare to a MFC allograft when transplanted into a defect in a MFC. Prior to starting the study, a power analysis was computed to help determined sample size. For the primary outcome of comparing surface geometry, we assumed that the standard deviation of the matched MFC allograft relative to the original surface was 0.5 mm. In order to detect a difference of 0.75 mm, slightly less than the deviation criterion of 1.0mm, the required sample size is n=8, and n=10 was chosen to provide a safety factor. In addition, n=10 allowed assessment of the percentage (±10%) of grafts that did not meet the tolerance criteria of ± 1 mm.

Thirty frozen human knee condyles (20 MFCs and 10 LFCs) were provided by JRF (Denver, CO). All specimens were inspected to assure that there were no visible defects in the articular surfaces. 10 MFCs were used as recipient sites; the other 10 MFCs were used to

create donor osteochondral plugs as were 10 LFCs. All donor and recipient samples that were matched in the study corresponded to different individuals.

### Osteochondral Recipient Sites

Each of the 10 intact MFC recipient specimens (i.e., prior to creating an osteochondral defect) were photographed and scanned by micro-computed tomography (μCT). μCT scanning was performed on a Skyscan 1076 at 18 μm isotropic voxel size (Skyscan, Kontich, Belgium) by applying an electrical potential of 100kVp and current of 100uA, and using a 0.038mm copper + 0.5mm aluminum filter.

Following the baseline scans, a 20mm defect was created along the weight-bearing portion of each recipient MFC. The defects were created by three orthopedic surgeons experienced in osteochondral allograft transplantation using Allograft OATS instrumentation (Arthrex, Naples, FL). After inserting a drill tip guide pin, a defect was drilled to a depth of 6-9 mm, with the long axis of the defect perpendicular to the articular surface. The defect was positioned so that the native articular cartilage surrounding the defect was intact, thus creating a contained defect.

### Osteochondral Allograft Transplantation

The same three orthopedic surgeons performed the implantations. Osteochondral cylindrical donor cores, 20mm diameter, were harvested from (A) a site-matched region of an MFC allograft and (B) an area of an LFC allograft that grossly matched the contour along the MFC at the site of the defect. Due to concerns with alterations in the recipient MFC specimens while removing the first implanted graft, the order of implants was varied so that half had medial femoral condyle allografts placed first and the other half had lateral femoral condyle allografts placed first. In order to match the donor core to the recipient site, the depth of each lesion was measured in four quadrants. The donor core plugs were cut to the appropriate depth of the defect and then inserted using a tamp. The surgeons transplanted the grafts to their perceived best fit, attempting to minimize circumferential step-off and optimize surface contour restoration. All surgeons felt the transplants were anatomic once the procedures were completed.

Each of the transplanted/repaired recipient MFCs were again photographed and imaged by μCT. After insertion of the first donor allograft plug and μCT imaging, the initial allograft plug was atraumatically removed, leaving an empty MFC defect. The defect was then subsequently implanted with the second donor allograft plug. The recipient MFCs were then imaged again with μCT.

### Image Analysis

From the μCT image data, geometrical analyses were performed on the 10 recipient MFCs (MFCr), 10 LFC-repaired MFCs, and 10 MFC-repaired MFCs to characterize the degree of surface match. The software packages DataViewer and CTAn (Skyscan) were used to visualize the datasets, and MATLAB (MathWorks Inc., Natick, MA) was used for all image processing. Each set of three images were registered to each other and to a cylindrical coordinate system, aligned with the axis of the cylindrical defect and the medial-lateral

direction defining the angle (180°-0°). The cartilage surface of each image was identified by thresholding. From these surfaces, two metrics of surface match were determined.

First, the height difference between the repair surface and the intact surface was then mapped and summarized. Differences between the repair and intact samples were calculated by subtracting the surface positions, and color maps showing surface deviations were created. Thus, positive distances indicated that the repair surface was elevated (proud), and negative distances indicated that the repair surface was recessed (sunk). The overall surface deviation (either proud or recessed) was computed as the Root Mean Square ($A_{RMS}$). The percentage area of the transplanted plug that was in the range of acceptable tolerance of ±1 mm ($A_{acc}$) was calculated, as were the percentage areas that were >1mm proud and sunk ($A_{unacc,proud}$ and $A_{unacc,sunk}$, respectively).

Second, the step off in height between the repair surface and the intact surface was mapped and summarized. This height was calculated in 2° increments circumferentially as the local difference in height between implant and host, correcting for the difference in height between these positions in the intact recipient sample. The same sign convention was used for step off heights to indicate if the graft was locally proud or sunk, relative to the host. Also analogous to the calculations for area, those for step off were mapped, and then summarized as overall circumferential Root Mean Square height deviation ($h_{RMS}$), percentage circumference in the acceptable step off range of ±1 mm ($h_{acc}$), as well as percentage circumferences that were >1mm proud and sunk ($h_{unacc,proud}$ and $h_{unacc,sunk}$, respectively).

### Statistical Analyses

The effect of repair (with MFC versus with LFC) on each of the surface match parameters ($A_{RMS}$, $A_{acc}$, $A_{unacc,proud}$, $A_{unacc,sunk}$, $h_{RMS}$, $h_{acc}$, $h_{unacc,proud}$, and $h_{unacc,sunk}$,) is presented as mean±StDev and was assessed by *t*-test. Percentage data were arcsin transformed before statistical testing. An alpha level of 0.05 was used to conclude if variations were statistically significant.

## Results

(Table 1) includes data on surface area and step-off for all 20 allografts (10 MFC recipients; 10 MFC donors; 10 LFC donors). As shown for a typical sample, MFCr defects were filled using both orthotopic MFCd and non-orthotopic LFCd (**Figure 1**). In sagittal (**Figure 2A-C**) and coronal (**Figures 2D-F**) planes, the μCT images delineated surface contours for the intact recipient (**Figures 2A and D**) and the repair with an MFC donor (**Figures 2B and E**) and an LFC donor (**Figures 2C and F**). Specimen-specific surface color maps for the MFCr after implant of the MFCd (**Figure 3A**), and after implant of LFCd (**Figure 3B**) were generally similar. Histogram analyses of the color maps indicated the distribution of surface deviations for the MFCd (**Figure 3C**) and LFCd (**Figure 3D**). Circular maps of step off quantified the extent of deviation near the edges (Figures 3E and 3F).

The cartilage surface locations indicated that the repairs resulted in acceptable matches both in absolute terms, and in comparing MFCd and LFCd (**Table 2**). On average, the MFCr site

exhibited a typical contour, and the MFCd and LFCd were slightly elevated. Both types of OCA, MFCd and LFCd (Fig 3), matched well, with an overall height deviations of 0.63mm and 0.0.47 for area and step off, respectively, with no difference between MFCd and LFCd (p=0.92 and p=0.57, respectively) and acceptable deviation based on area (87.6% overall) and step off (96.7% overall) with no significant difference between MFCd and LFCd (p=0.87 and p=0.22, respectively). A small portion of the implant was proud, (12.1% of area and 2.6% of circumference step off height) with no significant difference between MFCd and LFCd (p=0.26 and p=0.27, respectively). A very small portion of the implant area and edge was sunk (0.3% of area and 0.6% of circumference) with no significant difference between MFCd and LFCd (p=0.29 and p=0.86, respectively).

## Discussion

The purpose of this study was to determine whether an osteochondral allograft from a LFC could be transplanted into a MFC defect with restoration of the articular surface as well as a MFC graft. The achievement of excellent OCA surface match with either an MFC or LFC donor graft into the common MFC recipient site suggests that nonorthotopic LFC-to-MFC transplants could lead to outcomes similar to orthotopic MFC-to-MFC transplants. The placement of grafts, while generally within the 1mm deviation target, but more often proud than sunk for both MFCd and LFCd, may reflect the surgeons' experience. With post-surgical joint loading, OCA may settle slightly into the recipient site. The reason for the slight difference due to the order of implants remains to be established, but may be due in part to visualization of the original surface at the time of the first implant.

The decision to choose an acceptable range of +/− 1mm with respect to the 3-dimensional surface topography and recipient-allograft articular step-off was based on biomechanical and clinical studies.[10,19,21,23,24,25,35,52] From a clinical standpoint, surgeons that perform osteochondral allograft transplants attempt to minimize recipient-graft articular step-off. As our results indicate, we were able to implant grafts within the desired +/− 1mm of step-off in 98.6% of the circumferences of the 10 MFC grafts and 94.5% of the LFC grafts. 5 of 10 (50%) of the MFC grafts and 4 of 10 (40%) of the LFC grafts were 100% within the acceptable range. For the grafts that did not have 100% of the circumference within the acceptable range of step-off, only a small percentage of each graft was either greater or less than 1 mm proud or recessed. Shortening the graft height for grafts that were proud or inserting bone graft deep to the graft for those that were recessed might improve the areas of the graft that were not within the acceptable range, but would result in undesired changes in the areas of the graft that were acceptable. In clinical situations, we are of the opinion that an implanted graft that has more than 90% of the circumference within +/− 1mm of step-off is very acceptable and a situation that we would not attempt to improve. The surgeon's ability to achieve 100% acceptable circumferential step-off is dependent of many factors, including the surface topographies of the recipient and donor condyle, the angle of the created recipient socket with respect to the articular surface, and the angle that the osteochondral plug was harvested from the donor condyle. Slight deviations from perpendicular when creating the recipient socket or harvesting the allograft plug can lead to areas of the transplant that can become proud or recessed.

Our study is the first to assess the three-dimensional surface contour of osteochondral allografts and compare them to the recipient condyle. There is no published data on surface geometry restoration, and no way, clinically, for surgeons to assure adequate restoration of the articular surface contour. As our data shows we were able to match the original MFC articular surface contour within +/− 1mm in 87.4% of the MFC grafts and 87.7% of the LFC grafts. The ability to accurately assess the exact match of surface contour with the eye is certainly not as accurate as the assessment done by μCT. As there are no two condyles with the exact surface contour, then some variability and tolerance should be expected with osteochondral allograft transplants. Restoring the surface area topography is dependent on the topography of the donor condyle, but as we have shown, acceptable restoration of the surface contour of the medial femoral condyle can be accomplished with either a MFC or LFC allograft for lesions ≤20 mm.

The results of this study have a number of clinical implications. The MFC is the most common location for full thickness chondral defects in the knee, and most surgeons that perform osteochondral allograft transplantation request a MFC allograft for these defects. Since many factors contribute to differences in condyle geometry, even a size-matched orthotopic allograft, does not assure that the surface contour will be similar to that of the recipient femoral condyle. Joint Restoration Foundation's 2012 statistics reveal that nearly 75% of available and suitable allograft condyles are LFCs. The limited availability of MFCs grafts can result in prolonged waiting for surgeons and patients, which in some cases, can lead to further joint deterioration. The present results suggest that a LFC graft can be used to restore the articular surface of a MFC as well as a MFC graft for moderate sized, contained defects.

There are several limitations to the present study. Only 20 mm defects were assessed. Although this size is not inclusive of all osteochondral allograft transplants, 20 mm represents a common size allograft transplanted as a single plug in our clinical experience. These results are also relevant to larger lesions that are treated with osteochondral allografts. Lesions that are larger than 25 mm are usually larger in the anterior-posterior dimension. Given that 75% of the harvested medial femoral condyles are less than or equal to 27 mm in the medial-lateral dimension ( data on file, Joint Restoration Foundation, Centennial, CO ), our preferred method of transplant in cases of larger lesions is to stack one to three allograft plugs of less than or equal to 20 mm to better match the native articular surface. The lesions in this study were also created in the weight-bearing portion of the MFC and contained; lesions that were uncontained or on the edge of the condyle were not assessed. The articular surface contour along the lateral-most portion of the MFC, a common location for an osteochondritis dissecans lesion, differs substantially from the medial side of the lateral femoral condyle. Using a LFC allograft in this situation may be more challenging. The study also only assessed the surface contours at time zero and did not address potential graft settling as the subchondral bone potentially resorbs and revascularizes. Finally, the study did not examine the quality of the articular cartilage or the subchondral bone. Differences in cartilage stiffness between donor and graft may affect load transmission on the recipient condyle.[26] We chose to focus on surface congruity, as it has been identified as an important factor in the success of osteochondral allograft transplantation.

In summary, an LFC allograft fits as well as a MFC allograft for 20 mm defects in the MFC. Clinical studies comparing MFC-to-MFC and LFC-to-MFC grafts would be of interest. If the similar articular surface match of non-orthotopic LFC-to-MFC and orthotopic MFC-to-MFC OCAs translates into similar surgical efficacies **in the long-term**, there will be increased availability of OCAs for MFC defects.

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**Clinical Relevance**

If the similar articular surface match of non-orthotopic LFC-to-MFC and orthotopic MFC-to-MFC OCAs translates into similar surgical efficacies, there will be increased availability of OCA for MFC defects.

What is know about this subject:

While osteochondral allograft transplantation has been successfully performed for many years, there are no published guidelines or recommendations on suitable and appropriate graft sources. Historically, surgeons have used matched femoral condyle allografts for transplants ( MFC allograft for MFC lesion ). Non-orthotopic osteochondral autografts are well described ( use of osteochondral plugs from the lateral side of the trochlea for defects in the weightbearing portions of the femoral condyles ), but there are no published articles on the use of lateral femoral condyle allografts for medial femoral condyle lesions.

**What this study adds to existing knowledge:** This is the first study that has looked at the suitability of using a LFC allograft as a transplant source for a MFC lesion. The results of this study support their use for MFC lesions. The results could increase suitable grafts available to surgeons and patients.

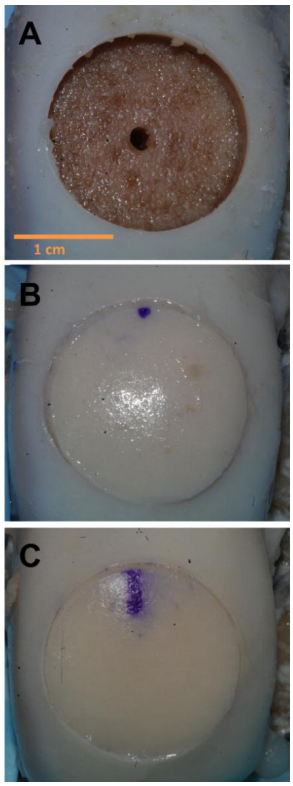


**Figure 1.**

En face gross images of a representative recipient MFC sample. **(A)** MFCr after creation of a defect and showing the remaining guide wire hole at the center. **(B)** Defect filled with an OCA from an MFC donor. **(C)** Defect filled with an OCA from a LFC donor.

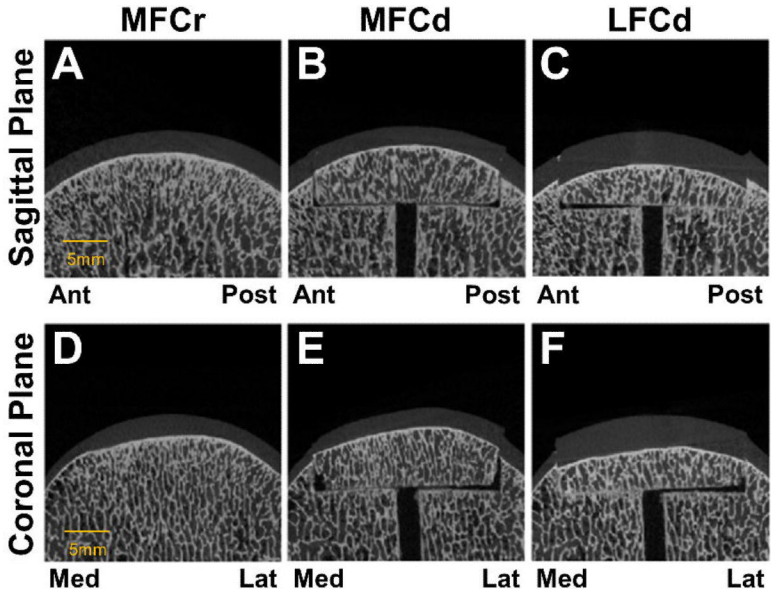


**Figure 2.**

Registered μCT images of a representative sample. **(A,B,C)** Sagittal slices and **(D,E,F)** coronal slices of a MFC recipient sample. Black region is air, white areas are subchondral bone, and gray region between air and bone is articular cartilage. **(A,D) MFCr**, intact recipient before defect creation. **(B,E) MFCd,** recipient site after repair with MFC donor tissue. **(C,F) LFCd,** recipient site after repair with LFC donor tissue.

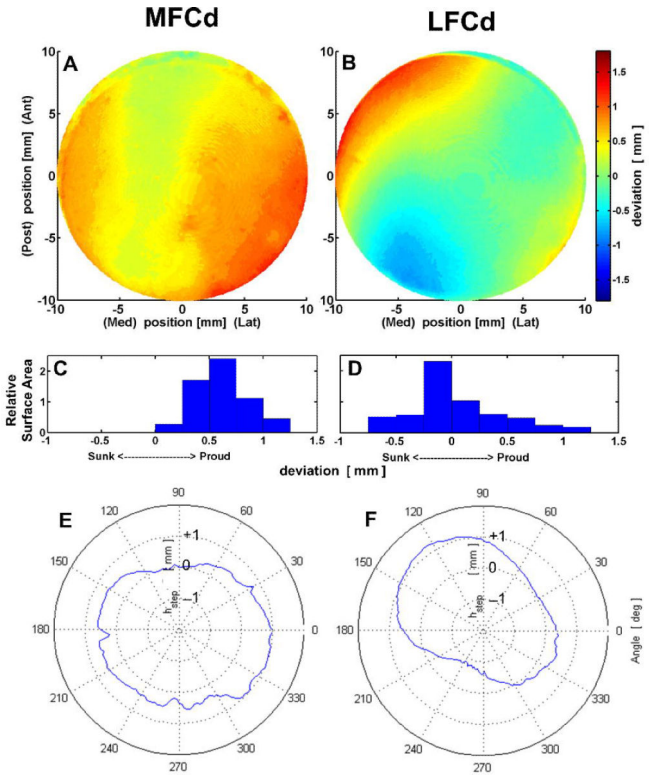


**Figure 3.**

Cartilage surface deviation from intact recipient for representative **(A,C,E) MFCd** and **(B,D,F) LFCd** implants, shown in Figure 2. **(A,B)** Color maps of deviation. **(C,D)** Histograms of deviation. **(E,F)** Polar plots of step-off heights.

**Table 1**

Area and stepoff height parameters of recipients implanted with MFC and LFC grafts. Mean ± StDev. *t*-test p-values of MFC vs. LFC implanted grafts.

| Implanted grail | $A_{RMS}$ (mm) | $A_{acc}$ (%) | $A_{unacc,proud}$ % | $A_{unacc,sunk}$ (%) | $h_{RMS}$ (mm) | $h_{acc}$ (%) | $h_{unacc,proud}$ % | $h_{unacc,sunk}$ (%) |
|---|---|---|---|---|---|---|---|---|
| MFC | 0.64 ± 0.24 | 87.4 ± 22.1 | 12.6 ± 22.1 | 0.0 ± 0.0 | 0.45 ± 0.10 | 98.6 ± 2.1 | 0.7 ± 1.6 | 0.7 ± 1.8 |
| LFC | 0.63 ± 0.31 | 87.7 ± 25.7 | ll.7 ± 26.0 | 0.6 ± 1.6 | 0.48 ± 0.13 | 94.9 ± 7.4 | 4.6 ± 7.8 | 0.6 ± 1.0 |
| OVERALL | 0.63 ± 0.27 | 87.6 ± 23.3 | 12.1 ± 23.5 | 0.3 ± 1.2 | 0.47 ± 0.12 | 96.7 ± 5.7 | 2.6 ± 5.8 | 0.6 ± 1.4 |
| *t*-test p-value (MFC vs. LFC) | 0.92 | 0.87 | 0.26 | 0.29 | 0.57 | 0.22 | 0.27 | 0.86 |

| | | | | AREA measurements | | | | | | Step off measurements | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type** | **Sample ID** | **Order** | **Recipient** | **Donor** | **$S_{rms}$ (mm)** | **Aacc(%)** | **Aproud(%)** | **Asunk(%)** | **$\%A_{unacceptable,proud}$** | **$\%A_{unacceptable,sunk}$** | **$h_{AVG(mm)}$** | **$h_{step,RMS}$ (mm)** | **$\%h_{acc}$** | **$\%h_{unacc,proud}$** | **$\%h_{unacc,sunk}$** |
| MFC grafts | A1 | 1 | MFCr1 | MFCd4 | 0.650 | 92.4% | 99.8% | 0.1% | 7.6% | 0.0% | 0.50 | 0.566 | 99.4% | 0.6% | 0.0% |
| | B1 | 1 | MFCr2 | MFCd1 | 0.406 | 99.9% | 34.0% | 59.7% | 0.1% | 0.0% | −0.17 | 0.416 | 100.0% | 0.0% | 0.0% |
| | C1 | 1 | MFCr3 | MFCd6 | 0.449 | 99.8% | 29.1% | 65.1% | 0.2% | 0.0% | −0.16 | 0.361 | 98.9% | 0.0% | 1.1% |
| | D1 | 1 | MFCr4 | MFCd3 | 0.404 | 99.7% | 95.4% | 2.2% | 0.3% | 0.0% | −0.01 | 0.317 | 100.0% | 0.0% | 0.0% |
| | E1 | 1 | MFCr5 | MFCd7 | 0.666 | 99.7% | 100.0% | 0.0% | 0.3% | 0.0% | 0.26 | 0.362 | 100.0% | 0.0% | 0.0% |
| | F2 | 2 | MFCr6 | MFCd2 | 0.542 | 96.4% | 84.8% | 11.6% | 3.6% | 0.0% | 0.28 | 0.503 | 100.0% | 0.0% | 0.0% |
| | G2 | 2 | MFCr7 | MFCd5 | 0.768 | 85.8% | 96.0% | 3.2% | 14.2% | 0.0% | 0.25 | 0.557 | 94.4% | 0.0% | 5.6% |
| | H2 | 2 | MFCr8 | MFCd10 | 0.486 | 100.0% | 80.1% | 15.6% | 0.0% | 0.0% | 0.16 | 0.412 | 100.0% | 0.0% | 0.0% |
| | I2 | 2 | MFCr9 | MFCd9 | 1.128 | 30.9% | 100.0% | 0.0% | 69.1% | 0.0% | 0.51 | 0.608 | 98.3% | 1.7% | 0.0% |
| | J2 | 2 | MFCr10 | MFCd8 | 0.888 | 69.6% | 98.5% | 1.5% | 30.4% | 0.0% | 0.29 | 0.420 | 95.0% | 5.0% | 0.0% |
| LFC grafts | A2 | 2 | MFCr1 | LFCd4 | 0.413 | 96.7% | 42.8% | 48.6% | 3.3% | 0.0% | 0.24 | 0.656 | 83.9% | 16.1% | 0.0% |
| | B2 | 2 | MFCr2 | LFCd8 | 0.601 | 94.2% | 74.0% | 22.9% | 4.8% | 1.0% | −0.03 | 0.468 | 98.9% | 0.0% | 1.1% |
| | C2 | 2 | MFCr3 | LFCd5 | 0.648 | 94.8% | 3.1% | 95.4% | 0.0% | 5.2% | −0.02 | 0.359 | 100.0% | 0.0% | 0.0% |
| | D2 | 2 | MFCr4 | LFCd6 | 0.580 | 93.7% | 92.4% | 2.9% | 6.3% | 0.0% | 0.21 | 0.390 | 100.0% | 0.0% | 0.0% |
| | E2 | 2 | MFCr5 | LFCd10 | 1.461 | 14.8% | 99.3% | 0.5% | 85.2% | 0.0% | 0.69 | 0.738 | 80.0% | 20.0% | 0.0% |
| | F1 | 1 | MFCr6 | LFCd2 | 0.542 | 96.4% | 84.3% | 13.6% | 3.6% | 0.0% | 0.25 | 0.582 | 90.6% | 9.4% | 0.0% |
| | G1 | 1 | MFCr7 | LFCd3 | 0.612 | 99.5% | 90.0% | 7.4% | 0.5% | 0.0% | 0.10 | 0.460 | 97.2% | 0.0% | 2.8% |
| | H1 | 1 | MFCr8 | LFCd7 | 0.349 | 100.0% | 79.8% | 16.2% | 0.0% | 0.0% | 0.13 | 0.335 | 100.0% | 0.0% | 0.0% |
| | I1 | 1 | MFCr9 | LFCd1 | 0.461 | 96.2% | 74.2% | 19.6% | 3.8% | 0.0% | −0.13 | 0.437 | 98.3% | 0.0% | 1.7% |
| | J1 | 1 | MFCr10 | LFCd9 | 0.589 | 90.7% | 82.5% | 15.3% | 9.3% | 0.0% | 0.05 | 0.405 | 100.0% | 0.0% | 0.0% |