Anterolateral Tibial Osteotomy for Accessing Osteochondral Lesions of the Talus in Autologous Osteochondral Transplantation: Functional and T2 MRI Analysis

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Abstract

Background: Autologous osteochondral transplantation (AOT) is a primary treatment strategy for large or cystic osteochondral lesions of the talus (OLT) or a secondary replacement strategy after failed bone marrow stimulation. The technique requires perpendicular access to the talar dome, which is often difficult to obtain for posterior or lateral lesions. Traditional methods to access these areas have required disruption of the syndesmotic complex with concern over osteotomy reduction, malalignment, and ligament disruption. An alternate to these traditional methods of access is an anterolateral tibial osteotomy. The purpose of this study was to report functional and magnetic resonance imaging (MRI) outcomes in a series of patients that underwent AOT for treatment of an OLT via an anterolateral tibial osteotomy.

Methods: Records of patients that underwent an anterolateral tibial osteotomy for AOT were retrospectively reviewed. Pre- and postoperative Foot and Ankle Outcome Scores (FAOS) and demographic data were recorded. Magnetic resonance observation of cartilage repair tissue (MOCART) was used to assess morphologic state of tibial cartilage at the repair site of the osteotomy. Quantitative T2 mapping MRI was analyzed in the superficial and deep cartilage layers of the repair site of the osteotomy and in adjacent normal cartilage to serve as control tissue. Seventeen patients with a mean age of 36.9 (range, 17-76) years underwent anterolateral tibial osteotomy with a mean follow-up of 64 (range, 29 to 108) months. MOCART data were available in 9 of 17 patients, and quantitative T2 mapping was available in 6 patients.

Results: FAOS significantly improved from an average 39.2 (range, 14 to 66) out of 100 points preoperatively to 81.2 (range, 19 to 98) postoperatively (<.01). The average MOCART score was 73.9 out of 100 points (range, 40 to 100). Quantitative T2 analysis demonstrated relaxation times that were not significantly different from the normal native cartilage in both the deep half and superficial half of interface repair tissue (> .05).

Conclusion: This study demonstrated that the anterolateral tibial osteotomy was a reasonable alternative for accessing central or posterolateral OLT for AOT with limited morbidity associated with the osteotomy. The evidence demonstrated adequate osteotomy and cartilaginous healing with improvement in functional outcome scores at medium-term follow-up.

Level of Evidence: Level IV, retrospective case series.

Keywords: osteochondral lesion, talus, anterolateral tibial osteotomy, autologous osteochondral transplantation

Osteochondral lesions of the talus (OLT) are a common source of pain and functional limitation in the active population, affecting many patients who experience an ankle sprain. Arthroscopic bone marrow stimulation is the primary treatment strategy for symptomatic lesions less than 150 mm² for larger lesions, lesions with a large cystic component, or lesions that have failed prior bone marrow stimulation, autologous osteochondral transplantation (AOT) utilizing an open approach is an effective replacement strategy with good clinical results in short-term studies.¹⁰,¹¹,²¹

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One of the unique challenges of AOT is that it requires perpendicular access to the talar dome. As a result, a malleolar or tibial osteotomy is often needed for sufficient access to the posterior aspect of the talar dome. The need for an osteotomy presents another potential source of morbidity and postoperative pain. Lamb et al found that to access medial OLT, the medial malleolar osteotomy provides both sufficient access to the talar dome with good rates of osteotomy healing and no increased morbidity specific to the osteotomy at 34 months follow-up. For lateral lesions, several unique approaches have been described including anterolateral tibial osteotomy (Chaput-type) and anterolateralarthrotomy with anterior talofibular ligament release. In addition, approaches requiring osteotomy of the fibula have been reported including an oblique osteotomy distal to the syndesmosis as well as a fibula and Chaput fragment osteotomy. Potential concerns with these approaches include disruption of the syndesmosis and challenges with restoring normal anatomical rotational alignment. In addition, osteotomy of the fibula does not always allow perpendicular access to the talar dome.

We describe an anterolateral osteotomy for accessing centrolateral and posterolateral talar osteochondral lesions for AOT. The purpose of this study was to retrospectively analyze a series of patients that underwent this anterolateral distal tibia osteotomy and report (1) functional outcomes by evaluating patient pain and symptoms postoperatively, (2) the rate of bony union on magnetic resonance imaging (MRI), and (3) the integrity and morphology of the cartilage infill at the tibial interface at the site of the osteotomy through MRI and T2 mapping. We hypothesized that the anterolateral distal tibia osteotomy would provide good functional outcomes and satisfactory healing with fibrocartilaginous repair tissue at the osteotomy interface, as well as minimal postoperative morbidity specific to the osteotomy.

Methods

This retrospective review was approved by our Institutional Review Board. Patients were identified using our institution’s registry database. To meet inclusion criteria, patients were required to have undergone AOT via an anterolateral tibial osteotomy for treatment of an OLT. Patients with insulin-dependent diabetes mellitus or rheumatoid arthritis were excluded from the study. All patients were treated under the care of the senior author.

Patient Demographics

Between March 2004 and October 2010, 17 patients, 13 males and 4 females, at an average age of 36.9 (range, 17-76) years underwent AOT of the talus via an anterolateral tibial osteotomy. Patient demographic data are summarized in Table 1. Mean follow-up was 64 (range, 29 to 108) months.

Table 1. Patient Demographics and Clinical Data.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Total number of patients</td>
<td>17</td>
</tr>
<tr>
<td>Number of female patients</td>
<td>4 (24%)</td>
</tr>
<tr>
<td>Mean age and range (years)</td>
<td>36.9 (17-76)</td>
</tr>
<tr>
<td>Mean duration of symptoms and range (months)</td>
<td>37.4 (1-60)</td>
</tr>
<tr>
<td>Lesion area and range (mm²)</td>
<td>83.6 (50.6-158.0)</td>
</tr>
<tr>
<td>Follow-up time and range (months)</td>
<td>64 (29-108)</td>
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</table>

The mean duration of symptoms prior to the surgery was 37.4 (range, 1-60) months, with 13 (76%) patients experiencing previous trauma. Eight (47%) of the patients underwent concomitant procedures including scope debridement of anterior or posterior impingement, lateral ligament reconstruction, flatfoot reconstruction, and osteophyte removal. Three (18%) patients underwent double-plug AOT. Ten right ankles (58%) and 7 left ankles (42%) were treated.

The most common lesion location was centrolateral (59%), followed by posterolateral (41%). The average lesion size was 83.6 mm² (range, 50.6 to 158.0). These smaller lesions, which were included in the study, either had failed previous microfracture or had a large cystic component. A total of 8 patients had undergone previous bone marrow stimulation. The remaining lesions were larger in size. To determine lesion size, we used an ellipse formula \( \text{Area} = \pi \times \text{radius}^2 \).

Preoperative Clinical Evaluation

Each patient underwent a complete history and physical exam prior to surgery. Prior to surgery, patients were evaluated using the Foot and Ankle Outcome Score (FAOS). Preoperative standard weight-bearing radiographs and MRI of the symptomatic ankle were obtained. Lesion size was determined on MRI by the senior radiologist and confirmed intraoperatively by the senior surgeon with the use of a ruled probe (Smyth and Nephew PLC, London, UK). The lesion location was also determined both on MRI and intraoperatively and was defined using a previously described 9-zone localization scheme described by Elias et al.

Operative Technique

The operative technique of AOT performed in this study was uniform for all patients as previously described. A vertical incision was made just medial to the usually palpable superficial peroneal nerve (SPN) (Figure 1). The incision was extensile and measured approximately 3 cm in length. The medial fibers of the anterior inferior tibiofibular ligament (AITFL) were identified, and the periosteum was elevated just medially. The lateral aspect of the tibia was still maintained.
After the ankle joint was adequately exposed and visualized, the osteotomy site was prepped and predrilled parallel to the surface of the talus. This helped ensure proper reduction of the osteotomy at the conclusion of the procedure (Figure 2). The width and depth of the osteotomy were based on lesion location on preoperative imaging as well as the degree of plantarflexion possible for each patient. Intraoperative fluoroscopy was used as supplementary imaging to confirm the degree of possible plantarflexion and required osteotomy.

The osteotomy was then made using an oscillating saw and cooled with saline to prevent thermal necrosis. The first cut was made perpendicular to the talocrural line and in a craniocaudal fashion (Figure 3). This was done at approximately 40-60 degrees anterior to posterior. This allowed for adequate exposure of the lesion. The medial and lateral cuts were made 2-3 cm apart starting from the most lateral portion of the exposure. These cuts were made in a 20-degree convergent manner.

The saw did not violate the articular surface, and the osteotomy was completed with a sharp osteotome (0.0127-m) (Figure 4). At this point the ankle was plantarflexed to expose the lesion, which was debrided back until a stable rim of cartilage contained the defect. An appropriate sized recipient site trephine (Arthrex, Inc, Naples, FL) was then used to prepare the defect (Figure 5). The osteochondral autograft was subsequently harvested from a non-weight-bearing aspect of the lateral trochlear ridge of the ipsilateral distal femur and carefully tamped into position so that the graft was neither proud nor countersunk. At this point, the osteotomy was anatomically reduced using a 4.0-mm Titanium screw and a washer (Figure 6). Final hardware fixation and reduction was confirmed via intraoperative fluoroscopy (Figure 7).

Postoperative Rehabilitation and Evaluation
Following surgery, patients were placed in a short-leg splint for 14 days. After 2 weeks, the splint was removed and the ankle was placed in a controlled ankle movement (CAM) boot for the following 4 weeks. For the first 2 weeks in the CAM boot, patients were advised to perform dorsiflexion and plantarflexion exercises while remaining non-weight-bearing. At 4 weeks postoperatively, patients were instructed to increase weight-bearing activities by 10% each day so that by 6 weeks the patients were fully weight-bearing. Patients then...
began a physical therapy regimen. Weeks 1 to 4 of physical therapy consisted of stabilization and balance exercises, while weeks 5 to 10 focused on strength training and gradual return to sports-related activities. In addition, a detailed history of the patient’s progress postoperatively and a physical examination were conducted at each postoperative visit.

**Magnetic Resonance Imaging**

Magnetic resonance imaging of the ankle joint was performed on a 3 Tesla clinical imaging system (GE Healthcare, Milwaukee, WI). A musculoskeletal radiologist evaluated articular cartilage morphology at the site of the tibial osteotomy using fast-spin-echo proton density sequences. Evaluation of the interface of the osteotomy was performed by senior radiologists for all patients using the magnetic resonance observation of cartilage repair tissue (MOCART) scoring system.

Quantitative T2 mapping was performed by the same radiologist using a 16-cm field of view and $512 \times 512$ matrix (0.3 mm pixel spacing) (Figure 8). T2 relaxation...
values (average and standard deviation) were measured using a linear least-squares estimation (FuncTool 3.1; GE Healthcare, Milwaukee, WI) in a 0.2 mm² region of interest. Measurements were recorded in the deep and superficial articular cartilage over the interface of the osteotomy. For an internal control, T2 relaxation values of adjacent normal cartilage were also measured using the same 0.2-mm² region of interest. The synovial fluid and subchondral plate were excluded from the measurements. Magnetic resonance imaging was obtained postoperatively for 15 (88%) patients, at an average of 17.9 (range, 3-24) months following surgery. Two patients were unable to obtain postoperative MRI due to insurance provider restrictions.

For the description of the repair tissue, the MOCART classification system was used to analyze 9 of the 15 ankles. Nine variables describe the morphology and signal intensity of the repair tissue compared to the adjacent native cartilage. Goebel et al described how the MOCART score is broken down into a score out of 100 points giving mean point values for “defect fill,” “cartilage interface,” “surface,” “adhesions,” “structure,” “signal intensity,” “subchondral lamina,”
“subchondral bone,” and “effusion.” Total points values for individual defects ranged from 0 to 100 points reflecting poor and excellent repair, respectively. The repair was considered complete when the repair tissue appeared as thick as the adjacent native cartilage with complete integration of the margins, and a smooth articular surface that reproduced the original articular contour with no adhesions and an intact subchondral bone plate and marrow.

T2 mapping was performed on 11 of the 15 patients (73%), 6 (55%) of whom could be quantitatively analyzed without hardware susceptibility artifact. The signal intensity of the repair tissue was separately determined in fast spinecho (dual T2-FSE) and fat-suppressed gradient-echo (3DGE-FS) sequences, and a complete repair was graded as isointense if it appeared as intense as the adjacent native cartilage. With regard to T2 mapping MRI, calculated relaxation times have been related to changes in articular cartilage with respect to collagen presence and orientation.

Statistical Analysis

A signed rank test was used to compare pre- and postoperative FAOS scores. A signed rank test was also used to compare mean T2 mapping relaxation times at the interface of the osteotomy to normal cartilage in both the deep and superficial halves of the cartilage. All analyses were performed using commercially available software.

Results

Clinical and Functional Outcomes

The FAOS improved significantly from preoperative to postoperative time points from a mean of 39.2 (range, 14 to 66) out of 100 points preoperatively to a mean of 81.2 (range, 19 to 98) postoperatively ($P < .01$).

Two patients (12%) underwent subsequent hardware removal, 1 of whom reported irritation and inflammation specifically due to hardware 2 years following AOT (FAOS, 44.4 to 72.2). This patient was tender on palpation of the anterolateral joint line and was also diagnosed with anterior impingement after MRI evaluation. At the 2-year postoperative time point the hardware was removed during arthroscopic debridement of anterior impingement. The patient’s hardware-related symptoms resolved 5 weeks following the secondary procedure. The second patient who underwent hardware removal did not have pain or any symptoms specific to the hardware but had the screw removed at the time of arthroscopic debridement of anterior impingement (FAOS, 20.0 to 69.4). The hardware was removed 8 months following the index procedure and the patients symptoms improved 2 months later. A third patient reported anterolateral tenderness 1 year after surgery, which was attributed to scarring in the anterior aspect of the ankle joint (FAOS, 30.6 to 96). The patient’s symptoms were resolved after steroid injection and deep tissue massage therapy. A fourth patient reported ankle joint stiffness 6 months after surgery. Symptoms resolved following physical therapy (FAOS, 66.7 to 83.3).

Magnetic Resonance Imaging

The tibial cartilage at the site of the osteotomy was obscured by hardware susceptibility artifact in the remaining 6 ankles, thus prohibiting MOCART evaluation. Therefore, in the remaining 9 patients, the mean MOCART score was 73.9 out of 100 points (range, 40-100).

The relaxation values were not significantly different from the normal cartilage in the deep zone ($P = .31$) or the superficial zone ($P = .84$) (Table 2). Bony union was also evident in all ankles on plain radiograph and for the 15 patients that obtained postoperative MRI.

Table 2. Quantitative T2 Mapping Relaxation Values of Tibial Cartilage at the Site of the Osteotomy and Control Cartilage in 6 Patients.

<table>
<thead>
<tr>
<th>Region of Interest/Zone</th>
<th>Relaxation Value (ms) ± SD</th>
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<tbody>
<tr>
<td>Deep zone</td>
<td>32.5 ± 4.6</td>
</tr>
<tr>
<td>Superficial zone</td>
<td>38.5 ± 6.4</td>
</tr>
<tr>
<td>Control deep zone</td>
<td>35.4 ± 5.6</td>
</tr>
<tr>
<td>Control superficial zone</td>
<td>37.7 ± 4.8</td>
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</tbody>
</table>

Discussion

Success of AOT requires perpendicular access to the talar dome, which is often difficult to obtain for far lateral or posterior lesions. Obtaining perpendicular access to achieve proper graft placement is crucial because a lack of graft congruency with the surrounding host talus can result in altered mechanical joint loading. Muir et al found that on average, 20% of the lateral talar dome is inaccessible without osteotomy. However, there is concern that operative disruption of the syndesmosis may result in morbidity, including rotational instability. The results from our study demonstrate that the anterolateral tibial osteotomy is a reasonable alternative for accessing lateral or posterior lesions for AOT with limited morbidity associated with the osteotomy, strong evidence of adequate osteotomy healing, and good clinical outcomes.

The results from our study are consistent with previous reports of a tibial osteotomy for accessing lateral lesions. Sammarco and Makwana first reported the clinical results of the use of a tibial bone block for accessing lateral osteochondral lesions. In their study, they removed a tibial bone block with 5 faces and a rectangular base. The blocks were 10 mm wide, 20 mm deep, and 30 mm high and were also removed with an oscillating saw. All 12 of their patients expressed satisfaction with the procedure and had significant improvement in AOFAS scores at a mean follow-up of 25.3 months.
Kreuz et al later described the removal of a pyramidal bone block with 4 faces. In their study they found that by removing a pyramidal bone block, there were fewer saw cuts required and a smaller part of the distal tibial plafond was removed, exposing the tibial cartilage to less risk of cartilage incongruity. At 6 months follow-up, their postoperative MRI found no signs of incongruency or malunion. Postoperative MRI in our study demonstrated bony union in all ankles. We also demonstrated that there was no difference in quantitative T2 mapping values of the cartilage at the site of the tibial osteotomy compared to control region. This, along with MOCART score results, suggests that the osteotomy does not significantly disrupt tibial cartilage and that the tibial cartilage interface appears to be robust. However, the sample size must be taken into consideration.

While we did not quantify the exposure of the talar dome with the anterolateral tibial osteotomy, previous cadaveric studies demonstrate it provides sufficient access to the talar dome. Garras et al compared 5 different approaches to access the posterolateral talar dome and found that the anterolateral tibial osteotomy exposed 68.5% of the sagittal dimension of the lateral talar dome compared to 43.3% with an anterolateral arthrotomy with anterior talofibular ligament (ATFL) release and 91.2% with a lateral malleolar osteotomy with ATFL release. Muir et al reported similar results with the anterolateral arthrotomy providing access to only 36% of the sagittal dimension of the lateral talar dome and the anterolateral tibial osteotomy and lateral malleolar osteotomy exposing 62% and 100%, respectively. While the lateral malleolar osteotomy provides greater access to the talar dome, the tibialis anterior osteotomy has the advantage of obviating lateral ligament release and has less risk of rotational malunion. Peters et al demonstrated in their cadaveric study that anterolateral soft tissue exposure with plafondplasty provides sagittal access to 81% of the lateral talar dome.

One of the potential risks of the anterolateral tibial osteotomy is that the tibial cartilage is disrupted and may lead to subsequent chondral damage. To our knowledge, this is the first study to morphologically assess the tibial cartilage after an anterolateral tibial osteotomy. The similar quantitative T2 mapping relaxation values in both the superficial and deep halves of the tibial repair cartilage at the site of the osteotomy and nearby control tissue are encouraging. These results suggest that after the osteotomy, the tibial repair tissue consisted of hyaline-like infill in both the deep and superficial zones.

The presence of subchondral edema at the osteotomy site in 55.6% of ankles and damage of the surface repair tissue in nearly half of ankles (44.4%) is concerning. Subchondral edema is likely due to hydrostatic pressure forcing synovial fluid up through the osteotomy site at repair tissue and native host tissue interface. Both of the ankles that had incomplete integration of the interface between the repair tissue and native cartilage on MRI had evidence of tibial subchondral edema. This, in conjunction with damage of the surface of the repair tissue, warrants further long-term follow-up to see if subchondral pathology results in future morbidity or resolves over time.

This study has several limitations. First, our study was small and retrospective, and thus maintains the biases inherent to such a study design. Unfortunately, hardware susceptibility artifact obscured the repair tissue in several ankles limiting the number of ankles we could evaluate with MOCART and T2 mapping. In addition, it is recommended that MRI follow-up studies take place at 3 to 6 months after a cartilage repair procedure and again before the end of the first postoperative year. The first follow-up at 3 to 6 months is for the purpose of evaluating integration of repair tissue and volume of the cartilage. The next round of follow-up imaging, administered within the first year after surgery, allows for assessment of cartilage maturation. The average MRI follow-up time of 17.9 months was reported in this study. We are assessing late enough, on average, for the cartilage to be beyond the repair, integration, and maturation phases. The wide range, however, is a limitation of our study and is the result of the retrospective nature of our study. Furthermore, while we defined what symptoms were attributable to the osteotomy versus the talus, there may have been patients who had vague symptoms that were related to the osteotomy that we did not detect. Given the nature of the procedure, it was impossible to truly delineate which symptoms were results of the primary procedure versus the osteotomy. Despite these limitations, this is the first study to demonstrate that the morphological and clinical morbidities associated with the anterolateral tibial osteotomy are limited.

**Conclusion**

The results from our study demonstrate that the anterolateral tibial osteotomy provided adequate exposure of center-lateral or postero-lateral OLT for AOT with good medium-term functional results and adequate healing. Assessment of the tibial interface cartilage in both superficial and deep halves of the site of the osteotomy revealed hyaline-like infill demonstrating integration between the repair tissue and the native host tissue. Future long-term studies comparing the functional and morphological outcomes of the anterolateral tibial osteotomy directly to other techniques for accessing lateral OLT for AOT are warranted.

**Declaration of Conflicting Interests**

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Arthroscopy (ESSKA), International Society for Cartilage Repair of the Ankle (ISCRA).

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