Comparison of Mini-Open Versus Arthroscopic Harvesting of Osteochondral Autografts in the Knee: A Cadaveric Study

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Purpose: To prove that the assessment of osteochondral graft perpendicularity with magnetic resonance imaging (MRI) will allow for a precise measurement of graft perpendicularity and for an improved comparison of arthroscopic versus mini-open harvest techniques. **Methods:** Ten fresh cadaveric knees (mean age, 39.4 years) underwent harvest of 6-mm osteochondral plugs using the Osteochondral Autograft Transfer System (OATS; Arthrex, Naples, FL). A total of 8 plugs were harvested per knee from 3 donor sites: the lateral supracondylar ridge, the medial supracondylar ridge, and the lateral intercondylar notch. Two surgeons performed the graft harvest, alternating between mini-open (5 specimens) and arthroscopic (5 specimens) techniques to minimize bias. The osteochondral plugs were labeled and plated by a novel agar plating technique and then underwent MRI for measurement of graft perpendicularity. The data were analyzed to look for a significant difference in perpendicularity between the 2 harvest techniques, as well as overall graft acceptability. **Results:** One specimen in the open harvest technique group was unable to undergo optimal MRI because of difficulties encountered with the novel agar plating system resulting in graft movement during imaging. When we compared the mini-open and arthroscopic harvest techniques, the mean angle of perpendicularity at the lateral intercondylar notch harvest site was 84.1° and 84.2°, respectively ($P = .958$). At the medial supracondylar ridge harvest site, the mean angle of perpendicularity for the mini-open and arthroscopic techniques was 88.4° and 81.0°, respectively, with a mean difference of 7.4° ($P = .006$). At the lateral supracondylar ridge harvest site, the mean angle of perpendicularity for the mini-open and arthroscopic techniques was 85.7° and 87.1°, respectively ($P = .237$). **Conclusions:** A significant difference in osteochondral autograft perpendicularity was noted at the medial supracondylar ridge when we compared the mini-open and arthroscopic harvesting techniques. This suggests that when one is harvesting autologous osteochondral grafts from the medial supracondylar ridge, the mini-open technique may be preferred. **Clinical Relevance:** When harvesting autologous osteochondral grafts from the medial supracondylar ridge of the knee, the mini-open technique will potentially allow for a more perpendicular graft for implantation.

The management of chondral and osteochondral defects of the weight-bearing surfaces of the knee and talus remains a challenge for orthopaedic surgeons. Establishing the optimal treatment of these lesions is difficult. Treatment options include debridement, microfracture, abrasion chondroplasty, osteochondral autograft transfer, autologous chondrocyte implantation, and osteochondral allograft.[1-4] The choice of treatment is dictated by several factors including size, stability and location of the lesion, and the patient's age and activity level.[5] Osteochondral autograft transfer is a valuable treatment option for the high-demand patient with an isolated chondral lesion of the femoral condyle and is typically reserved for

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lesions less than 2 to 3 cm.[5,6] Despite potential limitations of the use of osteochondral autografts, such as donor-site morbidity, cartilage thickness mismatch, and cartilage radius-of-curvature mismatch, this technique has been used successfully to allow excellent return of function.[5-8]

Proper harvest technique is paramount in obtaining an acceptable plug for transfer, with emphasis placed on achieving graft perpendicularity and avoiding levering. Duchow et al.,[9] in a porcine model, showed that levering of the chisel used for harvest can result in decreased press-fit stability. During the harvesting of osteochondral plugs, emphasis is placed on ensuring perpendicularity of the graft to allow adequate filling of the recipient site and achieve articular congruence. A perpendicular graft will provide a congruent recipient surface and allow for adequate filling with minimal articular incongruity. Pearce et al.,[10] in a chondral defect animal model, found that articular congruence has a significant influence on the quality of incorporated graft tissue during healing. They found that as little as a 1-mm step-off between the graft and the recipient articular surface led to poor graft incorporation and poor quality of tissue healing.[10] This congruity is dependent on the size and orientation of the harvested plug in relation to the defect. Keeling et al.,[11] using simple trigonometry, showed that the angle suitable for grafting depends on the diameter of the plug. This number is higher (closer to 90°) for large-diameter plugs and lower for smaller-diameter plugs.

Many factors such as cartilage thickness, radius of curvature, and potential morbidity are considered when choosing an osteochondral harvest site. Donor sites for osteochondral transfer include the posterior femoral condyles and the anterolateral aspect of the intercondylar notch, as well as the lateral supracondylar ridge (LSR) and medial supracondylar ridge (MSR).[12,13] Although contact pressure studies suggest that the medial trochlea is subject to the least amount of pressure[12,13] compared with other harvest sites, no definitive studies exist correlating harvest site location with clinical morbidity.

Two recent studies have compared open versus arthroscopic harvesting techniques with respect to graft perpendicularity, and no significant difference was noted between the 2 methods.[11,14] However, the use of plain radiographs[14] and the measurement of graft perpendicularity from a line drawn parallel to the subchondral bone,[11] as opposed to the actual chondral surface, may not provide an accurate measure of graft perpendicularity. Assessment with magnetic resonance imaging (MRI) provides a more precise measurement of osteochondral graft perpendicularity because it accounts for cartilage thickness variability, which allows for measurement of graft perpendicularity from the chondral surface as opposed to subchondral bone. Therefore the purpose of this study was to compare graft perpendicularity between mini-open and arthroscopic harvest techniques using MRI assessment of perpendicularity. We hypothesized that better perpendicularity would be achieved with the mini-open technique compared with the arthroscopic technique.

METHODS

Ten fresh-frozen cadaveric knees were studied (mean age, 39.4 years; mean body mass index, 29.1; 5 male and 5 female specimens). The cadaveric specimens had no history of surgery around the knee, had intact cruciate ligaments, and had no arthroscopic visual evidence of International Cartilage Research Society grade III or IV cartilage changes. All specimens were stored frozen and then thawed 24 hours before the experiment.

For osteochondral plug harvesting, the Arthrex Osteochondral Autograft Transfer System (OATS; Arthrex, Naples, FL) was used to harvest 6-mm plugs according to the manufacturer's guidelines. This system consists of tubular chisels of 6 mm in diameter specifically designed for graft harvest. Two sports medicine fellows performed the graft harvest and alternated between arthroscopic and mini-open technique to minimize bias. Cadaveric specimens were chosen at random to be selected for 1 of the 2 harvest techniques, with 5 specimens undergoing arthroscopic harvest and 5 undergoing mini-open harvest. By use of a technique similar to that of Keeling et al.,[11] each cadaveric limb was loaded into a vice clamp and secured in place with the knee being able to be positioned from full extension to flexion. A diagnostic arthroscopy was performed with an arthroscopic pump and a 30° arthroscope. A 4.5-mm-wide full-radius shaver was used to debride excessive synovium or fat pad to make visualization adequate for harvest. Using OATS circular chisels (Arthrex) 6 mm in diameter, each surgeon harvested specimens from 3 areas of each cadaveric knee: 2 from the MSR, 3 from the lateral intercondylar notch (LIN), and 3 from LSR. These areas were chosen because they are non–load-bearing or partial load-bearing regions of the knee and the most commonly used donor sites for osteochondral plug harvest.[12,13] The arthroscopic camera was positioned in the lateral portal for the harvest of grafts

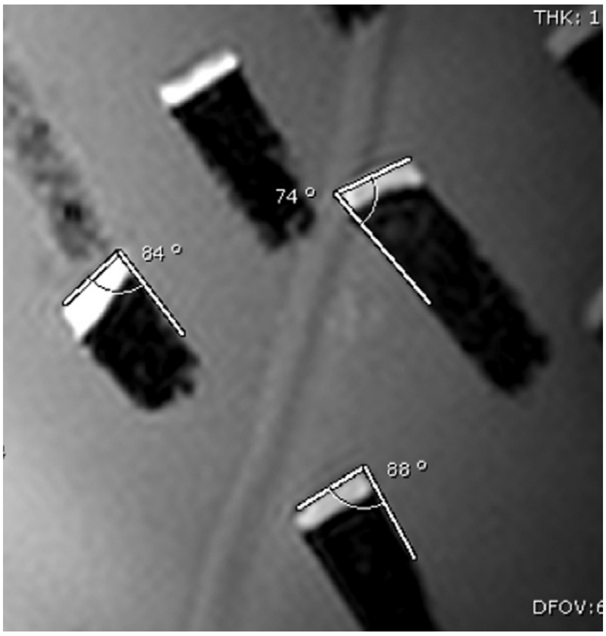

FIGURE 1. Coronal slices from gradient echo, fluid-sensitive MRI of osteochondral autografts. Perpendicularity of the grafts was measured by use of the intersection of a line drawn parallel to the cartilage cap and a line drawn parallel to the long axis of the osteochondral plug.

from the LSR and LIN. The cannula was introduced through a lateral suprapatellar portal for LSR harvest and through the inferomedial portal for LIN and MSR harvest. The chisel was then deployed onto the harvest area to harvest a plug with the cartilage cap oriented 90° to the long axis of the graft. Observing the "laser lines" on the chisel, visualizing the chisel from multiple viewpoints, and orienting the device accordingly were performed to aid harvest orientation. Once seated in the cartilage, a mallet was used to advance the chisel to a depth of 15 mm. The harvested plugs were retrieved with gentle twisting and extraction and then labeled and aligned for later imaging. Care was taken to avoid levering of the chisel to assist with graft extraction.

The mini-open harvest technique was adapted from that of Keeling et al.[11] Each surgeon harvested the specimens with the mini-open approach using a 3-cm incision. Digital palpation of the area of interest was used, followed by appropriate positioning of the limb: extension of the knee for LSR and MSR harvest and flexion of the knee to 90° for LIN harvest. A No. 15 blade was used to perform a skin incision less than 3 cm for each area of harvest through superolateral, medial parapatellar, or lateral parapatellar incisions, followed by sharp dissection into the joint capsule. As previously described, the 6-mm chisel was positioned into place and seated and a small mallet was used to advance the chisel through cartilage and into subchondral bone. Once retrieved, these grafts were appropriately labeled and aligned for later imaging as above.

All the plugs were labeled according to the site and specimen and stored in a freezer for later imaging analysis. Harvested plugs were labeled according to the site of harvest, harvester, and method of harvest technique. Plugs were placed in an agar plate to aid in anchoring the grafts and prevent movement during imaging (Fig 1). The grafts were oriented so that the maximal angulation between the cartilage surface and the longitudinal axis of the graft could be calculated. One advantage of MRI is its multiplanar capability. Indeed, this was 1 of the original intended purposes of this study; however, because of relatively limited access to the MRI machine, we chose to make these measurements in the plane of maximal angular deformity. The agar plates were then immersed in normal saline solution to allow for optimal imaging and underwent MRI. Fluid-sensitive, gradient echo images with 2.5-mm slices in the coronal plane were obtained for each specimen. By use of digital calipers, the angle between the cartilage surface and the long axis of the bone plug was measured in the coronal plane. Additional measurements were performed in an attempt to account for variable cartilage thickness, including the angle between the subchondral bone and the long axis

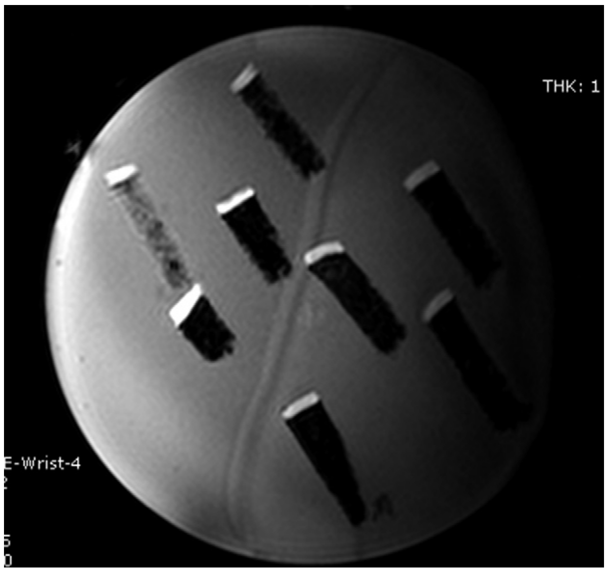

FIGURE 2. Scout view from gradient echo, fluid-sensitive magnetic resonance image of osteochondral autograft specimens in agar plate filled with normal saline solution.

of the bone plug (Fig 2). Independent *t* tests were used to compare perpendicularity between the mini-open and arthroscopic techniques at each harvest site. In addition, independent *t* tests were used to compare the measurement of perpendicularity between the cartilage surface and the subchondral bone.

It should be noted that this study chose to address a specific question regarding the best way to achieve perpendicularity during the harvest of osteochondral plugs and did not focus on techniques of implantation.

RESULTS

One specimen in the open harvest technique group was unable to undergo optimal MRI because of difficulties encountered with the novel agar plating system resulting in graft movement during imaging. Two additional plugs, 1 from the MSR and 1 from the LIN, were also unable to be measured because of suboptimal MRI quality. All 9 other specimens underwent MRI as described earlier. Of all plugs, 88% (70 of 80) were measured, 39 by the arthroscopic technique and 31 by the mini-open technique. When we compared the open and arthroscopic harvest techniques, the mean angle of perpendicularity at the LIN harvest site was 84.1° and 84.2°, respectively ($P = .958$). At the MSR harvest site, the mean angle of perpendicularity for the open and arthroscopic techniques was 88.4° and 81.0°, respectively, with a mean difference of 7.4° ($P = .006$). At the LSR harvest site, the mean angle of perpendicularity for the open and arthroscopic techniques was 85.7° and 87.1°, respectively ($P = .237$) (Table 1).

When we compared the angle of perpendicularity in reference to the cartilage surface and that of the subchondral bone, the mean angle was 85.2° and 84.0°, respectively ($P = .116$) (Table 2). In addition, we found that all plugs harvested, using either the open or arthroscopic technique, were greater than the angle of 71.6° and thus were considered suitable for transfer.[11]

Table 1. *Summary of Osteochondral Harvest Results*

Harvest Site and Technique	Total No. of Plugs Measured	Mean Angle of Graft Perpendicularity (°)	Difference (°)	P Value
LIN			0.1	.958
Open	12	84.1 (78.0-90.0)		
Arthroscopy	14	84.2 (74.0-90.0)		
MSR			7.4	.006
Open	7	88.4 (86.0-90.0)		
Arthroscopy	10	81.0 (72.0-89.0)		
LSR			1.4	.237
Open	12	85.7 (81.0-90.0)		
Arthroscopy	15	87.1 (84.0-90.0)		

Table 2. *Comparison of Graft Perpendicularity With 2 Measuring Techniques*

Measured Perpendicularity	Mean Angle (°)	Mean Difference (°)	P Value
Cartilage	85.2	1.2	.116
Subchondral	84.0		

DISCUSSION

Several long-term follow-up studies have shown that osteochondral autograft transfer is an effective treatment option for isolated chondral lesions of the knee and talus.[5-8,15-18] Joint surface congruity is an important factor in the outcome of osteochondral autograft transfer and is dependent on proper harvest and implantation technique. Osteochondral autograft harvest presents a challenge for many orthopaedic surgeons, because it is essential to achieve graft perpendicularity. Histologic studies have identified the necessity of matching the articular surface of the recipient to obtain the best histologic incorporation.[10] Although it is the preference of some surgeons to harvest osteochondral plugs arthroscopically in an attempt to minimize the morbidity of graft harvest, some may prefer a mini-open technique, which may provide a perception of better visualization.[11]

In previous studies, when authors compared open versus arthroscopic harvest techniques to achieve perpendicularity, no significant difference was noted.[11,14] Keeling et al.,[11] in a cadaveric study using a 7-mm OATS chisel from common knee donor sites, found that there was no statistically significant differences ($P < .05$) in graft suitability regardless of the technique used or donor-site location. They found that 69% of arthroscopic and 56% of mini-open graft harvests would result in articular incongruity of less than 1 mm. One potential limitation of that study is the use of plain radiographs for assessing graft perpendicularity as measured from a line drawn along the long axis of the graft and a line parallel to the subchondral bone. This technique fails to take into account the thickness of the autograft chondral surface, which can vary among graft sites.[12] Diduch et al.,[14] in a cadaveric study comparing arthroscopic versus open harvesting techniques for osteochondral autograft plugs, found

TABLE 3. *Comparison of Perpendicularity at Various Harvest Sites*

Study	Harvest Technique	MSR (°)	LSR (°)	LIN (°)	MFC (°)	LFC (°)
Current study	Open	88.4	85.7	84.1	NA	NA
	Arthroscopic	81.0	87.1	84.2	NA	NA
Keeling et al.,[11] 2009	Open	NA	79.0	72.2	73.3	73.6
	Arthroscopic	NA	76.2	78.2	73.7	79.5
Diduch et al.,[14] 2003	Open	NA	87.625	85.125	NA	NA
	Arthroscopic	NA	86.250	81.875	NA	NA

Abbreviations: LFC, lateral femoral condyle; MFC, medial femoral condyle; NA, not available.

that plugs harvested from the superior lateral trochlear ridge (86.9°) were statistically more perpendicular than the plugs harvested from the intercondylar notch (83.3°). They found no statistically significant difference between the open (86.4°) and arthroscopic (83.8°) harvesting techniques. However, specimen measurements were performed with a handheld goniometer, which can inherently limit the accuracy of the authors' measurements. When our results were compared with those of the 2 previously noted studies investigating the superiority of open versus arthroscopic harvest techniques,[11,14] our results were similar when the LIN and LSR were chosen for harvest sites (Table 3). However, these studies did not use the MSR as the site of harvest, and therefore no comparison can be made. At the MSR, we found a significant difference comparing the 2 harvesting methods. One possible reason for this is that the MSR is an anatomically smaller area[12] than the LSR and may be harder to visualize with an arthroscopic technique.

We chose 3 common harvest sites, the MSR, LSR, and LIN, for osteochondral graft harvest. Although an ideal harvest site has not yet been identified, Ahmad et al.,[12] in a biomechanical cadaveric study found that donor sites from the distal-medial trochlea were completely non–load bearing, with the intercondylar notch and lateral trochlea showing areas of partial load bearing. In addition, they found that the lateral and medial trochlea radii of curvature better matched recipient sites on the femoral condyles. Garretson et al.[13] showed in a biomechanical cadaveric model that the lowest patellofemoral contact pressures are found along the medial patellofemoral articulation just proximal to the sulcus terminalis and recommended this site for harvest of plugs less than 5 mm. It has been suggested that because the distal medial trochlea is not involved in patellofemoral load bearing, it may be the preferred donor site for autologous osteochondral transfer.[12,13]

It should be noted that despite routine use of osteochondral allograft for the treatment of chondral lesions, harvest of autologous osteochondral plugs from the knee is not without morbidity. Reddy et al.,[19] in a retrospective review of 11 patients undergoing mosaic autogenous osteochondral transplantation for talar osteochondral lesions, found significant donor-site morbidity in a series of patients.

In this study we chose to use a 6-mm chisel to harvest our osteochondral plugs. The size of autologous grafts used for transfer typically depends on the size of the lesion being filled, as well as the surgeon's preference for multiple smaller plug harvests versus 1 larger plug harvest. To minimize differences in articular geometry between the femoral condyle or talus and the harvested grafts, multiple smaller plugs may be used.[15,18,19] The caveat is that this may result in increased fibrocartilage between the osteochondral plugs.[15,18] The treatment of large osteochondral defects of the talus can be achieved with mosaic autologous osteochondral transplant, with donor grafts ranging in size from 3.5 to 6.5 mm.[18,19] In a biomechanical cadaveric study using pressure transducers to measure contact pressures after transplant, Choung and Christensen[20] showed that the use of a greater number of smaller plugs resulted in better restoration of joint contact pressure as opposed to a smaller number of larger plugs. Although the treatment of femoral condyle lesions can be performed using a smaller number of larger plugs, we chose to use a 6-mm harvest for our study, so as not to limit the applicability of our results to lesions of the knee.

To calculate our "acceptable" graft perpendicularity, we used a method previously described by Keeling et al.[11] They used simple trigonometry to calculate the theoretic graft axis angular discrepancy allowable to ensure that the edge mismatch between the graft and donor articular margin is less than 1 mm. This angle is higher for larger-diameter grafts and lower for smaller-diameter grafts, which means that with larger-diameter grafts, there are fewer margins for error when one is performing graft harvest. Prior calculations by Keeling et al. provide us with an acceptable graft perpendicularity of 71.6° to ensure a less than 1-mm articular step-off. This means that all grafts with greater than 71.6° were considered acceptable for transfer for the purposes of this study.

The results of our study highlight the difficulty in achieving graft perpendicularity with arthroscopic graft harvest from the MSR in cadaveric knees. One may consider the use of a 70° arthroscope during graft harvest from the MSR to assist with visualization as opposed to the 30° arthroscope used in this study. In addition, an accessory superolateral portal may be used to better visualize graft harvest from the MSR.

Limitations of our study include the experience and ability of the 2 orthopaedic sports medicine fellows who performed the harvesting. In addition, this was a cadaveric study, and the variable quality of cadaveric bone may have influenced the perpendicularity of our graft harvest. It should also be noted that cadaveric testing does not always equate to in vivo scenarios. Our small sample size is another limitation of this study, which was compounded by the loss of 1 of the mini-open specimens because of difficulties with our novel agar plating technique. This allowed for a discrepancy in the total number of plugs measured using the mini-open and arthroscopic techniques. Lastly, it should be noted that the perpendicularity of transplanted autografts is only 1 factor that influences the outcome of osteochondral grafting for the treatment of osteochondral defects. Other factors that contribute to overall outcomes, such as graft length and graft stability, should be considered when one is performing this procedure.

CONCLUSIONS

A significant difference in osteochondral autograft perpendicularity was noted at the MSR when we compared the mini-open and arthroscopic harvesting techniques in cadaveric knee specimens. This suggests that when one is harvesting autologous osteochondral grafts from the MSR, the mini-open technique may be preferred.

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