9 Cartilage Techniques for Osteochondral Lesions of the Talus

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9.1 Introduction

Osteochondral lesions of the talus (OLT) are a common ankle pathology and have been shown to occur in over 65% of chronic ankle sprains and 75% of ankle fractures [1, 2]. OLT can be a significant source of pain and disability and may have a potential to progress to arthritis. Conservative management, including physiotherapy, injections, and a period of non-weight-bearing, may relieve symptoms in the short term, but they often recur due to inadequate healing of the lesion and require surgical treatment.

The surgical management of OLT is largely dependent on the size of the lesion, the occurrence of cysts, and whether the patient has failed previous surgeries. Surgery can be broadly divided into reparative and replacement procedures [3]. Reparative procedures include bone marrow stimulation procedures (BMS) such as microfracture [4]. Replacement procedures include autologous osteochondral transplantation (AOT) and osteochondral allograft transplantation [5]. Autologous chondrocyte implantation (ACI), matrix-induced autologous chondrocyte implantation (MACI), autologous matrix-induced chondrogenesis (AMIC), and scaffolds as adjuncts to surgery have become popular in recent years, but further studies are required to substantiate their widespread use [6]. Biological adjuncts, including platelet-rich plasma (PRP) and concentrated bone marrow aspirate (CBMA), have been shown to have promising evidence and may be utilized alongside surgery to improve healing potential [7].

Despite the advances in the treatment of OLT in the last few years, no gold standard treatment exists and surgical treatment should be individualized to the patient in order to optimize outcomes [8].

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9.2 Microfracture

9.2.1 Indications

Microfracture is a reparative technique, where the subchondral bone in the defects is perforated with awls to release the mesenchymal stem cells and growth factors from bone marrow, leading to the

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formation of fibrous cartilage repair tissue. Microfracture is indicated for smaller lesion which is typically less than 150 mm^2 in area or 15 mm in diameter [9, 10]. However, a recent systematic review by Ramponi et al. demonstrated that microfracture may be optimal for lesions smaller than 107.4 mm^2 in area and/or 10.2 mm in diameter [11]. Ankle stability, joint alignment, lesion size, the presence of a cyst, previous cartilage repair procedure, and uncontained lesion are all prognostic factors when performing microfracture [9, 10]. There are several disadvantages with microfracture, including the quality of fibrocartilage which is inferior to native hyaline cartilage, permanent damage to the subchondral bone, and deterioration of the fibrocartilage over time [12].

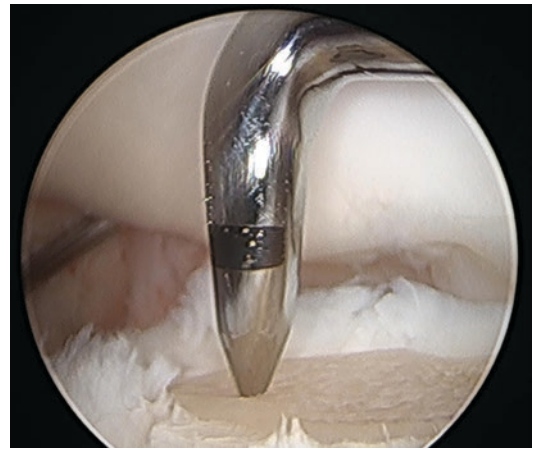

Fig. 9.1 Arthroscopic image of the microfracture awl penetrating the subchondral bone plate

9.2.2 Technique

Microfracture is typically performed arthroscopically using anteromedial and anterolateral portals. After inspection of the ankle joint, the OLT is prepared prior by debriding all unstable cartilage by shaving or curettage until there is a stable rim of articular cartilage. The calcified cartilage layer of bone should be removed; however, care should be taken not to disrupt the subchondral bone excessively.

Once the defect site is prepared, an awl <1 mm is used to perforate the subchondral bone. A smaller awl may result in less damage to the subchondral bone and may be preferable. Additionally, the distance between the awl apertures should be 3–4 mm apart to minimize damage to the subchondral bone (Fig. 9.1). After the holes have been created, the tourniquet should be turned off to assess for bleeding and fat droplet extrusion. Biological adjuvants, including PRP or CBMA, may be added, which may improve fibrocartilage repair tissue.

9.2.3 Outcomes

Microfracture has been shown to result in favorable short-term outcomes in several systematic reviews, with typically >85% of patients resulting in good to excellent clinical outcomes [8, 13]. In regard to return to play sports following microfracture, Hurley et al. found in a systematic review that 86.8% of patients returned to sport at previous levels, with a mean return at 4.5 months [14].

Despite successful outcomes in the short to mid-term, there is a concern about deterioration of the fibrocartilage repair tissue over time, which may potentially affect the clinical outcomes in the longer term [12, 15, 16]. Ferkel et al. found deterioration of clinical scores in up to 35% of patients within 5 years following BMS [12]. Lee et al. found that only 30% of patients who underwent BMS showed lesion integration at second look arthroscopy at 12 months postoperatively [17]. In addition, van Bergen et al. reported that one-third of patients progressed ankle arthritis by one grade on plain radiographs at a mean follow-up of 141 months [18].

Recent studies have focused greater attention on the subchondral bone, which provides significant joint loading [15, 19]. Seow et al. found in a systematic review that there was permanent alteration of the subchondral bone following BMS in preclinical studies [15]. This subchondral bone alteration will reduce its mechanical support and may contribute to fibrocartilage deterioration. Therefore, techniques minimizing damage to the subchondral bone will be important for cartilage longevity. In a translation animal model Orth et al. found that the use of small-diameter awls

offers better articular cartilage repair than large-diameter awls on histological exam [20]. Gianakos et al. evaluated different microfracture awl sizes in a cadaver talus model, and found that smaller awl sizes may help diminish the amount of subchondral bone microarchitectural disturbances [21]. Additionally, biologics may play a role in reducing the deterioration of the fibrocartilage, although the long-term evidence on this is still limited.

9.2.4 Particulated Juvenile Cartilage Allograft

PCA (DeNovo NT; Zimmer Biomet, Inc.) is a scaffold containing juvenile chondrocytes and particulated juvenile cartilage, typically harvested from donors less than 3 years old. PCA is theoretically advantageous as an adjunct to microfracture, as their high metabolic activity level and differential gene expression may have the potential to reproduce more hyaline cartilage than adult chondrocytes (Fig. 9.2).

The supporting evidence for PCA is limited; however several in vitro studies have found PCA has a superior chondrogenic potential to adult cartilage [19]. These studies showed improvement in histological, biochemical, and biomechanical analyses, but not in gene expression [19]. Karnovsky et al. performed a retrospective comparative study of the results of patients treated with microfracture and PCA, and those treated with microfracture alone, at a mean follow-up of 30 months [22]. The authors found both groups still showed fibrocartilaginous growth that did not appear normal on MRI, and there was no difference in functional outcomes between the two groups. The current role of PCA remains unclear, and further long-term high-level studies are needed.

9.2.5 Micronized Cartilage Allograft

MCA (BioCartilage; Arthrex, Inc) contains an allogeneic extracellular matrix, including type II collagen, proteoglycans, and cartilaginous growth factors. MCA is theoretically advantageous as an adjunct to microfracture, by inciting the migration of stem cells to the defect site of the defect, while MCAs facilitate chondrogenesis by acting as a tissue network promoting cell interaction (Fig. 9.3).

The evidence supporting MCA is still limited, although the results of early literature appear promising. Fortier et al. found that alongside microfracture, MCA with PRP improved the quality of cartilage repair tissue compared to

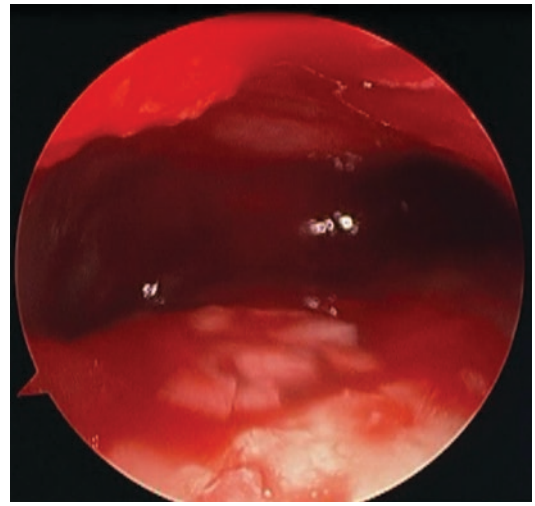

Fig. 9.2 PCA application into the defect, mixed with CBMA or PRP

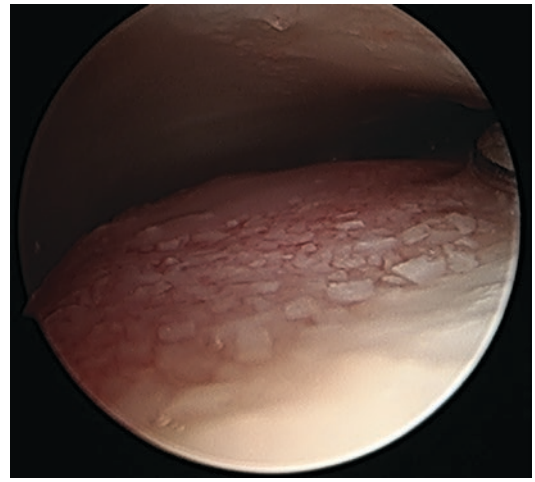

Fig. 9.3 MCA application into the defect, mixed with CBMA or PRP

microfracture alone in an equine model [23]. Desai et al. reported on the results of nine patients treated with microfracture and MCA at a mean follow-up of 12 months [24]. Seven patients had excellent outcomes, and two patients reported good outcomes, although no quantitative outcome measures were noted. However, no comparative studies comparing MCA with microfracture to microfracture alone have been reported. Therefore, long-term high-level studies are warranted to justify its current widespread use [19].

9.3 Autologous Osteochondral Transplantation

9.3.1 Indications

AOT is a cartilage replacement technique where a graft is harvested from the host, and transferred into a prepared site at the defect in the talus. As AOT replaces the local subchondral bone, it may result in the restoration of the native biological environment leading to improved functional outcomes and survivorship over BMS. It is typically indicated in primary cystic lesions, lesions >10 or 100 mm^2, and revision procedures following a failed primary procedure [11, 25–27]. A recent systematic review by Ramponi et al. found that AOT is indicated in lesions greater than 107.4 mm^2 in area and/or 10.2 mm in diameter [25]. Lesion containment, the requirement greater than two grafts, previous BMS, and body mass index can be prognostic factors when performing an AOT [25, 28–30]. There are several disadvantages to AOT, including donor site morbidity, the possible need for an osteotomy to approach the lesions, and differences in cartilage biology/mechanics between the host and graft tissues.

9.3.2 Technique

The OLT may be accessed by a medial or lateral osteotomy depending on the location of the lesion. In the case of a medial OLT, a medial malleolar osteotomy may be utilized to adequately visualize the lesion (Fig. 9.4). A Chevron osteotomy is preferred for this approach as it provides appropriate alignment, stability, a large surface area for healing, and greater visualization [5]. However, an anteromedial lesion may only require a standard arthrotomy for visualization. Anterolateral lesions may be exposed via standard arthrotomy of the ankle joint, although if it is in a central or posterior position an anterolateral tibial osteotomy may be required. After the lesion is visualized, a trephine is utilized to remove the damaged cartilage and underlying bone at the recipient site. A depth of 12–15 mm is the optimal depth to drill the lesion site.

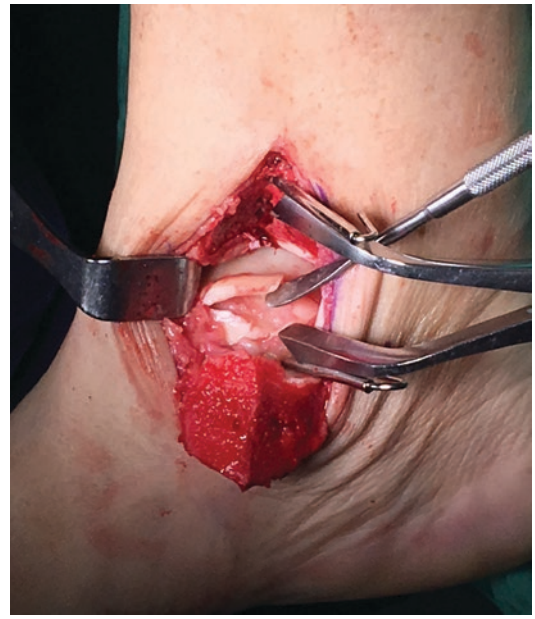

Fig. 9.4 A medial malleolar osteotomy utilized to adequately visualize the lesion

Multiple donor sites exist for graft harvesting; however, our preferred technique is to harvest from a non-weight-bearing portion of the ipsilateral femoral condyle. This site is utilized as it is technically undemanding to access and the variation in topography closely matches the talar dome. It also has a large surface area, allowing for at least three grafts to be harvested without compromising the patellofemoral articulation. Additionally, the superior aspect of the lateral femoral condyle experiences less pressure than other articular surfaces. There is a low incidence

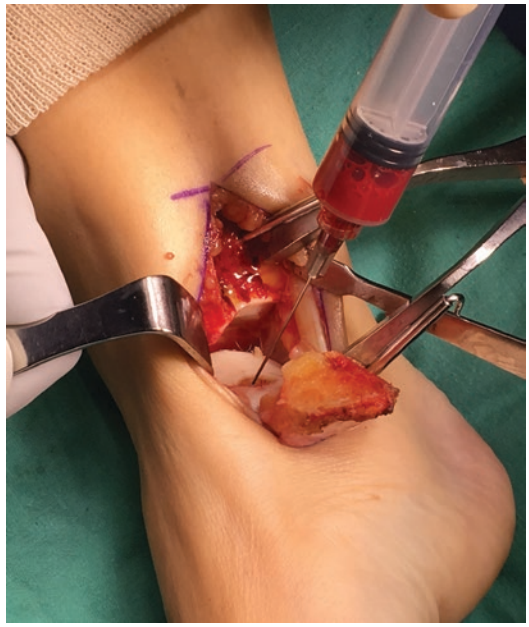

Fig. 9.5 Application of PRP or CBMA into the defect site

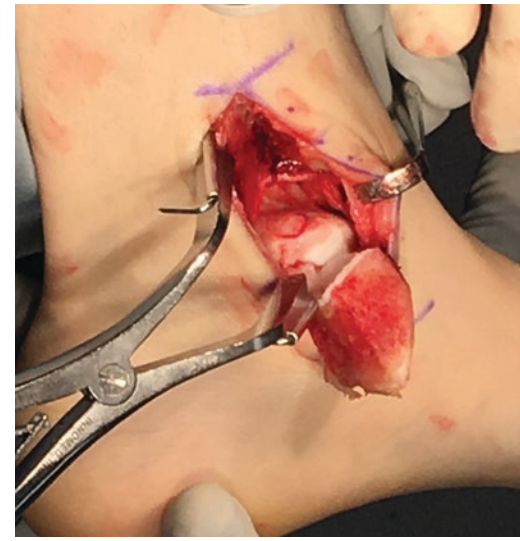

Fig. 9.6 The osteochondral graft transplant being placed into the created recipient site

of donor site complications, typically less than 5% in large series [5, 31–33]. Larger lesions may require two grafts, which should be "nested" next to each other to reduce risk of fibrocartilage formation and synovial fluid inflow between the grafts [5, 34].

Prior to graft implantation, biological adjuvants, including PRP or CBMA, are added, which may facilitate biological integration of graft and host interface (Fig. 9.5). The AOT plug is then transferred to the prepared recipient site. Congruency of the implanted graft is essential as the final graft position should be as flush as possible to match the surrounding cartilage, and care should be taken during surgery to achieve an articular surface as closely as possible to the native talus (Fig. 9.6) [35].

9.3.3 Outcomes

The clinical outcomes following AOT have been shown to be excellent in multiple studies, and a recent systematic review by Shimozono et al. found 87% of patients had good to excellent outcomes at mid-term follow-up [33]. Fraser et al. found that in athletes, 90% of professional athletes and 87% of recreational athletes were able to fully return to pre-injury activity levels at a mean of 24 months follow-up [36]. However, Paul et al. showed patients engaging in high-impact and contact sports required partial modification of sporting activities and a reduced level of participation [29]. Additionally, several studies have shown improved radiological outcomes following AOT, with a low incidence of joint space narrowing [33]. There is still lack of evidence regarding the long-term outcomes of AOT for OLT.

Complications remain a concern with AOT; Shimozono et al. found in a systematic review that 10.6% of patients had complications, with the most common being donor site morbidity [33]. Yoon et al. found that while 9% patients had early donor site morbidity all of these resolved at 48 months follow-up, and Fraser et al. found an early donor site morbidity of 12.5% but this decreased to 5% at a mean of 41-month follow-up [27, 37]. Shimozono et al. found that the overall rate of reoperations was 6.2%; however, only 1% of patients were considered a clinical failure at mid-term follow-up [33]. The osteotomy may be a concern for some surgeons; however, studies have found minimal morbidity when performing

an osteotomy to access the talar dome [17, 38]. Lamb et al. found that in 62 patients a chevron-type medial malleolar osteotomy provided satisfactory healing on T2 mapping MRI and only four patients reported some pain postoperatively [39]. Additionally, postoperative cysts have been shown to occur in up to 65% of patients following AOT, although the clinical significance of this remains unclear. Savage-Elliott et al. found that clinical influence of postoperative cyst formation was not significant in the short term [40]. Finally, the congruency of the graft is paramount to restore contact mechanics in the ankle [35]. Fansa et al. found that implantation of the osteochondral graft in the most congruent position possible restored the force, mean pressure, and peak pressure on the medial region of the talus comparable to intact levels [35].

9.4 Osteochondral Allograft Transplantation

9.4.1 Indications

Osteochondral allograft transplantation is a cartilage replacement technique similar to AOT in which the graft is harvested from a cadaver. There are two types of osteochondral allograft: bulk type and cylindrical plug type. Bulk allograft is generally considered as a salvage surgery if previous surgeries fail, but can be performed as a first-line procedure for excessive large lesions whose successful outcomes cannot be expected by other procedures. Osteochondral allograft transplantation using cylindrical plug has similar indications to AOT, but is usually indicated in preference to AOT in knee osteoarthritis, history of knee infection, and patients concerned with donor site morbidity in the knee. Patient counseling is important in deciding on autograft or allograft, and the pros/cons must be discussed with the patient. There are several disadvantages to allograft, including potential higher failure rate, increased cost, disease transmission, and differences in immunology/cartilage biology between the host and cadaveric tissues [41, 42].

9.4.2 Technique

The recipient site for osteochondral allograft transplantation may be accessed and prepared in a similar manner to AOT. However, bulk allograft may require an anterior approach in the majority of cases. Additionally, bulk allograft may require more extensive preoperative imaging utilizing 3D-CT planning to accurately determine the sizing of the graft needed.

AOT can be harvested from either cadaveric knees or ankles, and there is no consensus over which is the optimal site. Cadaveric talus may be preferable as the cartilage biology, tissue mechanics, and topography may more closely match the recipient site. Fresh nonfrozen allografts less than 28 days old may be preferable to maintain chondrocyte viability, as less than 70% chondrocyte viability is associated with poor outcomes and osteochondral allograft transplantation loses approximately 30% viability at 28 days [43, 44]. Prior to graft, biological adjuvants, including PRP or CBMA, can be utilized, as Oladeji et al. have found that utilizing CBMA in allograft improves radiographic integration [45]. The osteochondral allograft transplantation should be placed in a manner as congruent as possible to AOT, in order to as closely match the local biomechanics and of the local joint. Additionally, bulk allograft requires screw fixation in order to secure the graft, and in this instance a headless screw is preferable.

9.4.3 Outcomes

Studies have found mixed clinical outcomes following osteochondral allograft transplantation for OLT. The results of osteochondral allograft transplantation differ whether it is bulk or cylindrical plug allograft, as bulk allograft may experience poorer outcomes due to larger size of the lesions treated. VanTienderen et al. found in a systematic review of 91 OLTs treated with bulk allograft that at a mean of 45 months follow-up the average AOFAS score improved from 48 to 80 and the mean VAS score improved from 7.1 to

2.7 [42]. Raikin et al. found in 15 patients treated with bulk allograft at a mean of 54 months that the mean VAS score improved from 8.5 to 3.3 and the mean AOFAS score improved from 38 to 83, with 11 patients reporting good/excellent results [46]. However, two patients required conversion to arthrodesis [46]. On plain radiographs, some evidence of collapse or resorption of the graft was found in 67% of patients [46]. El-Rashidy et al. showed using cylindrical plug allograft in the treatment of OLT significantly improved clinical outcomes at a mean follow-up of 3 years, although there was a 10.4% failure rate over this time [47]. Ahmad et al. found similar clinical outcomes following cylindrical plug allograft and autograft for OLT at 35.2 months [48]. However, 18.8% of patients in allograft group required revision surgery due to non-union at the graft/host integration site.

Complications including failure and reoperations remain a concern with osteochondral allograft transplantation. VanTienderen et al. found in their systematic review that 13.2% of patients were considered clinical failures and 25% required reoperation [42]. The cause of the early failure is likely a combination of chondral wear, chondral fissuring, and cyst formation in the graft's subchondral bone, due to poor graft/host bone incorporation. Additionally, differences in the cellular biology between the graft/host and the chondrocyte viability may be a cause for the higher failure rates. Neovascularization may also play a role in the failure of allograft, as Neri et al. found that only 10 out of 15 osteochondral allografts showed gene expression matching the recipient, indicating blood supply between the graft/host interface [41].

9.5 Autologous Chondrocyte Implantation

9.5.1 Indications

ACI is a two-step cartilage reparative technique where autologous chondrocytes are harvested from a non-weight-bearing area and culture expanded in vitro. ACI is then placed into a prepared site at the defect in the talus and covered in an autologous periosteal membrane. The aim of this procedure is to regenerate damaged cartilage with hyaline-like tissue. ACI is indicated in larger lesions or revision procedures following a failed primary procedure. There are several disadvantages to ACI, including two steps to the procedure, cost, and potential failure rates.

9.5.2 Technique

ACI is a two-step procedure, whereby in the first step chondrocytes are harvested from the ankle, the osteochondral fragment itself, or the ipsilateral knee [49]. These cells are then expanded and cultured in vitro for 2–3 weeks.

Once the cells are prepared, the patient returns for the second step where the chondrocytes are implanted, either arthroscopically or via an open incision. The OLT recipient site is first prepared, where it is debrided to the subchondral bone and any cysts present are removed. In larger subchondral cystic defects, a "sandwich" technique can be utilized. This is where after cyst debridement, the autologous bone graft obtained is placed into the defect creating a smaller defect, followed by placement of a periosteal patch. The periosteal patch is taken from the distal or proximal tibia and is made 1–2 mm larger than the defect to account for shrinkage. The patch is then secured over the defect, cambium side down, with sutures and fibrin glue.

9.5.3 Outcomes

ACI has been shown to result in good clinical outcomes, and a recent systematic review by Niemeyer et al. found a clinical success rate of 89.9% in 213 patients at a mean follow-up of 32 months [6]. Giannini et al. reported on the clinical and MRI outcomes of ten patients following ACI for OLT at 10-year follow-up [50]. The authors showed in patients with a mean

lesion size of 3.1 cm^2 treated with ACI at a mean follow-up of 119 months that the AOFAS score improved from 37.9 preoperatively to 92.7 postoperatively with well-modeled restoration of the articular surface on MRI. Additionally, Giannini et al. found that in 46 patients at a mean follow-up of 87.2 months there were only three failures [51]. Battaglia et al. evaluated 20 patients following ACI at a mean follow-up of 5 years and found that, on MRI evaluation, all patients showed a T2 mapping value consistent with normal hyaline cartilage [52].

ACI has a low rate of complications specific to the procedure, and most complications are those associated with ankle arthroscopy or osteotomy, particularly non-union, scar tissue formation and nerve damage as this is a two-stage procedure. However, there is a concern of periosteal hypertrophy due to overgrowth of the repair tissue, which may require debridement.

9.6 Scaffolds

9.6.1 Matrix-Induced Autologous Chondrocyte Implantation

Matrix-induced autologous chondrocyte implantation (MACI) is where a biodegradable polymer scaffolds embedded with chondrocytes is utilized as a scaffold. MACI is a third generation version of ACI and a two-step procedure. However, it is advantageous as it is a self-adherent scaffold, and avoids complications related to the graft harvest.

Aurich et al. reported on the results of 19 patients treated with MACI and observed improvement of the AOFAS score from 58.6 to 80.4 at a final follow-up of 24 months [53]. Additionally, they found 81% of patients returned to play sports after MACI for OLT, including 56% returning to their pre-injury level. Similarly, Magnan et al. showed improvement in the mean AOFAS score from 36.9 to 83.9 in 36 patients, with 18 returning to sport within 2 months [54].

9.6.2 Autologous Matrix-Induced Chondrogenesis

Autologous matrix-induced chondrogenesis (AMIC) is where a porcine collagen I/III matrix is utilized at the site of the defect following microfracture and is a one-step procedure. The supporting theory is that this porcine collagen matrix supports the growth of cartilage following microfracture.

The literature on AMIC is limited to a few small case series, but the results seem promising. Valderrabano et al. reported in a series of 26 patients that 84% of patients had normal/near normal signal intensity of the repair tissue compared with the native cartilage on MRI [55]. However, Wiewiorski et al. observed a significant difference in T1 relaxation times between AMIC repair tissue and the surrounding cartilage, suggesting lower glycosaminoglycan content in the repair tissue [56].

9.6.3 Bone Marrow-Derived Cell Transplantation

Bone marrow-derived cell transplantation (BMDCT) is a combination of CBMA and scaffold material and is a one-step procedure. BMDCT is theoretically beneficial as the mesenchymal stem cells and the growth factors in CBMA support the scaffold in chondrogenesis, to develop hyaline-like cartilage at the site of the defect.

Similar to AMIC, the clinical evidence supporting the use of BMDCT is limited albeit promising. Vannini et al. reported on 140 athletes treated with BMDCT at a mean of 48 months follow-up and found the overall mean AOFAS score improved from 58.7 to 90.9 [57]. The authors also showed that 72.8% of athletes were able to return to pre-injury level of sports. Buda et al. evaluated 80 patients treated with ACI or BMDCT at 48 months follow-up [58]. There was no significant difference in clinical outcomes, but the rate of return to sports was

slightly higher with BMDCT, although the difference was not statistically significant. However, this shows that BMDCT may be a viable alternative to ACI, with the advantage of being a one-stage procedure.

9.7 Biologics

9.7.1 Platelet-Rich Plasma

PRP may be considered as adjuncts to surgical therapies in the treatment of OLT to improve the local healing potential. PRP is an autologous blood product that contains at least twice the concentration of platelets above the baseline value, or >1.1 × 10^6 platelets/μl. PRP contains an increased number of growth factors and bioactive cytokines, including transforming growth factor, vascular endothelial growth factor, fibroblast growth factor, and platelet-derived growth factor [59]. PRP is harvested by drawing venous blood from a peripheral site, and then is put in a preparation kit where it is spun to formulate PRP. This may be performed in either the office or in the operating room.

There is strong basic science evidence to support the use of PRP in cartilage repair. Smyth et al. performed a systematic review and found that 18 of 21 (85.7%) basic science literature studies reported positive effects of PRP on cartilage repair, establishing a proof of concept [7]. Smyth et al. also showed that the application of PRP at the time of AOT implantation in a rabbit model improved the integration of the osteochondral graft at the cartilage interface and decreased graft degeneration [60]. Similarly, Boayke et al. found using PRP alongside AOT in a rabbit model that there was increased TGF-β1 expression at the graft/host interface compared to saline-treated controls, and thus PRP may play a chondrogenic role [61].

Several randomized controlled trials have shown a benefit of PRP in the treatment of OLT and ankle osteoarthritis. Guney found PRP at the time of surgery improved the AOFAS scores and pain-related scores of BMS in the treatment of OLT compared to a placebo control [62]. Additionally, Gormeli et al. and Mei-Dan et al. both found that PRP improved the clinical outcomes and pain scores of patients with ankle osteoarthritis compared to hyaluronic acid in the short term [63, 64].

9.7.2 Concentrated Bone Marrow Aspirate

CBMA may be considered as adjuncts to surgical therapies in the treatment of OLT to improve the local healing potential in a similar manner to PRP. CBMA is an autologous blood product harvested from the long bones, typically the iliac crest or the tibia. CBMA contains a similar growth factor and cytokine profile compared to PRP, with the addition of interleukin 1 receptor antagonist protein in CBMA, which is a potent anti-inflammatory agent [65]. CBMA may be harvested in either the office or in the operating room. However, as CBMA harvest can be painful and may be difficult to perform in the office, we typically only harvest this in the operating room.

Fortier et al. have shown that CBMA improves both the histological and radiological outcomes in the repair of cartilage defects in an equine microfracture model, compared to a control without CBMA [66]. Fortier et al. found increased fill of defect and improved integration of repair tissue with surrounding cartilage [66]. In addition, Saw et al. found in a goat model that CBMA and hyaluronic acid (HA) improved defect coverage and repair tissue following BMS compared to HA alone [67].

Hannon et al. found patients who underwent BMS with CBMA in the treatment of OLT had comparably good mid-term clinical outcomes, but improved MOCART scores compared to BMS alone [68]. While the clinical evidence is limited in the use of CBMA in the treatment of OLTs, Chahla et al. performed a systematic review and showed CBMA was a promising treatment in the treatment of osteochondral defects in the knee [69].

9.8 Summary/Conclusion

The surgical management of OLT remains controversial. Based on the current available clinical evidence, both reparative and replacement procedures have a role in the surgical treatment of OLT and have been shown to result in good clinical outcomes. MACI, which is a next-generation technique of ACI, has become increasingly utilized in recent years. Additionally, biological adjuncts and scaffolds have increasingly gathered attention and provided promising clinical results. However, further high-level studies are still needed to develop standardized clinical guidelines for the treatment of OLT.

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