Current Concepts in the Diagnosis and Treatment of Osteochondral Lesions of the Ankle

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Osteochondral lesions of the ankle are a more common source of ankle pain than previously recognized. Although the exact pathophysiology of the condition has not been clearly established, it is likely that a variety of etiological factors play a role, with trauma, typically from ankle sprains, being the most common. Technological advancements in ankle arthroscopy and radiologic imaging, most importantly magnetic resonance imaging, have improved diagnostic capabilities for detecting osteochondral lesions of the ankle. Moreover, these technologies have allowed for the development of more sophisticated classification systems that may, in due course, direct specific future treatment strategies. Nonoperative treatment yields best results when employed in select pediatric and adolescent patients with osteochondritis dissecans. However, operative treatment, which is dependent on the size and site of the lesion, as well as the presence or absence of cartilage damage, is frequently warranted in both children and adults with osteochondral lesions. Arthroscopic microdrilling, micropicking, and open procedures, such as osteochondral autograft transfer system and matrix-induced autologous chondrocyte implantation, are frequently employed. The purpose of this article is to review the history, etiology, and classification systems for osteochondral lesions of the ankle, as well as to describe current approaches to diagnosis and management.

Keywords: osteochondral defects; osteochondral lesions; osteochondritis dissecans; foot and ankle surgery; arthroscopy
degenerative joint disease, joint malalignment, and genetic predisposition. Konig hypothesized that vascular occlusion of subchondral bone leads to a process of local inflammation and development of a subchondral cyst. Although such a sequence may be specific to osteochondritis dissecans, the most widely accepted cause of OCLs of the ankle is trauma, usually in the form of ankle sprains. In a seminal study, Berndt and Harty reproduced the mechanism of injury for both lateral and medial talus dome OCLs. It was proposed that lateral injuries occur in inversion and dorsiflexion of the ankle, while posteromedial injuries are the result of ankle plantar flexion and inversion. Flick and Gould studied more than 500 patients with OCLs and found that 98% of lateral dome lesions and 70% of medial dome lesions were associated with a history of trauma.

In several series, however, a significant percentage of patients with OCLs reported no trauma, lending support for the role of genetic, metabolic, or endocrine causes. Mubarak and Carroll described an autosomal dominant inheritance pattern in some osteochondritis dissecans patients characterized by endocrine dysfunction and collagen and epiphyseal abnormalities. Other authors have cited a high incidence of familial inheritance or populations of patients with OCLs in multiple joints. Trias et al noted significant rates of hypothyroidism in a series of OCL patients. Although most patients with OCLs have a history of trauma, in some instances analysis of laboratory values related to endocrine and metabolic bone disorders, such as serum vitamin D, calcium, phosphorus, and parathyroid hormone, may be indicated, particularly in patients with bilateral or polyarticular disease or those with a family history of the condition.

**CLASSIFICATION**

In 1959, Berndt and Hardy established a 4-stage classification system of ankle OCLs based on the severity of the lesion on plain radiographs (Figure 1). This was based on a thorough review of the literature pertaining to “transchondral fractures of the talus” from 1856 through 1956 combined with their own data from reproduction of transchondral fractures in 15 cadaveric specimens. Their classification was subsequently modified by Loomer et al to include a fifth subtype of radiolucent, cystic lesions, as seen on CT scans. The principal advantage of the Berndt and Hardy system is its widespread use and simplicity. However, in 1 prospective study of 92 patients, 50% of OCLs were not detected on plain radiographs. Moreover, the system is largely based on lesions with a traumatic origin, and does not differentiate or incorporate the spectrum of de novo lesions. As newer imaging technologies have emerged, a variety of additional classification systems have been proposed (Table 1). Taranow et al used MRI to describe the condition of both the cartilage and subchondral bone by employing the classic 4-stage grading to the bony component while describing the cartilage to be either viable and intact (grade A) or nonviable (grade B). The MRI-based system by Hepple et al is based on the original Berndt and Harty classification, but uncouples traumatic, cystic, and idiopathic etiologies of OCLs. Mintz et al established a correlation between MRI and arthroscopic findings. Because of the large degree of signal change that can arise secondary to edema after even mild ankle injuries, some authors believe MRI may overdiagnose or overestimate the extent of OCLs, and they urge caution in the use of these classification systems.

Alternative classification systems using arthroscopic findings have emerged as well. Pritsch et al graded talar OCLs based on cartilage quality, as seen on arthroscopic visualization. Cheng et al (unpublished data, 1995) used arthroscopy to describe the condition of the talar cartilage, ranging from smooth, soft, and ballotable cartilage (stage A) to increasingly rough and fibrillated or fissured cartilage to a more unstable lesion culminating in a loose, displaced fragment (stage F). The disadvantage of an arthroscopic classification system is that it focuses on the cartilage insult and is unable to consider the underlying bony component of the lesion.

**DIAGNOSIS**

**Clinical Presentation**

Osteochondral lesions of the ankle are being recognized as an increasingly common injury that may occur in up to 50% of acute ankle sprains and fractures. Advances in imaging techniques and an increasing number of ankle arthroscopies being performed each year, in conjunction with participation in sporting activities among all ages, are expected to contribute to a rise in frequency of this injury. The average age of patients with an OCL is 20 to 30 years, with a male preponderance of 70%, and bilaterality being reported in 10% of cases.
Although most patients with OCLs complain of ankle pain after a traumatic event, other patients present with chronic ankle pain. Associated swelling, stiffness, and weakness about the ankle are also common. Symptoms are typically exacerbated by prolonged weightbearing or high-impact activities such as running or jumping sports. Authors have also established a strong link between OCLs and chronic ankle instability, which may also be part of the posterior, lateral, oblique) remain the preferred first-line imaging studies for assessing patients with a suspected OCL, in part to rule out fractures. A Canale view (pronation of the foot to 15°, x-ray beam angled 75° cephalad) may also be helpful to assess the subchondral surfaces. However, because plain radiographs may miss up to 50% of OCLs and are unable to assess the state of cartilage, we believe that more advanced imaging technologies are appropriate. Computed tomography lacks the ability to assess cartilage, although it is useful in obtaining greater detail about the bony injury such as specific size, shape, and extent of displacement. Magnetic resonance imaging has been shown to detect bone bruises, cartilage damage, and other soft tissue insults and correlates closely with arthroscopic findings. T2-weighted MRI is recommended as it can offer greater sensitivity to cartilage change, as well as allowing identification of the zonal orientation of the collagen fibrils, thus facilitating clarification of the depth of cartilage damage. Although MRI is emerging as the gold standard for OCL diagnosis, clinicians should be aware that signal patterns in the talus may overestimate the severity of the bone injury.

### Radiologic Imaging Tests

Standard weightbearing radiographs of the ankle (anteroposterior, lateral, oblique) remain the preferred first-line
Anatomy and Location of Lesions

Talus. Articular cartilage in adults possesses neither a blood supply nor lymphatic drainage and is relatively ineffective in responding to injury. Thus injuries confined to the cartilage alone stimulate only a slight reaction in the adjacent chondrocytes. The talus has 60% of its surface covered in cartilage, which may increase the risk of vascular compromise. In contrast, involvement of the subchondral bone via penetration of the subchondral plate allows a typical inflammatory wound-healing response. Cells recruited from marrow elements attempt to fill the defect but the degree of success is predicated on age, as well as the size and location of the defect.

In 2007, Millington et al used a high-resolution stereophotography system to quantify the articular cartilage topography and thickness within the ankle joint. These factors are important in the assessment of the extent of OCLs, to determine the best mode of treatment. The authors found that the thickest articular cartilage occurs over the talar shoulders. The mean thickness of both the talar (1.1 ± 0.18 mm) and tibial (1.16 ± 0.14 mm) cartilage was significantly thicker than the fibular cartilage (0.85 ± 0.13 mm).

A recent study sought to evaluate the true frequency of OCLs on the talar dome by location and morphological characteristics. The authors developed a novel, 9-zone anatomical grid system. They identified 428 OCLs in 428 ankles and found that medial talar dome lesions were both more common and significantly larger than lateral lesions. With regard to specific zones on the talus, centromedial lesions were the most common (n = 227) with centrolateral the next most frequent site (n = 110). Posteromedial and anterolateral lesions were rarely found. A prior study by the same group studying MRI changes over time also reported that of 29 OCLs of the talus, 19 (66%) were located at the medial talar dome.

Tibial Plafond. Osteochondral lesions of the tibial plafond (Figure 2) are rare, particularly in comparison to the incidence of OCLs of the talus. This may be due to differences in the thickness and mechanical properties of the cartilage in these regions, as well as the rich arterial supply to the distal tibia. Distal tibial cartilage has been shown to be stiffer than talar cartilage. Anterolateral and posteromedial cartilage at the distal tibia is also stiffer than the corresponding areas on the talar dome, with the softest cartilage found in the posterior half of the talus.

TREATMENT AND RESULTS

Nonoperative Treatment

Osteochondral lesions of the talus that are asymptomatic or are discovered as incidental findings can be treated nonoperatively. Low-grade OCLs, particularly osteochondritis dissecans lesions in the pediatric population, may resolve completely with variable need for immobilization or protected weightbearing. However, it is rarer to observe spontaneous healing in adult patients. One series demonstrated good or excellent results in only 54% of patients with chronic, cystic talar lesions treated nonoperatively. While rates of ankle osteoarthritis were low in this cohort, follow-up averaged only 38 months. In a comprehensive review of treatment strategies for OCLs of the talus, Tol et al noted that of a total of 201 patients from 14 studies who had nonoperative treatment, 91 (45%) were reported to have had successful outcomes, with patients with chronic symptoms (>6 weeks) actually having better results (average success rate 56%) than the overall cohort. The authors divided the nonoperatively treated patients into 2 groups: group 1 pursued rest or restriction of sport or activities with or without use of nonsteroidal anti-inflammatory drugs, while group 2 underwent cast immobilization for 3 weeks to 4 months. Group 1 had good or excellent results in 59% of patients, compared with 41% of patients in group 2. Typical indications for nonoperative treatment in these studies were minimal symptoms; Berndt and Harty stage I, II, and medial stage III lesions; or lesions with intact cartilage. Shearer et al have noted a poor correlation between changes in lesion size and clinical outcome. Therefore, a reduction in the size of the OCL that may be seen over time with conservative measures may not necessarily correlate with symptomatic improvement, so conversion to operative treatment may be warranted, if symptoms persist.

Patients who are asymptomatic or minimally symptomatic with lesions that involve cartilage alone may be treated nonoperatively with rest, ice, temporarily reduced weightbearing, and, in case of ankle malalignment, an orthosis. Clinicians should be aware, however, that nonoperative management has shown relatively high rates of...
failure in the literature. Further research into which patients may have successful outcomes with nonoperative care is warranted.

Surgical Management

The principal aim of surgical treatment is revascularization of the bony defect. Because articular hyaline cartilage is avascular and has poor regenerative capabilities, injuries that do not penetrate the subchondral plate have no stimulus for an inflammatory reaction and healing. When the depth of a talar OCL injury extends to the subchondral bone, marrow cells are stimulated to produce new tissue in an attempt to fill the defect. However, this process involves the formation of fibrous cartilage, which lacks the favorable biomechanical properties of normal articular hyaline cartilage. In the case of smaller lesions, this fibrocartilage substitute may suffice, and is the basis behind techniques such as microfracture and micropicking. However, with larger lesions, fibrocartilage may not be adequate to support the longevity of the joint. Therefore, the majority of recently developed treatment approaches are aimed at providing a method of replacing damaged articular cartilage with tissue that more closely resembles hyaline cartilage. These have included primarily transplantation of osteochondral autograft plugs from distant donor sites, allograft transplantation, or harvesting and culturing chondrocytes that are later transplanted into the site of the osteochondral defect.

Cartilage Stabilization/Pinning

Traumatic osteochondral fragments that have not detached from the underlying bone may be suitable for fixation. Whenever possible, large unstable OCLs with a viable bony component are preferentially treated with stabilization rather than debridement alone, which may precipitate pain and degenerative changes within the joint. Although traditional OCL fixation has involved metal implants that require subsequent removal, more recent techniques have utilized compression or stabilization with bioabsorbable materials, such as polyglycolic acid (PGA) or polylactic acid (PLLA) bioabsorbable pins, which do not require removal. While the literature on use of these new materials in the ankle is limited, 1 small series, in which PGA/PLLA copolymer pins were used in conjunction with debridement of the bony bed, demonstrated healing in 6 of 7 cases, with no evidence of an inflammatory reaction in any cases.

Retrograde Drilling

Retrograde drilling (RD) is indicated for subchondral bone lesions over which the overlying cartilage remains intact, with the clear advantage of providing the integrity of the articular cartilage, compared with antegrade drilling (Figure 3). However, it is critical not only to decompress the lesion but also to address the structural integrity of the subchondral cyst or defect, to prevent subsequent articular collapse. Although previous authors have described the use of solid bone graft, given the difficulty in adequately filling the contours of the lesion, other investigators have used surgical-grade calcium sulfate as an alternative bone-graft substitute that can be injected in liquid form into the defect after drilling. As an adjunct, a bone-marrow aspirate may be harvested from the iliac graft and its pluripotent cells isolated by centrifuge and mixed with the calcium graft to promote more rapid healing (Deland and Young, unpublished data, 2001). Retrograde drilling was first described by Lee and Mercurio for the knee in 1981 as an open procedure, but now is frequently performed arthroscopically in the ankle, along with fluoroscopic radiographic imaging. Because posteromedial and posterolateral lesions present a challenge when using a standard drill-targeting device arthroscopically, we have also employed the use of computer-assisted techniques to improve the accuracy of targeting lesions. These techniques have been employed successfully in other studies.

Outcomes studies investigating RD have shown good results overall. Kono et al compared transmalleolar drilling (TMD) with RD in 30 patients with unilateral OCLs without detachment of the cartilage, and re-look arthroscopy was performed at 1 year to assess the cartilage. In the TMD group, 11 lesions (58%) were unchanged (grade I) and 8 lesions (42%) had deteriorated from grade 0 to I, compared with the RD group, in which 3 lesions (27%) had improved from grade I to 0 and 8 (73%) were unchanged (2 grade 0 lesions, 6 grade 1 lesions). In another series of 16 patients with symptomatic OCLs of the medial talar dome treated arthroscopically with percutaneous RD through the sinus tarsi, mean American Orthopaedic Foot and Ankle Society (AOFAS) scores increased from 53.9 points to 82.6 points, with no complications reported.

Microfracture/Microdrilling

Microfracture and microdrilling (Figure 4) procedures have the same objective: to stimulate fibrocartilage development by breaching the subchondral plate with subsequent introduction of serum factors and development of

Figure 3. Fluoroscopic image of talar retrograde drilling.
scar tissue at the defect site. While the efficacy of microfracture in ankle OCLs is somewhat controversial, most series have demonstrated that it provides symptomatic relief. In the presence of a small (<6 mm), shear-type lesion characterized primarily by chondral damage, but minimal subchondral bone involvement, this technique may be optimal. Chuckpaiwong et al investigated 105 cases of talar OCLs treated with microfracture, reporting no failures of treatment with lesions smaller than 15 mm (n = 73) regardless of location, but only 1 successful outcome in lesions greater than 15 mm (n = 32). The authors also highlighted increasing age, higher body mass index, history of trauma, and presence of osteophytes as factors negatively affecting outcome.

Tissue Transplantation

For transplant of osteochondral constructs into the talus, perpendicular access is generally required to the injured area. Most areas of the talar dome can be accessed perpendicularly without the necessity for a malleolar osteotomy. Muir et al demonstrated that, on average, only 17% of the medial talar dome and 20% of the lateral talar dome could not be accessed without an osteotomy. After an anterolateral osteotomy, they reported an increase of 22% in sagittal exposure, while malleolar osteotomies provided access to the entire medial and lateral talar dome areas with a residual central 15% of the talar dome remaining inaccessible perpendicularly. Several well-accepted techniques for medial malleolar osteotomy have been described. Critical to all methods of osteotomy is a precise reduction and fixation to avoid fibrous non-union or malunion. Three-screw fixation (Figure 5) may be beneficial to reduce translation of bony fragments that can occur with 2-screw fixation (Figure 6).

Mosaicplasty. For treatment of larger talar lesions, Hangody et al described a method for autologous grafting using numerous cylindrical osteochondral plugs taken...
from the nonweightbearing segment of the medial or lateral femoral ridge of the knee and transferring them to a talar dome defect with a surface area of no more than 4 cm² and approximately 10 mm in diameter. The authors recommend a mini-arthrotomy and identify OCLs in the medial or lateral aspect of the dome (rather than the central part of the talus) and otherwise normal tibial and talar articular surfaces as factors associated with better results. Good-to-excellent results have been reported in as high as 94% of patients in some series. In a study with 2- to 7-year follow-up, 36 talar OCLs were reviewed, with excellent results in 26 patients, good in 6, and moderate in 2, based on the Hanover scoring system. A second-look arthroscopy procedure was performed in 8 patients and showed normal and congruent-appearing surfaces, with specific staining revealing type II-specific normal articular cartilage collagen and articular cartilage proteoglycans that were of similar quality to a control biopsy specimen. However, other authors have emphasized the technical challenge of reproducing a smooth articular surface, with protrusion of plugs in an “organ pipe” arrangement. Patient complaints such as a “catching” sensation and late-onset postoperative pain have also been described.

Osteochondral Autologous Transfer System. Osteochondral autologous transfer system (OATS) has been advocated for the treatment of large cystic OCLs, such as type V lesions (Figure 7). Based on the course of a large cohort of patients with failures after simple drilling, curetting, debridement, or bone grafting, Scrafton suggested that type V lesions (as described by Hepple et al) greater than 6 mm in diameter with articular disruption should be indicated for OATS (Table 1). After arthroscopic identification or confirmation of a lesion greater than 6 mm in diameter with disrupted cartilage, conversion to open surgery is pursued, with a posteromedial lesion generally requiring a medial malleolar osteotomy. Some authors advocate release of the anterior talofibular ligament, anterior subluxation, and forced plantar flexion to achieve adequate exposure for posterolateral lesions. The lesion is debrided at the edges and matched to a graft of equal size harvested from a nonweightbearing area of the ipsilateral knee. One series reported 90% patient satisfaction in a retrospective review of 50 OATS cases with a lesion diameter from 8 mm to 20 mm. In another series with average follow-up of 16 months and an average lesion size of 12 mm × 10 mm, the mean postoperative AOFAS score was 88, the Lysholm knee score (assessing donor-site pain) was 97, and 89% of patients said they would have the procedure again. The authors believe OATS to be an effective salvage procedure for patients with failed previous procedures and long-standing symptoms. Studies have suggested that viability of chondrocytes in the periphery of the graft may be affected by the acquisition method, with manual punches being associated with better survival of cells than use of a power trephine system.

Osteochondral Allograft Transplantation. As an alternative to OATS, osteochondral allograft transplantation may be more suitable for very large OCLs of the talus, and has the advantage of optimization of matching graft morphologic characteristics with the defect site, which is done with both radiologic and direct measurements intraoperatively. Raikin classified OCLs as “massive” or not viable for standard repair options when the volume exceeds 3 cm³ and suggested that this grade may represent a sixth stage to the Berndt and Harty classification system. Some authors prefer fresh osteochondral allografts over fresh-frozen grafts, citing a decline in chondrocyte viability in the latter. In such cases, transplantation should be performed within 7 days of the death of the donor. However, other authors report good results with frozen allografts that were frozen for less than 14 days before insertion. Typically, the defect is burred to create an even-edged rectangular defect with a flat base that can be packed with cancellous graft from distal tibia or donor talus to aid subsequent graft integration. The transplanted allograft is usually held in place by screw fixation.

Only 2 small series involving the use of an osteochondral allograft exist in the literature. Raikin reported on 6 cases, 5 of which involved the medial talar dome and 1, the lateral talar dome. Five of the 6 OCLs were of traumatic origin. Two patients had fresh allograft transplantation, and 4 had fresh-frozen talus allografts, with all approaches except for 1 involving a malleolar osteotomy. Mean AOFAS ankle scores improved from 42 preoperatively to 86 postoperatively, which included 1 patient who went on to have an ankle arthrodesis for persistent pain. All patients stated they would have the procedure performed on the contralateral side if necessary. Gross et al reported on 9 cases of talar OCLs treated with fresh osteochondral allograft transplantation, 6 of which remained in situ at a mean follow-up of 11 years. The remaining 3 patients required ankle arthrodeses, secondary to resorption and fragmentation of the graft.
Autologous Chondrocyte Implantation/Transplantation (ACI/ACT). Autologous chondrocyte transplantation is an alternative to osteochondral grafting techniques. The technique, as described by Giannini et al., involves harvesting a small amount of cartilage arthroscopically from the knee ipsilateral to the ankle injury for chondrocyte cultures, which are grown in vitro for approximately 30 days. The OCL is debrided and filled with autologous cancellous bone harvested from the ipsilateral distal tibial metaphysis. Periosteum is acquired from the ipsilateral proximal tibial metaphysis to cover the transplant area and is fixed with resorbable sutures. Before the flap is fully sutured down, the chondrocytes are transplanted in liquid media through the remaining unsutured area, which is then sutured and sealed with fibrin glue. Malleolar osteotomy is fixed with 1 or more screws. At 1 year, the screws are removed, and at that time an ankle arthroscopy is performed to assess the graft site. The authors reported on 8 patients treated with ACT, with average preoperative to postoperative AOFAS scores improving from 32.1 points to 91 points at 2 years. Baums et al. reported on 12 similarly treated patients, 11 of whom had good-to-excellent results after 63 months of follow-up, with an average preoperative AOFAS score of 43.5 increasing to 88.4 postoperatively. One recent study suggests that decreased postoperative pain may be an advantage of ACI, compared with other techniques. Goebi et al. compared surgical outcomes in 33 similarly sized talar OCLs treated with chondroplasty (11 cases), microfracture (10 cases), and OATS (12 cases). Although no significant difference was detected between the groups, with reference to AOFAS or single-assessment numeric evaluation scores, the numeric pain intensity was significantly greater at 24 hours postoperatively with OATS than with the other 2 techniques. Disadvantages of ACI include the cost of culturing hyaline cells, the need for 2 surgical procedures, and the durability of the graft.

Most recently, Giannini et al. have reported on the results of ACI incorporating the use of a hyaluronan-based 3-dimensional scaffold (Hyalograft C, Fidia Advanced Biopolymers, Abana Terme, Italy) for symptomatic post-traumatic osteochondral talar dome lesions in 46 patients. It involved a 3-step process with initial cartilage harvest from the detached osteochondral fragment, chondrocyte culture on the Hyalograft C scaffold, and subsequent arthroscopic implantation of the 3-dimensional scaffold. They reported excellent clinical and histologic results, with an increase in AOFAS scores from 57.2 to 86.8. Hyaline-like cartilage regeneration was identified histologically in samples obtained at second-look arthroscopy in 3 patients at an average of 18 months after surgery.

Treatment of Tibial Plafond Lesions

Because of the rarity of tibial plafond OCLs, there are few reports in the literature related to treatment recommendations. In the largest series involving distal tibial OCLs, Mologne and Ferkel retrospectively reviewed 880 consecutive ankle arthroscopies, 23 (2.6%) of which involved treatment of tibial plafond OCLs. They concluded that arthroscopic treatment methods used for talar OCLs (excision, curettage, and abrasion arthroplasty) were also effective for those of the distal tibia, based on average AOFAS ankle-hindfoot score improvement from 52 preoperatively to 87 postoperatively and good or excellent results in 14 of 17 patients at medium-term follow-up.

Ueblacker et al. reported on a new technique for retrograde osteochondral autograft transplantation for treatment of OCLs of the proximal and distal tibia. Their series involved 5 patients, 2 of whom had painful chondral lesions of the distal anterocentral and posteromedial tibia. All patients were satisfied with the surgery. Follow-up arthroscopy showed the osteochondral cylinders well integrated and flush with the articular surface.

One case report described a female patient with bilateral distal tibial OCLs after several months of intensive military training. One month after cessation of active training and nonoperative therapy, the severity of pain decreased considerably and the patient remained asymptomatic in her daily activities at 3 years. A second case report described osteochondral allografting of a distal tibial OCL, with 2-year follow-up radiographs demonstrating satisfactory incorporation of the graft without collapse and with preservation of joint space.

Adjunctive Treatments/Future Directions

Viscosupplementation Therapy

Despite a dearth of convincing outcomes data to support their use, the popularity of intra-articular hyaluronic acid (HA) derivative injections, also known as viscosupplementation therapy, continues to grow for arthritis and other conditions in a variety of joints. Pleimann et al were among the first authors to report on the use of HA injections as an adjunct in the nonoperative treatment of ankle arthritis in 2002. Salk et al. recently performed a controlled trial in which 22 patients were randomized to receive either 5 weekly intra-articular injections of Hyalgan (sodium hyaluronate) or saline placebo injections for ankle osteoarthritis, demonstrating significantly better improvement in the HA treatment group. Tyberleigh-Strong et al. reported increased markers of articular cartilage survival and function in a sheep model, in which viscosupplementation therapy was used as an adjunct to osteochondral grafting of the knee. Other studies have supported these findings as well. Most recently, Cohen et al conducted a double-blind randomized controlled study examining the safety and efficacy of intra-articular sodium hyaluronate in the treatment of pain associated with ankle osteoarthritis. Thirty consecutive patients were enrolled, and those treated demonstrated a significantly greater improvement from baseline on the Ankle Osteoarthritis Scale at 3 months than did the control group. The authors concluded that sodium hyaluronate may be a safe and effective option for pain associated with ankle osteoarthritis but advocated the need for larger studies.

Because of the presumed benefits of HA derivatives on synovial fluid and chondrocyte function, the senior author of this review (J.G.K.) routinely uses viscosupplementation
as adjunctive treatment with all methods of surgical treatment of ankle OCLs. We are involved in a clinical trial that aims to establish how HA may help in maintaining the integrity of cartilage transplants in patients undergoing the OATS procedure. It is known that the peripheral rim of the graft suffers chondral cell death and that the graft itself may also have reduced chondral viability after transplant due to integrative problems as well as the impact forces involved in graft placement.91,127 The authors hypothesize that HA will act in these cases, as it does in degenerative joint disease, to preserve existing cartilage and produce a more robust graft. However, it must be emphasized that ongoing clinical trials are needed to confirm the efficacy of this treatment. Hyaluronic acid may be an adjunct to improve outcomes in compromised cartilage in the future, but at this time, it is not standard practice to employ it in this fashion.

Electrical/Electromagnetic Stimulation

Although the efficacy of electric and electromagnetic stimulation on bone repair and healing of cartilage defects is controversial, studies have suggested an upregulation of known molecular healing factors, such as transforming growth factor–beta (TGF-β) and various bone morphogenetic proteins (BMPs, which are members of the TGF-β superfamily), as well as osteoclasts.2,14,20,71,126 One proposed mechanism is that pulsed electromagnetic fields stimulate chondrocyte proliferation by means of a nitrous oxide pathway.96 A recent study investigating bone formation and graft stabilization in a sheep model of osteochondral autograft treatment suggested that pulsed electromagnetic field treatment leads to improved results.12 Based on a growing body of evidence, the use of electric and electromagnetic stimulation may play an increasing role in the future treatment of ankle OCLs.

Ultrasound Stimulation

Ultrasound is a propagating pressure wave that transfers mechanical energy into tissues.130 Low-intensity ultrasound has been studied as a modality with properties that can enhance bone52,64 and cartilage healing.29,90 In a recently studied rabbit model with bilateral knee OCLs, the effects of low-intensity pulsed ultrasound in repairing osteochondral injuries was compared with the untreated contralateral side, revealing significantly higher scores in gross appearance grades, histologic grades, and proteoglycan quantity on the treated side.96 More evidence is needed to assess the role of low-intensity pulsed ultrasound in the acceleration of repair of osteochondral injuries.

Mesenchymal Stem Cells

Mesenchymal stem cells (MSCs) from bone marrow have been cultured in vitro and induced to form cartilage before implantation into the chondral defects in rabbits.124 Bone marrow has been aspirated from the iliac crests in a caprine model and chondrogenesis of the MSCs induced.17 Mesenchymal stem cells represent a valuable adjunct in that they may be harvested with relative ease by means of a bone-marrow aspirate and a small number of pluripotent cells can be isolated, grown in vitro if necessary, and then introduced into osteochondral defects. They have the capability to differentiate into articular cartilage and induce the formation of subchondral bone. Recently, MSCs have been used with success in hybrid scaffolds to repair osteochondral defects in animal models.48,55,56 Although still in the early stages of application, this unique approach may have great potential in treatment of human cartilage defects.

Platelet-Rich Plasma

At the site of any injury involving bone, a clot will form that consists of red blood cells, white blood cells, and platelets in a fibrin matrix. In bone healing, the alpha granules within the platelets are a valuable reservoir of exogenous factors.35 These factors include platelet-derived growth factor, insulin-like growth factor, and TGF-β, which along with a number of other factors play a critical role in bone healing.57 Platelet-rich plasma has recently been studied in conjunction with autologous chondrocyte transfer, showing promise both as a scaffold in which to help hold ACI cells and as a reservoir of growth-stimulating factors.15,84

Computer-Aided Navigation and Robot-Assisted Surgery

As computer navigation techniques become more sophisticated and more user-friendly, their integration into orthopaedic procedures increases (Figure 8). Computer navigation is particularly attractive for OCLs given the importance of precise localization and the potential for minimally invasive procedures.60,61 Robot-assisted surgery may also be ultimately favored over conventional orthopaedic techniques in the treatment of OCLs because of the optimization of accuracy and precision in the preparation of bone surfaces, and the potential for more reliable and reproducible outcomes with regard to spatial accuracy. How rapidly these technologies advance in foot and ankle surgery, and orthopaedic surgery as a whole, remains to be seen.

Tissue Engineering

Tissue engineering can be defined as the application of biological, chemical, and engineering principles to the repair, restoration, or regeneration of living tissue by using biomaterials, cells, and factors alone or in combination.63 There are 3 common tissue engineering approaches used to address osteochondral injuries113: extraction of the appropriate cells from the patient, in vitro culture, followed by transplantation back into the body defect that requires regeneration; placement of biologic factors, such as molecules or growth factors, into body defects; and use of 3-dimensional porous materials (eg, titanium, tantalum) to stimulate the ingrowth of new tissue. A combination of these 3 approaches may also be used, such that there are osteoinductive, osteoconductive, and osteogenic elements, thus providing an optimal environment for bone growth.63
polymer scaffolds, with the resultant implant placed in full-thickness OCLs in 80 rabbits. Significant enhancement of the quality of the repair tissue with more hyaline-appearing cartilage and a smoother surface was observed in both BMP-7 and Shh gene–treated animals versus controls.

CONCLUSION

Osteochondral lesions of the ankle are being recognized with increasing frequency, in part because of heightened understanding and awareness, and in part because of improved MRI and arthroscopic technology. As a result, treatment strategies and techniques continue to be rapidly developed and improved upon. However, outcomes research remains sparse on this subject; despite a number of emerging future directions that hold promise in the treatment of OCLs, more evidence is necessary before they can be treated with consistent efficacy and safety.

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