Abstract: Osteochondral lesions of the talus (OLT) frequently occur after ankle sprain or fracture. Although there has been a growing interest in OLT treatment recently, the pathology has been recognized for hundreds of years. Yet there is a lack of consensus as to the most effective treatment strategy. Because of a lack of vasculature and the relative hypopcellularity of articular cartilage, OLT are difficult to treat. Arthroscopic bone marrow stimulation (BMS) has become a commonly used method of treating smaller, primary OLT because of technical simplicity, the advantages of minimally invasive access, and the potential to improve cartilage repair and outcomes. Results of BMS are good in the short-term with high overall success rates reported in the literature. However, the fibrocartilagenous repair tissue formed after BMS confers inferior biological and mechanical properties compared with native hyaline cartilage. Poorer outcomes have also been demonstrated in large and uncontained talus shoulder lesions. Subchondral bone comminution and thermal necrosis with drilling may be the cause for concern. There is also evidence of high rates of cracks and fissuring in fibrocartilage and inadequate integration with native hyaline cartilage postoperatively. Furthermore, there is a lack of long-term BMS outcome data available. Concerns with BMS have prompted investigation of biological adjuncts that could potentially improve the quality of BMS repair tissue and form a more hyaline-like repair. Arthroscopic BMS has much promise for the future but long-term, high-level studies are required. Enhancement of BMS with biological adjuncts and improved surgical instrumentation has the potential to improve cartilage repair and outcomes.

Level of Evidence: Diagnostic Level 5. See Instructions for Authors for a complete description of levels of evidence.

Key Words: arthroscopy, bone marrow stimulation, talus, osteochondral lesion, orthobiologics

LEARNING OBJECTIVES
After participating in this CME activity, participants should be better able to:
1. Apply the appropriate diagnostic tools for patients with a suspected osteochondral lesion of the talus to facilitate effective preoperative planning.
2. Select and implement the appropriate treatment course for osteochondral lesions of the talus based on individual patient characteristics, lesion location, and lesion size.
3. Effectively manage patient expectations regarding the outcomes of arthroscopic bone marrow stimulation and retrograde drilling.

HISTORICAL PERSPECTIVE
Osteochondral lesions of the talus (OLT), although once given little acknowledgment, are common injuries that often occur after ankle sprain or fracture. As many as 70% of sprains and fractures may result in OLT. These lesions are increasingly recognized as a consequence of improved imaging techniques and higher rates of ankle arthroscopies. The primary etiology is traumatic injury, but numerous nontraumatic causes have been reported. Repetitive microtrauma also appears to be a common cause. Although smaller lesions may respond to conservative management, some lesions in pediatric patients, OLT are thought to more often progress from small cracks and fissuring in the cartilage and subchondral plate to more substantial pathology as synovial fluid under hydrostatic pressure.

INSTRUCTIONS FOR OBTAINING AMA PRA CATEGORY 1 CREDIT™
Techniques in Foot & Ankle Surgery includes CME-certified content that is designed to meet the educational needs of its readers. This activity is available for credit through March 31, 2016.

Earn CME credit by completing a quiz about this article. You may read the article here, on the TFAS website, or in the TFAS iPad app, and then complete the quiz, answering at least 80 percent of the questions correctly to earn CME credit. The cost of the CME exam is $10. The payment covers processing and certificate fees. If you wish to submit the test by mail, send the completed quiz with a check or money order for the $10.00 processing fee to the Lippincott CME Institute, Inc., Wolters Kluwer Health, Two Commerce Square, 2001 Market Street, 3rd Floor, Philadelphia, PA 19103. Only the first entry will be considered for credit, and must be postmarked by the expiration date. Answer sheets will be graded and certificates will be mailed to each participant within 6 to 8 weeks of participation.

Need CME STAT? Visit http://cme.lww.com for immediate results, other CME activities, and your personalized CME planner tool.

Accreditation Statement
Lippincott Continuing Medical Education Institute, Inc. is accredited by the Accreditation Council for Continuing Medical Education to provide continuing medical education for physicians.

Credit Designation Statement
Lippincott Continuing Medical Education Institute, Inc., designates this journal-based CME activity for a maximum of 1 (one) AMA PRA Category 1 Credit™. Physicians should only claim credit commensurate with the extent of their participation in the activity.

Address correspondence and reprint requests to John G. Kennedy, MD, FRCS (Orth), Department of Foot and Ankle Surgery, Hospital for Special Surgery, East River Professional Building, 523 East 72nd Street, New York, NY 10021. E-mail: KennedyJ@hss.edu.

Copyright © 2015 Wolters Kluwer Health, Inc. All rights reserved.
pressure invades the tissues. Pain likely onsets with repetitive pressure under weight-bearing due to sensitization of the highly innervated subchondral bone. This presents a challenging problem to orthopedic surgeons as the avascular status of cartilage results in rare occurrence of spontaneous healing; leaving OLT susceptible to gradual degradation and the potential for osteoarthritis to ensue over time.

Improved understanding of osteochondral lesions and cartilage biology seems to have stimulated abrupt interest in treating the pathology, however, Alexander Monroe described the first osteochondral loose body in the ankle joint in 1737 and reports of physicians attempting to treat damaged articular cartilage date back over 250 years. As a variety of surgical procedures have been developed including debridement and curettage, arthroscopic bone marrow stimulation (BMS; including microfracture and microdrilling), autologous matrix-induced chondrogenesis, autologous chondrocyte implantation, particulated juvenile allograft cartilage, osteochondral allograft, and autologous osteochondral transplantation (AOT), among other strategies.

Arthroscopic BMS remains the one of the most commonly employed treatment strategies. It is typically considered the standard first-line treatment for unstable OLT, or after conservative therapies have failed, and is reserved for small, non-cystic lesions. Microfracture was first described in the knee by Steadman and colleagues and the procedure has gained widespread popularity since. The popularity of BMS, particularly microfracture, has likely been maintained because of marginal technical demand, low complication rates, access via the fibrocartilagenous repair tissue formed after BMS to withstand physiological stresses. Fibrocartilage has been demonstrated to confer inferior mechanical and biological properties compared with hyaline cartilage. This has generated concern with long-term clinical outcomes and investigation of the use of biological adjuncts aimed at improving the quality of repair tissue.

Still, BMS remains a viable first-line treatment, and the success of the procedure lies after precise indications, thorough preoperative planning, and meticulous technique. This article outlines preoperative planning for OLT, describes BMS surgical technique and postoperative management, and discusses the most recent evidence regarding outcomes, future directions for treatment, and use of biological adjuncts.

INDICATIONS AND CONTRAINDICATIONS

Asymptomatic or mildly symptomatic OLT that solely involve the articular surface should be managed with rest, ice, compression, and elevation. Appropriate physical therapy and orthotics can also be beneficial. Injection of corticosteroid, hyaluronic acid (HA), or platelet-rich plasma (PRP) can also be considered. However, high failure rates with nonoperative management have been reported so patients should be counseled accordingly. Arthroscopic BMS is indicated after conservative strategies have failed for primary, noncystic OLT that are smaller than 150 mm². For larger OLT or lesions with large subchondral cysts, replacement strategies are indicated. In the case of lesions that exclusively involve the subchondral bone with intact cartilage overlying the lesion, retrograde drilling should be carefully considered.

Contraindications include those for any arthroscopic procedure. Reduced joint space, limited range of motion, severe edema, degenerative joint disease, and questionable vascular status are relative contraindications. Absolute contraindications are infection (ie, septic arthritis) and severe degenerative joint disease. Again, the choice of surgical treatment strategy is dictated by lesion size. Arthroscopic BMS is contraindicated for lesions >150 mm² and lesions with large cysts or diffuse subchondral edema. To the author’s knowledge, there are no studies that have specifically investigated the effect of lesion depth on functional or radiographic outcomes. This is an important area of future investigations that could elucidate the prognostic factors and indications for BMS.

PREOPERATIVE PLANNING

Patients often present with deep ankle pain and tenderness along the anterior joint line with palpation. There is typically associated swelling. Clicking or a sense of locking within the ankle joint is also commonly reported in patients with OLT. Ankle inversion injury is a common etiology. Anterior drawer laxity, ankle inversion strength, elicitation of pain with inversion, and tenderness of the peroneal tendons on palpation are therefore crucial to assess. Pathology of lateral anatomic structures may need to be treated at the time of BMS. Joint

FIGURE 1. Preoperative coronal fast spin-echo proton density magnetic resonance imaging of an osteochondral lesion of the medial talus [(A); yellow arrow] and T2-weighted fat-suppressed magnetic resonance image of the same lesion [(B); yellow arrow].

42 | www.techfootankle.com Copyright © 2015 Wolters Kluwer Health, Inc. All rights reserved.
alignment must also be examined. Malalignments should be concomitantly corrected at the time of surgery. Imaging is the most essential aspect of preoperative planning when treating OLT. Plain radiographs may miss up to 50% of OLT so additional imaging must be used when osteochondral injury is suspected. Magnetic resonance imaging (MRI) is the preferred modality as it has the capacity to evaluate articular cartilage morphology and microstructure (Fig. 1). It is sensitive enough to determine changes in collagen orientation associated with degradation and is valuable for distinguishing between native cartilage and repair tissue (including fibrocartilage). This modality is also useful for assessing the extent of subchondral pathology, particularly edema, and concomitant extra-articular soft-tissue injury. Widely accepted cartilage MRI protocols include standard 2-dimensional multislice turbo or fast spin-echo proton density and fat-suppressed proton density sequences acquired in multiple planes. T2 mapping MRI sequencing can provide quantification of collagen architecture and biochemical status of cartilage when further assessment is required. Computed tomography (CT), although unable to capture the articular surface, may provide a more exact measure of lesion size. This modality is particularly useful for assessing subchondral bone involvement (Fig. 2). CT also provides further detail of loose osteochondral fragments.

Once the lesion has been diagnosed and BMS has been selected as the treatment option, surgical planning is based on lesion location. Most lesions can be accessed using standard anterior arthroscopic portals. Plantar flexion with soft-tissue distraction is recommended as it improves access to the joint. Invasive distraction is best avoided as complication rates may be up to 13.6%. Furthermore, approximately 48% of the talar dome is located anterior to the anterior distal tibial rim in patients with normal plantar flexion range. Lesions beyond the anterior distal tibial rim can be accessed with arthroscopic instrumentation. In the current authors’ experience, the anterior 75% of the talar dome can be accessed with arthroscopic portals. If access to the lesion proves difficult, a posterolateral working portal can be employed. Posterior arthroscopy can be utilized for lesions located in the most posterior aspect of the talus. A number of posterior approaches have been described, but the original 2-portal posterior approach has been demonstrated to provide safe, adequate access. Posterior arthroscopy provides the ability to treat not only posterior OLT but also other hindfoot, posterior ankle, subtalar joint, and extra-articular pathologies with good functional results.

Retrograde drilling should be considered when MRI indicates an intact articular surface overlying a subchondral lesion. The state of the articular cartilage can be confirmed arthroscopically. The cartilage should be probed to verify that the tissue is not uncharacteristically ballotable or fissured. Probing may also reveal delaminated cartilage when present.

**TECHNIQUE**

**Arthroscopic BMS**

The patient is placed supine on the operating table under general or spinal anesthesia and prepped and draped in the usual manner. A noninvasive soft-tissue distractor is fastened to the operating table and ankle with the joint in plantar flexion (Fig. 3). This expands the joint space and improves access. Fifteen pounds of distraction force is appropriate. When an anterior approach has been selected, an anterolateral portal is placed 5 mm distal to the joint line lateral to the peroneus tertius tendon. Care must be taken to avoid the superficial peroneal nerve, which can be palpated or visualized with the fourth toe in maximum plantar flexion. The anteromedial portal is placed 5 mm distal to the...
joint line just medial to the tibialis anterior tendon. A limited portion of the anterior distal tibial margin can be removed with a burr to improve access when necessary. Soft-tissue or scar tissue resection may also be required for proper visualization. Any other concomitant intra-articular procedures, including synovectomy, should be performed before BMS to avoid disrupting the clot with irrigation. The joint is then inspected using the 21-point systematic Ferkel evaluation. Once the lesion has been indentified, a curette is used to remove degenerated tissue until a vertical, stable rim of healthy cartilage has been created (Fig. 4). All delaminated cartilage should also be removed. A shaver is often useful for debridement as well. If a subchondral cyst is present, all degenerated bone and cystic lining is debrided. These steps are critical as results of second-look arthroscopy reported by Takao et al demonstrated improved repair when degenerative cartilage was removed before BMS. The calcified cartilage layer is also removed with a curette to facilitate clot adhesion and repair. The subchondral bone is then breached to a depth of 2 to 4 mm perpendicular to the surface using Kirschner wire drilling or a microfracture awl (Fig. 5). This promotes subchondral bleeding and recruitment of mesenchymal stem cells from the underlying marrow. Gaps of 3 to 4 mm are left between each breach. Surgeons must ensure that BMS is performed at the periphery of the defect to improve integration. Final lavage and arthroscopic evaluation is performed to ensure that no loose bodies are left within the joint. If a tourniquet is used, deflate it at this time to confirm the presence of fat droplets or bone marrow emerging from each BMS breach.

If a posterior approach has been selected, the patient is placed in the prone position with the ankle overhanging the end of the operating table. Alternatively, a triangular cushion can be placed at the end of the table under the distal tibia. To accurately place arthroscopic portals, a line parallel to the sole of the foot is drawn from the tip of the lateral malleolus to the tip of the medial malleolus with the ankle in neutral position. The posterolateral portal is placed 5 mm anterior to the lateral border of the Achilles tendon just proximal to the previously drawn line. The posteromedial portal is placed just proximal to the drawn line, 5 mm anterior to the medial border of the Achilles tendon (Fig. 6). Care must be taken to avoid the sural nerve and medial neurovascular bundle when creating the posterolateral and posteromedial portals, respectively. A systematic 4-quadrant approach is then used to sequentially address any associated hindfoot pathologies, with intra-articular injuries addressed during the final stage of the procedure. Adequate visualization and posterior OLT access can

FIGURE 4. Arthroscopic images depicting the identification and debridement of the medial osteochondral lesion of the talus shown in Figure 1. The lesion was identified and probed (A), revealing an unstable osteochondral fragment (B). The lesion was the debrided with a curette and graspers to establish a rim of stable cartilage (C).

FIGURE 5. Arthroscopic images of the medial osteochondral lesion of the talus depicted in Figures 1 and 4. Bone marrow stimulation within the debrided defect was performed using a microfracture awl.
typically be achieved with manual ankle dorsiflexion. BMS is then performed as described above.

**Retrograde Drilling**

If an intact articular surface overlying the lesion has been confirmed using standard anterior diagnostic arthroscopy, as described above, then retrograde drilling is warranted.\(^35,36,48\) The patient is placed supine on the operating table with noninvasive soft-tissue distraction in the standard manner. Multiplane preoperative imaging should be used to precisely locate the lesion and the location should be confirmed arthroscopically. In the case of medial lesions, a 1 cm lateral incision is made over the area of the sinus tarsi at the nonarticular junction between the neck and body of the talus as per the technique described by Taranow et al.\(^35\) The lateral process of the talus is accessed via blunt dissection to the lateral cortex, minding the peroneal tendons. A small-joint drill guide (Smith and Nephew, PLC) is then placed through the anteromedial arthroscopy portal over the OLT. Arthroscopic guidance is maintained through the anterolateral portal to ensure that the articular surface is not breached during drilling. A long 6.2-mm Kirschner guidewire directed at the lesion is then introduced into the talar body through the lateral process and gradually advanced to the center of the bony defect under fluoroscopic guidance. The guide is removed after drilling to a depth of 1 to 2 cm. Obtain images in both anteroposterior and lateral planes. It is imperative not to penetrate the articular surface with the guidewire. Under fluoroscopic guidance, a cannulated drill is introduced over the guidewire. The authors use a 4-mm cannulated, acorn-tipped tenodesis drill (Arthrex Inc.). After removing the drill and guidewire, the drill hole is debrided with an angled curette, ensuring that the entire lesion cavity and cystic lining are removed (Fig. 7). Loose debris should also be cleared away. Filling the lesion with autogenous bone graft has been previously described,\(^35\) but it is often difficult to fill the areas of the lesion that are not in direct alignment with the drill hole without aggressive packing and risk of further cartilage damage.\(^48\) Therefore, the current authors utilize an injectable calcium sulfate bone graft substitute (Wright Medical Technology Inc.). The graft substitute is hydrated, injected as a smooth paste, and then hardens to the strength of cancellous bone in approximately 5 minutes. This has the advantage of filling and entire defect while obviating the need to aggressively tamp or pack a graft. Gradual resorption and cancellous bone substitution occurs over a period of 8 weeks.\(^36,48,49\) When utilizing this method, the defect is gradually filled with injectable graft until the articular cartilage is noted to protrude very slightly on arthroscopic visualization. Allow the drill tract to fill with graft as the syringe is slowly removed from through the lateral incision. The graft can be observed fluoroscopically after delivery. Excess graft must be removed from the drill portal before wound closure.

Lateral lesions with an intact articular surface are reportedly uncommon,\(^50\) however, when lesions of this nature are encountered, a slightly different approach is recommended. Using the same general technique, guidewire placement and drilling should originate anteromedially from the junction of superior border of the spring ligament and the inferior border of the deltoid.\(^48\) Posterolateral and posteromedial lesions are particularly difficult to triangulate for retrograde drilling. Guidewire placement for posteroMedial and posterolateral lesions begins from the same...
incision points as described above for medial and lateral lesions, respectively. The drill guide and guidewire are simply directed posteriorly. Because triangulation may be difficult, thorough use of preoperative imaging and intraoperative fluoroscopy in multiple planes should be emphasized.9,48

RESULTS

Arthroscopic BMS
The objective of creating multiple breaches in the subchondral plate is to form channels for the flow of bone marrow from the underlying bone. Pluripotent mesenchymal stem cells present in the marrow coagulate and form a fibrin clot in the defect which initiates an inflammatory response, subsequent release of cytokines and growth factors, and stimulation of tissue healing.9,27 The expectation is that the mesenchymal stem cells differentiate chondrocyte-like cells and synthesize proteoglycan matrix and type II collagen-based repair tissue.14,28,51 There is, however, evidence that a gradual shift to type I collagen-based fibrocartilage occurs after 1 year as a result of continuous surface fibrillation, proteoglycan depletion, and chondrocyte death.14,28,52

In terms of clinical translation, outcomes of BMS are good in the short-to-midterm. Saxena and Eakin2 demonstrated significant improvements in American Orthopaedic Foot and Ankle Society Ankle-Hindfoot (AOFAS) scores in an athletic population with 96% return to sport at a mean of 15.1 weeks. Lee et al53 have also reported significantly improved AOFAS scores at a mean of 33-month follow-up. Furthermore, a recent systematic review found that the overall success rate of BMS was 85%.54 However, there is a profound lack of long-term data. To the author’s knowledge there is only 1 report of long-term outcomes in the literature. van Bergen and colleagues evaluated the results of BMS in 50 patients with a mean 12-year follow-up (range, 8 to 20 y).55 The median AOFAS score was 88 at final follow-up with 78% good to excellent Ogilvie-Harris scores. Eighty-eight percent of patients resumed sports and 94% resumed work. Sixty-seven percent of radiographs showed no progression of osteoarthritis compared with the preoperative grading and 33% showed progression by 1 grade. In addition, there is only 1 quasi-randomized comparative study assessing outcomes of several cartilage repair techniques.56 Gobbi and colleagues prospectively compared cartilage healing, microfracture, and AOT. Numeric pain intensity, subjective assessment numeric evaluation rating, AOFAS scores, and MRI outcomes were compared between techniques. At 52-month follow-up, there was no significant difference in outcomes between treatment groups. Incomplete infill and edema were prevalent after chondroplasty and microfracture on MRI. It is important to note, however, that there were only 11, 10, and 12 ankles included for chondroplasty, microfracture, and AOT, respectively, and that selection bias prevented the study from being considered truly randomized.56 Not only is there a general lack of long-term and high-level evidence, but there are a number of flaws in the data that are currently available. A systematic review of outcome data reporting after microfracture by Hannon et al67 found that while general demographic information and study design variables were well described in 96% of studies, 23 different outcome scoring systems were used across the 24 reviewed studies. This study highlighted the difficulty in interpreting BMS results in the literature. The review also found that lesion size, which has been demonstrated as a key indicator of outcome,24,25 was only reported in 46% of studies. Only 75% of studies reported follow-up imaging with at least 1 modality. MRI was reported in 54% and CT was not reported at follow-up in any study.57 Arthroscopic BMS appears to provide symptomatic relief and return to sport in the short-to-midterm, however, long-term results have yet to be determined. Other cartilage repair procedures must be compared with BMS in high-level studies to determine the most effective treatment algorithm for OLT.

Retrograde Drilling
Retrograde drilling was first described in the knee as an open procedure but good results have also been reported in the ankle.5,35,58,59 Taranow et al55 described results in 16 patients with medial OLT that underwent drilling through the sinus tarsi. At mean 24-month follow-up there were no complications and AOFAS scores increased from 53.9 to 82.6. Eighty-one percent of patients were satisfied with the procedure. Kono and colleagues compared 1 year postoperative second-look arthroscopic findings of 19 patients that underwent trasmalleolar drilling to 11 patients that underwent retrograde drilling. All lesions in the transmalleolar group were either unchanged in grade (58%) or deteriorated 1 grade (42%).59 Grading in the retrograde drilling group was significantly favorable ($P < 0.0001$); all lesions improved by 1 grade (27%) or were unchanged in grade (73%). Hyer et al60 later reported AOFAS and Short-Form 12 (SF-12) scores at mean 24-month follow-up in 7 patients. AOFAS and SF-12 physical component scores increased a mean 34 and 8.2 points, respectively. Maintaining the integrity of the articular surface may prove beneficial, but more data are required before the results of this procedure can be weighed against other surgical strategies.

Biological Adjuncts
Despite cost-effective, technically undemanding pain relief with BMS, concerns remain over the biological and mechanical quality of the fibrocartilage repair tissue formed after BMS. Specifically, Lee et al61 have demonstrated that only 30% or repair tissue was integrated with surrounding cartilage on second-look arthroscopy 12 months after BMS. MRI analysis 5 years after BMS by Becher et al13 indicated that 100% of lesions had cracks and fissuring in the repair tissue. The deterioration of fibrocartilage appears to be associated with outcome as Ferkel et al15 found deterioration in outcome scores in 35% of patients 5 years postoperatively. As a result, there has been growing interest in the use of biological adjuncts to improve the quality of fibrocartilage repair tissue and generate a more hyaline-like repair.

Concentrated bone marrow aspirate (CBMA) harvested from the iliac crest, or several other anatomic locations, has been proposed as a 1-step source of autologous mesenchymal stem cells and growth factors that can be applied during BMS procedures. Fortier et al62 compared the results of BMS with CBMA to BMS alone for repair of full-thickness cartilage defects in an equine model. Macroscopic and histologic assessment 8 months postoperatively demonstrated significantly higher scores with increased collagen type II and glycosaminoglycan content in the BMS with CBMA group compared with BMS alone. MRI analysis revealed increased infill and integration in the CBMA group. Unfortunately, there is limited clinical evidence for CBMA as an adjunct to BMS. However, Kennedy and Murawski23 applied CBMA to 72 AOTs. Although there was no control group without CBMA treatment, Foot and Ankle Outcome Scores and SF-12 scores had significantly improved at 28-month follow-up. Giannini et al17 applied concentrated bone marrow–derived cells to either a collagen powder or HA membrane as a 1-step repair in a prospective study of 48 patients. Significant
improvements in AOFAS scores were seen, however, repair tissue was not completely hyaline-like histologically. Clinical studies comparing the BMS with CBMA to BMS alone are required before any conclusions regarding the efficacy of the adjunct can be made.

PRP is an autologous blood product formed by centrifugation of whole blood to separate out fractional elements. The goal is to achieve a 2-fold or more increase in platelet concentration above baseline serum levels. Platelets and their associated growth factors have the theoretical capacity to improve cartilage repair. Chemotactic, anti-inflammatory, and anti-catabolic effects are proposed mechanisms of action. Growth factors associated with PRP that are postulated to contribute to cartilage healing include the transforming growth factor-β superfamily, fibroblast growth factor, epidermal growth factor, and vascular endothelial-derived growth factor. The role of PRP in cartilage repair has been well evidenced in in-vitro and in-vivo animal models but clinical evidence is limited. Mei-Dan et al performed a well-designed evidenced in in-vitro and in-vivo animal models but clinical evidence is limited. Mei-Dan et al performed a well-designed comparison of 3 PRP versus 3 HA injections for nonoperative treatment of OLT. Both HA and PRP injection increased AOFAS scores and decreased pain scores significantly. Significantly greater improvements were seen in the PRP group 28 weeks after injection. Guney et al recently investigated PRP as an adjunct to BMS for OLT in 19 patients and compared results to 16 patients that underwent BMS alone. Baseline AOFAS and Foot and Ankle Ability Measures were equivalent between groups at baseline but pain scores were higher in the PRP group. At an average of 16.2 months postoperatively, all outcome scales favored combined BMS and PRP intervention over BMS alone. Basic science data and early clinical results have warranted further, high-level investigation of PRP as an adjunct to cartilage repair. More generally, further investigation is required to determine to most effective combination of stem cells and growth factors that contribute to cartilage repair. Studies characterizing the content of both CBMA and PRP are also needed to optimize centrifugation protocols and so that the 2 adjuncts can be compared.

Although PRP was demonstrated to be more effective than HA by Mei-Dan et al, significant improvements in pain and functional scores were also demonstrated with HA. HA is a polysaccharide component found in synovial fluid commonly utilized as an off-the-shelf viscoelastic supplement. In addition to conferring viscoelastic properties and joint lubrication, HA may contribute to chondrocyte proliferation and act as a transmission buffer to nociception. A number of studies have reported good results with HA for knee and subtalar osteoarthritis, but little evidence remains for specifically for its use in the treatment OLT. A level 1 randomized control trial by Doral et al compared 41 patients that underwent BMS and postoperative HA injection to 16 patients that underwent BMS alone for OLT. Freiburg functional and pain and AOFAS scores improved significantly in each group, but significantly greater improvements were found in the HA injection group. Additional studies are needed to determine the efficacy of HA as a conservative treatment for OLT, as an adjunct for BMS, and to compare the efficacy of HA to other available adjuncts.

**COMPLICATIONS**

Complications of BMS include those for any arthroscopic procedure. Nerve injury, vascular injury, infection, and synovial fistula have all been described. Nerve injury is most commonly reported (1.9%), but most complications resolve within 6 months and do not lead to functional limitations. Overall complication rate appears to be as low as 3.5% with noninvasive distraction. Complications with posterior arthroscopy have been described as low as 2.3%, considerably lower than the 24% rate seen with open posterior procedures. Scrupulous surgical technique will contribute to minimizing these complications. A potential complication with BMS specifically is the creation of loose bony particles that may act as loose bodies after operation. Again, concluding the procedure with final arthroscopic joint inspection and lavage are recommended to avoid this issue.

**POSTOPERATIVE MANAGEMENT**

After arthroscopic BMS, the authors recommend that the patient is placed in a soft leg splint for 14 days. Dorsiflexion and plantar flexion ankle pump exercises should begin 72 hours postoperatively and continue for 4 weeks. A 20-degree arc of motion is permitted initially (10 degrees of dorsiflexion and 10 degrees of plantar flexion). Once 20-degree arc of motion ankle pumps can be performed without pain, the arc of motion is increased to the highest range that can be achieved without pain. Twenty minutes of ankle pumps each day prevent stiffness and scarring of the joint and facilitate nutrient supply to the cartilage from synovial fluid. After 2 weeks, the patient is transitioned to a controlled ankle movement walker boot. The boot is set to allow 20 degrees of plantar flexion and 20 degrees of dorsiflexion. The patient is instructed to begin bearing 10% of their weight 4 weeks postoperatively, increasing weight-bearing by 10% each day until achieving full weight-bearing at approximately 6 weeks after surgery.

After retrograde drilling, the patient should be non–weight-bearing for the first 2 weeks. The second 2 weeks consist of partial weight-bearing with active and passive range-of-motion exercises. The patient is allowed unrestricted ambulation 1 month postoperatively.

Formal physical therapy begins at 6 weeks. Rehabilitation should focus on reestablishing balance, proprioception, and stabilization. The focus is shifted to strengthening and sports specific
training at the 10-week time point. Return to full-contact sport must be continually assessed as symptoms improve.

Ideally, postoperative MRI should be obtained between 3 and 6 months after surgery to evaluate repair tissue integration and infill volume (Fig. 8). A second round of MRI should be obtained before the end of the first postoperative year to assess cartilage maturation.69

POSSIBLE CONCERNS AND FUTURE OF THE TECHNIQUE

Concerns with BMS lie in the questionable durability of fibrocartilage repair tissue and the poorer outcomes seen with larger lesions.24,25 Poorer outcomes are also associated with uncontainted lesions—lesions on the talar shoulder that are not encompassed by a rim of stable, healthy cartilage.70 Despite an overall 85% success rate, surgeons must be aware of the limitations of BMS.54 Evidence suggests deterioration of fibrocartilage repair tissue over time with gradual decline in clinical outcomes.13–15,28,61 A lack of high-quality data and long-term evidence may also be the cause for concern. There are also concerns over the effect of BMS instrumentation on subchondral bone architecture. Use of a microfracture awl may result in compaction of the bone around the perimeter of the hole, potentially causing blockage of porous trabecular channels that would allow inflow of bone marrow and preventing neo-vascularization of the bone.71 Drilling, conversely, may avoid compaction of the bone but concerns with inducing thermal necrosis have discouraged implementation of the technique.

Arthroscopic BMS and retrograde drilling should continue to be employed due cost-effectiveness, technical simplicity, minimal invasion, and short-to-midterm symptomatic relief and return to function. A crucial advantage of BMS as an index procedure is that secondary cartilage repair, particularly replacement procedures, can still be subsequently performed. The effect of prior BMS on other cartilage repair procedures remains to be determined, however. Biological adjuncts have the potential to improve repair tissue integrity and, in turn, improve patient outcomes. The ideal combination of growth factors, stem cells, and/or scaffolds that result in hyaline-like repair could alter the indications and results of BMS, but major gaps in knowledge need to be addressed before appropriate clinical applications can be recommended. There is a general lack of consensus in the literature as to which adjuncts are most effective, the specific formulations of each adjunct that should be utilized, the number of treatments needed to achieve optimal results, and the ideal chronology of adjunctive treatments. Understanding of feedback loops, log dose-response curves, and centrifugation protocols for blood-based/marrow-based adjuncts is also unclear. Discerning the most effective instrumentation to stimulate migration of mesenchymal stem cells without causing excessive iatrogenic damage could feasibly improve BMS outcomes as well. Finally, postoperative protocols and physical therapy programs after cartilage repair lack standardization. Future research should focus on refining these protocols. The best protocols will likely have the flexibility to be specifically tailored to each individual patient.

There is much room for improvement in BMS; however, the future of the procedure is promising. Further research regarding biological adjuncts, improved instrumentation, and diligent rehabilitation will provide key understanding for improving cartilage repair.

REFERENCES


CME QUESTIONS

1. A 22 year old male basketball player presents with a sense of “locking” and deep pain in the medial aspect of the ankle joint. The patient has a history of recurrent ankle inversion injury. Plain radiograph standard views from an outside institution have ruled out fracture or other notable acute injury. What is the recommended diagnostic modality?
   A. Ultrasound of the medial ankle
   B. Plain radiograph stress views
   C. Magnetic resonance imaging
   D. Single-photon emission computed tomography (SPECT)

2. Which of the following scenarios meets the indications for treatment with arthroscopic bone marrow stimulation?
   A. The patient has failed conservative treatment for a non-cystic osteochondral lesion of the talus smaller than 125 mm²
   B. The patient has failed conservative treatment for a non-cystic osteochondral lesion of the talus larger than 175 mm²
   C. The patient has not undergone conservative treatment but has been diagnosed with an osteochondral lesion of the talus that is cystic
   D. The patient has failed conservative treatment for a non-cystic osteochondral lesion of the talus that is 100 mm² with intact cartilage overlying the lesion

3. A 25 year-old female soccer player presents with deep ankle pain and “clicking” in the lateral aspect of her ankle. Magnetic resonance imaging indicates an osteochondral lesion measuring 90 mm² located in the lateral corner of the posterior 25% of the talus. Both bone and cartilage are involved. Prior conservative treatment options have failed. Which of the following is most appropriate approach for repairing this lesion?
   A. Autologous osteochondral transplantation via lateral malleolar osteotomy
   B. Bone marrow stimulation via anterior arthroscopic portals with plantar flexion and soft tissue distraction
   C. Bone marrow stimulation via 2-portal posterior arthroscopy and manual ankle dorsiflexion
   D. Retrograde drilling under arthroscopic guidance

4. A 50 year old male presents with dull pain in the medial aspect of the ankle joint that has been hindering his activities of daily living. Conservative treatment options have failed. Magnetic resonance imaging indicates a centromedial lesion of the talus with intact articular cartilage overlying a bony defect. Which step(s) should be employed before proceeding with retrograde drilling?
   A. Plain radiograph oblique views should be utilized to further assess the lesion
   B. Intraoperative fluoroscopy should be utilized to further assess the lesion
   C. Single-photon emission computed tomography (SPECT) should be utilized to further assess the lesion
   D. Probing of the lesion under arthroscopic visualization should be utilized to further assess the lesion

5. A 45 year old female patient has recently undergone arthroscopic bone marrow stimulation for an osteochondral lesion of the lateral talus measuring 80 mm². Which of the following is the most accurate representation evidence available in the literature regarding this patient’s outcome?
   A. There are few studies reporting short-to-midterm outcomes of arthroscopic bone marrow stimulation
   B. Numerous studies indicate good outcomes in the short-to-midterm, but there is little long-term evidence
   C. Numerous studies indicate that pain relief and integrity of the repair tissue will be sustained in the long-term
   D. This lesion was too large for bone marrow stimulation, and is not likely to result in a good short-to-midterm outcome
ANSWER SHEET FOR TECHNIQUES IN FOOT & ANKLE SURGERY
CME PROGRAM EXAM
March 2015

Please answer the questions on page 51 by filling in the appropriate circles on the answer sheet below. Please mark the one best answer and fill in the circle until the letter is no longer visible. To process your exam, you must also provide the following information:
Name (please print): __________________________
City/State/Zip: ________________________________
Daytime Phone: ________________________________
Specialty: ____________________________________

1. [ ] 2. [ ] 3. [ ] 4. [ ] 5. [ ]
6. [ ] 7. [ ] 8. [ ] 9. [ ] 10. [ ]

Your completion of this activity includes evaluating it. Please respond to the following questions below.

Please rate these activities (1 = minimally, 5 = completely)
This activity was effective in meeting the educational objectives
This activity was appropriately evidence-based
This activity was relevant to my practice

Please rate your ability to achieve the following objectives,
both before this activity and after it: 1 (minimally) to 5 (completely)
Pre Post
Apply the appropriate diagnostic tools for patients with a suspected osteochondral lesion of the talus to facilitate effective preoperative planning.
Select and implement the appropriate treatment course for osteochondral lesions of the talus based on individual patient characteristics, lesion location, and lesion size.
Effectively manage patient expectations regarding the outcomes of arthroscopic bone marrow stimulation and retrograde drilling.

How many of your patients are likely to be impacted by what you learned from this activity?
[ ] <20% [ ] 20-40% [ ] 40-60% [ ] 60-80% [ ] >80%

Do you expect that these activities will help you improve your skill or judgment within the next 6 months? (1 = definitely will not change, 5 = definitely will change)

How will you apply what you learned from these activities (mark all that apply):
In diagnosing patients [ ]
In monitoring patients [ ]
In educating students and colleagues [ ]
As part of a quality or performance improvement project [ ]
For maintenance of board certification [ ]
For maintenance of licensure [ ]

Please list at least one strategy you learned from this activity that you will apply in practice:

[ ] Yes! I am interested in receiving future CME programs from Lippincott CME Institute! (Please place a check mark in the box)

Mail the completed Answer Sheet and a check or money order for the $10 processing fee by March 31, 2016 to:
Lippincott CME Institute, Inc.
Wolters Kluwer Health
Two Commerce Square
2001 Market Street, 3rd Floor
Philadelphia, PA 19103