46 Joint Congruence Restoration in Osteochondral Defects: The Use of Mesenchymal Stem Cells with the "Sandwich" Technique

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Contents

46.1 Introduction

Cartilage lesion of the knee associated with significant subchondral bone loss (osteochondral lesion—OCL) can result in great morbidity, and treatment options providing durable repair are limited. Osteochondral autograft and allograft reconstruction of these lesions has been used extensively; however, these techniques often require much more invasive surgical exposure, and restoring the natural articular surface radius of curvature can be challenging, particularly in larger lesions. Cell-based repair of these lesions, using autologous chondrocyte implantation, in conjunction with bone grafting has been used with success, although this procedure requires a patient to undergo two surgeries, and access is often restricted due to the high associated costs. Comparable medium-term clinical outcomes have been demonstrated with scaffold-associated mesenchymal stem cell grafting, and this cell-based procedure may also be performed arthroscopically to minimize patient morbidity. In cases of cartilage injury associated with bone loss, this procedure has great potential to repair osteochondral injury when used in conjunction with bone grafting. We present the one-step arthroscopic technique of Biologic Inlay Osteochondral Reconstruction (BIOR) in the knee, using autologous bone graft and a hyaluronic acid-based scaffold embedded with bone marrow aspirate concentrate, to treat full-thickness cartilage lesions associated with significant subchondral bone loss.

The ankle is characterized by more congruency than the knee resulting in thinner cartilage that requires much more precision in chondral surface reconstruction. Biological treatment of osteochondral lesions of the talar dome aims to restore layers of a defect using biological material that undergoes further remodeling and integration with the surrounding tissue. The purpose of the reconstruction is to effectively recreate the shape of the talar dome in each different location, especially on the medial edge, where the most common traumatic lesions are located.

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46.2 Joint Congruency

Given that the knee and ankle joints are the most dynamic human weight-bearing joints, it is critical that there is proper matching of adjacent articular surfaces over the full range of motion. This important anatomic consideration is termed joint "congruence." Essentially, in order for weight-bearing joints to remain functional, and to avoid premature failure, the articulation should meet several criteria that are consistent with mechanical laws. From a mechanical point of view, two weight-bearing surfaces that are moving relative to each other should articulate over the functional range with the smallest frictional forces, which will minimize trauma to the opposing surfaces. The second important criterion is the optimization of joint contact surface area. Although a smaller surface area of articulation may allow for a reduction in frictional forces, a larger surface area will decrease pressures and peak loads on the weight-bearing surfaces, which are important factors to minimize the destructive mechanical forces that lead to progressive degenerative joint injury.

Currently, there is no consensus on the definition of joint congruence or its evaluation. Nevertheless, any measure of joint congruence implies the choice of a contact model that makes possible the decoupling of the contribution of articular geometry to the distribution of a contact load [1].

Considering the mechanical and geometric components of joint function, restoration of the articular cartilage surface after chondral injury is not complicated if subchondral bone remains intact and anatomically unaltered. In cases of subchondral bone hypertrophy, restoration of anatomic surface geometry may be accomplished with a shaver or burr, which can be used for removing the subchondral bony protuberance. In the case of large osteochondral defects that involve deep areas of subchondral bone careful reconstitution of the bone deficit with attention paid to restoration of the natural subchondral surface geometry is necessary for optimal reformation of the adjacent chondral layer.

Regarding cartilage restoration, biologic scaffolds are frequently used, and these may be implanted as cell-free scaffolds or cell-embedded scaffolds. Second- or third-generation autologous chondrocyte implantation procedures have been developed to provide cartilage restoration to treat instances of significant chondral injury. In cases of cartilage injury that is associated with significant subchondral bone loss, a dual-layer restoration procedure may be used, originally described by Peterson in 2003 as a "sandwich" technique. Despite advantages of Peterson's technique with respect to treating the entire injured osteochondral unit, it has not been widely adopted because of the resource-intensive nature of the technique and the low economic efficiency.

Successful reconstruction of both the injured cartilage and subchondral bone layers may be provided at reduced cost using the OATS method, developed by Hangody [12]. Extensive osteochondral defects may also be treated with mega OATS procedures, which involve the transplantation of one or more large osteochondral autografts. Unfortunately, the implantation of osteochondral blocks, even if is performed with great technical care, does not perfectly reproduce the contour of the anatomic articular surface (Fig. 46.1) [2], and may lead to slanted, prominent, or recessed osteochondral grafts that consequently disturb the pressure distribution over the loaded articular surface (Fig. 46.2) [3]. Interestingly, with respect to the mosaicplasty technique of osteochondral grafting, Elguizaoui

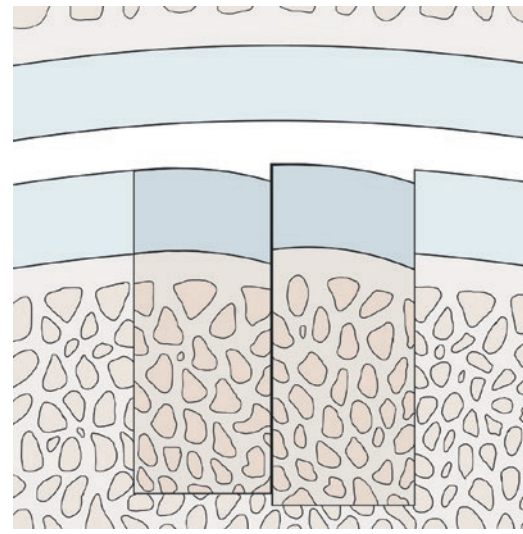

Fig. 46.1 Cartilage surface incongruency after mosaicoplasty

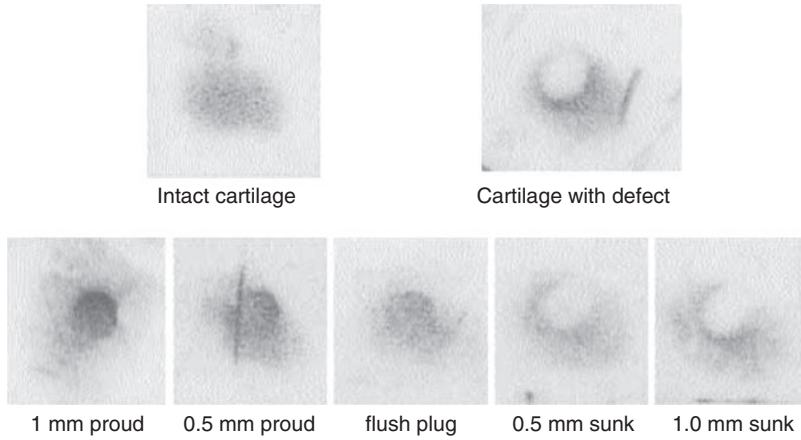

Fig. 46.2 Representative Fuji pressure-sensitive film imprints for the seven different conditions. Note increased color density at margins of empty defect and on elevated (proud) plugs

and Harris have reported that minor technical errors of the treating surgeon may, to some extent, be offset by the use of synthetic three-layer scaffolds, which may better conform to the opposing articular surface, due to the elastic and absorptive nature of the graft [4]. Unfortunately, in clinical practice, synthetic osteochondral implants are not considered to have sufficient potential for long-term remodeling and are often associated with the formation of abnormal fibrous tissue within the subchondral bone layer [5]. Currently available clinical outcome analyses have demonstrated significantly better outcomes and rates of return to sport in those undergoing autologous mosaicplasty, compared to those receiving synthetic biphase or three-phase plugs [6].

With respect to reconstructive surgical options to treat osteochondral injury, the concept of a cell-based "sandwich" technique has the potential for widespread use, if there is sufficient mitigation of associated costs and resource need. Of the available techniques described, the dual-layer, cell-based technique has the greatest potential to restore articular congruity. This is achievable through the surgical contouring of the restored osteochondral surface to match the native radius of curvature and the postoperative plastic adjustments that inherently occur as result of the forces from the opposing articular surface. Additionally, progress in biomaterial engineering has allowed for the development of three-dimensional scaffolds that are more malleable and therefore more amenable to secure seating within chondral defects, as opposed to periosteal tissue that was used by Petersen in the original method. Another important advancement in cell-based cartilage repair is the elimination of the two-stage ACI procedure. The use of autologous bone marrow aspirate concentrate in conjunction with biologic scaffolds, as described by Gobbi [7–9], has been introduced widely into clinical practice and is performed as a one-stage procedure, at considerably reduced cost compared to autologous chondrocyte procedures.

Recent advances in arthroscopic instrumentation have enabled the provision of minimally invasive procedures to treat chondral and osteochondral injury by methods of one-stage, single- or dual-layer, cell-based reconstruction techniques [10]. These developments in instrumentation and biomaterials have greatly reduced the need for procedures that involve invasive arthrotomies to treat chondral and osteochondral defects.

46.3 Knee

46.3.1 Introduction

Full-thickness cartilage injury may be associated with significant subchondral bone pathology and deficiency, leading to further challenges when undertaking cartilage restoration procedures of the knee. In cases of combined cartilage injury and

subchondral bone loss, lesions may not be amenable to treat by conventional chondral only repair techniques. Numerous techniques of cartilage and subchondral bone restoration are currently used: debridement, bone marrow stimulation, autologous or allogenic osteochondral grafting, AMIC-like procedures, cell-based techniques such as autologous chondrocyte implantation (ACI, MACI), and mesenchymal stem cell scaffold-based implantation combined with subchondral bone restoration procedures.

Considering OCL treatment is needed to ask several important questions. Is osteochondral defect reconstruction in the knee necessary? Can procedure be done arthroscopically or with the use of arthrotomy? Is bone grafting necessary or maybe only chondral reconstruction procedure is sufficient? What is the depth of a lesion which needs bone grafting?

The first choice in OCL treatment in the knee is only debridement with loose body removal if necessary. Although some papers describe good results after this procedure in the case of OCD, Linden in his work revealed that almost all patients developed osteoarthritis in 33 years with noticeable worsening after 20 years from OCD identification [11].

Bone marrow stimulation technique like microdrilling, microfracture, or spongiolization in OCL treatment can be performed in smaller lesions <2cm^2 with short- and mid-term good results, but poor quality and fulfillment don't support knee joint congruence and don't improve enough distribution of load; therefore, authors do recommend this technique only for small (<2cm^2), shallow (<5 mm in depth) lesion in young patient pursuing sedentary lifestyle.

With respect to the knee joint OCL, autologous osteochondral transfers or osteochondral allograft transplantation is a well-accepted method of repair for a wide range of cartilage lesion size and depth of bony deficiency. Autologous osteochondral transfer repair technique is recommended to treat lesions about 1–4 cm^2 and is limited by 8 cm^2 lesion size [12]. Although this technique can be performed arthroscopically, lesion bigger than 2–3 cm^2 is really challenging without miniarthrotomy. The advantage of this method is fast recovery, in sport especially. Autologous osteochondral transfer can cause donor site morbidity, particularly in the case of bone blocks >1–1.5 cm^2 in diameter. A limitation of mosaicplasty is requirement to use one or more cylindrical plugs of any given diameter, and for that reason OCL can't be fulfilled. The necessity of partly removing healthy cartilage and subchondral bone in the case of noncircular or irregular osteochondral lesions is further OATS technique limitation. Osteochondral allograft transplantation is further technique capable of repairing the damaged osteochondral unit; however, this is typically performed in an open fashion due to technique limitations. The use of allograft is reserved for large lesion, especially on the edge of the condyle, often after unsuccessful previous surgeries. Reconstitution of the anatomic contour of the articular surface may also be problematic with bigger osteochondral transfer or transplantation procedures, particularly if a mosaicplasty technique is employed.

In 1997 Kevin Stone published his own technique based on autologous osteochondral plugs (received like in mosaicplasty) impacted to paste. A paste was impacted into osteochondral lesion after its debridement to the level of cartilage base, but cartilage layer remained not fulfilled. The author presents good results after 10–23 years, but it is only case series without any control group [13].

Autologous chondrocyte implantation has been shown to provide durable cartilage repair and may also be used in conjunction with bone grafting to reconstitute subchondral bone deficiency [14]. There is no consensus about lesion depth which require filling with bone graft. In most papers authors used to perform this technique in bone loss from 5 to 10 mm in depth [15–17]. In cases of deep subchondral bone loss, "sandwich"-type ACI procedure may be used to reconstruct osteochondral lesions. Originally described by Peterson, the technique uses bone grafting in association with autologous chondrocytes contained between layered periosteal graft [17]. This technique has been modified by Bartlett et al., using a matrix-assisted chondrocyte implantation (MACI) technique in conjunction with bone grafting [18]. Unfortunately, the use of cell-based cartilage repair techniques with autologous chondrocytes may be limited by costs, as this is a

two-stage procedure that requires expansion of chondrocyte cell lines off-site.

Single-stage cell-free scaffold-based AMIC-like techniques are available (described in chapter E. KON) [19]. Another single-stage scaffold-based cartilage repair technique using mesenchymal stem cells sourced from bone marrow (BMAC—bone marrow aspirate concentrate) has been developed. The hyaluronic acid-based scaffold embedded with bone marrow aspirate concentrate (HA-BMAC) provides comparable durability of repair to ACI techniques, at significantly reduced cost and operative time [7, 8, 20]. Cartilage repair using implantation HA-BMAC has demonstrated durable cartilage restoration at medium-term follow-up, with preferential formation of hyaline-like repair tissue [21]. This technique has provided good to excellent clinical outcomes in a wide range of lesion sizes within the knee, including multicompartment lesions over 20 cm^2 in size [9].

Minimally invasive techniques of cartilage repair (ACI, AMIC-like techniques, HA-BMAC) are favored due to the lessened morbidity of surgery and the reduced postoperative recovery period. Arthroscopic cartilage restoration using a hyaluronic acid-based scaffold and activated bone marrow aspirate concentrate has been described previously and is used regularly by our institutions [10]. In cases of significant subchondral bone loss, this technique of cartilage repair may be used arthroscopically in conjunction with bone grafting to reconstruct a wide variety of osteochondral lesion types. We present the one-step arthroscopic technique of Biologic Inlay Osteochondral Reconstruction (BIOR) in the knee (Fig. 46.3a–e), using HA-BMAC and autologous bone graft inlay, to treat full-thickness cartilage lesions associated with significant subchondral bone loss.

46.3.2 Surgical Technique

46.3.2.1 Patient Positioning and Arthroscopic Preparation of Cartilage Defect

The patient is positioned supine in a typical manner for knee arthroscopy, and the operative knee is appropriately exposed. The ipsilateral iliac crest is prepared in anticipation of bone marrow aspiration, and the planned site of autologous bone graft harvest is also exposed. We prefer the ipsilateral proximal tibia as the site for bone graft harvest, with exception of cases that require a larger volume of graft, where the ipsilateral iliac crest may be used. Preoperative MRI is routinely performed to measure the size of the osteochondral lesion and to estimate the required volume of bone graft inlay. The patient is typically given a general anesthesia. An examination of the knee under anesthesia is performed, and concurrent treatment of associated pathology may proceed as indicated. Treatment of bony malalignment and restoration of knee stability will provide the optimal environment for cartilage repair tissue to mature and remodel.

A diagnostic arthroscopy of all knee compartments is performed to locate sites of osteochondral injury and to completely delineate the cartilage defect dimensions (Fig. 46.4). A thorough assessment is necessary to ensure visualization of the entire defect to confirm the appropriateness of arthroscopic treatment. Loose osteochondral fragments should be identified and removed. Comfortable access to the relevant knee compartment may be improved by strategic placement of retraction instruments to manipulate adjacent joint capsule and synovium (Arthroscopic Retracting System, ATMED-Z. Rafalski, Katowice, Poland) [22]. Preparation of the cartilage defect begins with excision of all unstable chondral flaps. The defect margins should be debrided back to a stable, vertical wall of cartilage that is perpendicular to the natural contour of the subchondral plate. A prepared defect that is well contained circumferentially is preferred, as this provides a more favorable environment for cartilage repair tissue to mature. Specialized arthroscopic instruments are often used at our institution to achieve consistent perpendicularity of the cartilage wall surrounding the defect (Chondrectomes Set, ATMED-Z. Rafalski, Katowice, Poland) (Fig. 46.5a). The condition of subchondral bone at the base of the defect should be examined in detail to identify bone deficiency that will be amenable to application of a bone graft inlay to restore the natural radius of curvature of the subchondral articular surface. Any calcified cartilage located within the base of the defect should be removed, and areas of planned bone grafting should be debrided back to healthy bone. The surface area of the defect

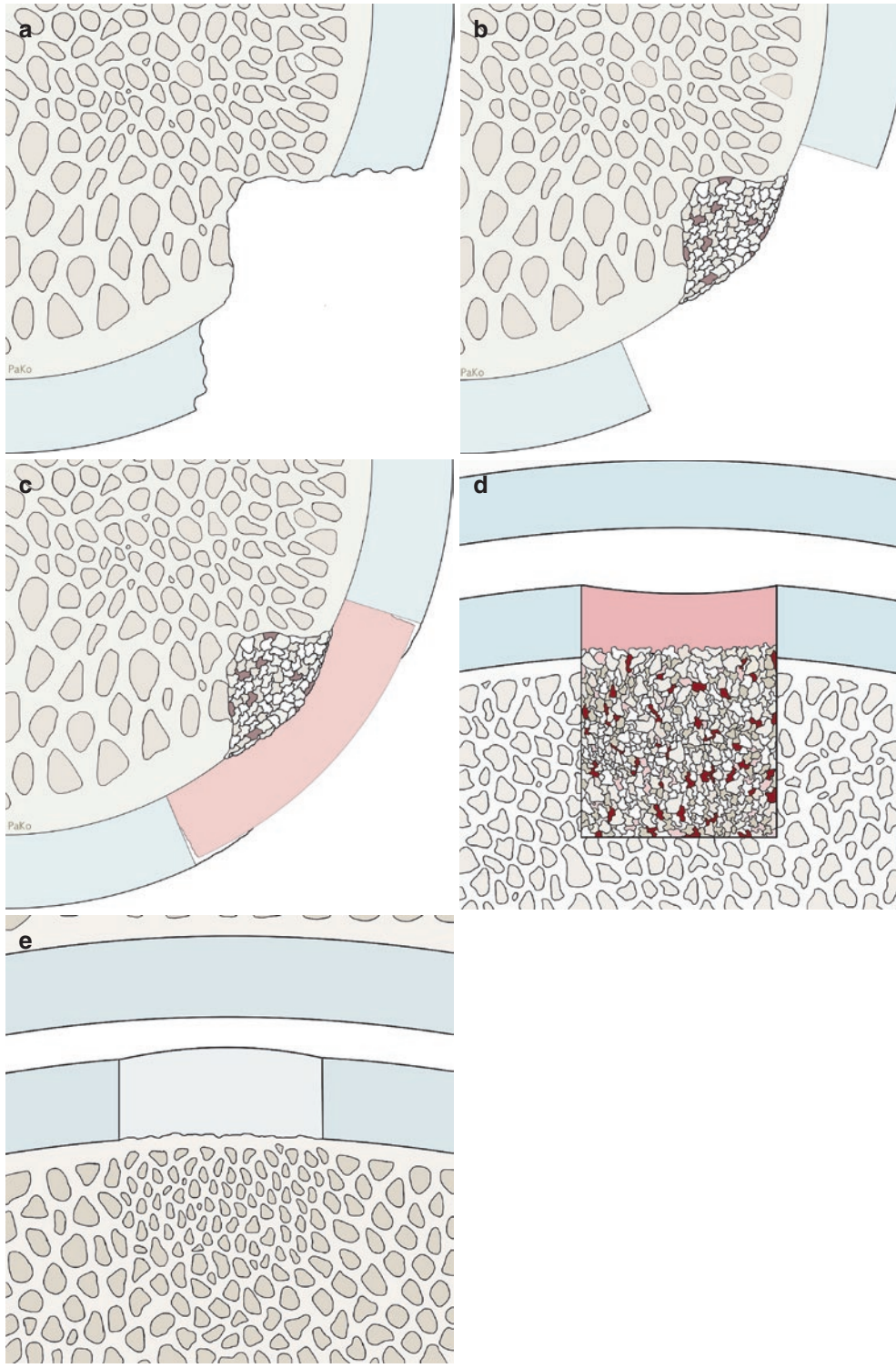

Fig. 46.3 (**a**) An osteochondral defect of the femoral condyle cross-section; (**b**) biologic inlay consists of autogenous morselized bone with fibrin glue and bone marrow aspirate concentrate (BMAC) impacted into the defect; (**c**) the bone inlay covered with hyaluronate or collagen scaffold embedded with BMAC fixed with fibrin glue, (**d**) BIOR (biologic inlay osteochondral repair) the inlay consists of compacted and autologous bony chips with BMAC (bone marrow aspirate concentrate) molded in its surface which is covered with collagen or hyaluronic scaffold immersed with BMAC, (**e**) the regenerate 2 years after BIOR procedure, the remodeled bone layer usually seems to be more compact than surrounding

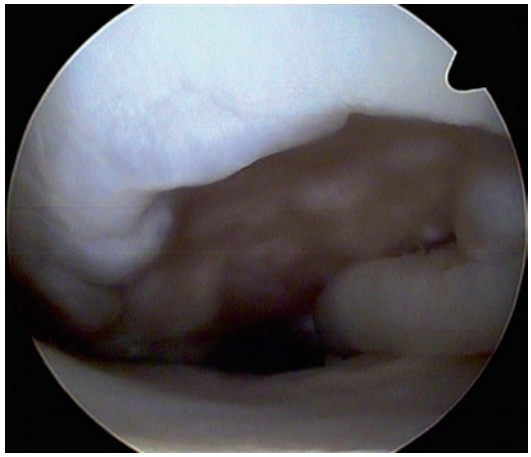

Fig. 46.4 OCL assessment during knee joint arthroscopic inspection

should be assessed using an arthroscopic measuring device or a template in order to accurately size-match the HA-BMAC graft.

46.3.2.2 HA-BMAC and Bone Graft Inlay Preparation

After estimating the volume of required bone graft, autologous cancellous bone harvest should proceed from either the ipsilateral proximal tibia or iliac crest. Bone marrow is aspirated from the ipsilateral iliac crest and a commercially available system is used to prepare the bone marrow concentrate (Harvest BMAC System, Terumo BCT). The morselized bone chips are inserted into the box chamber of the graft applicator. Several drops of BMAC and fibrin glue are added to the bone chips, and the graft is compressed into the 10 mm diameter barrel of the applicator. In the absence of such a bone inlay applicator, the bone chips may simply be mixed in a dish and later applied to the defect using an arthroscopic paddle or spoon via a valveless cannula or a halfpipe.

The three-dimensional hyaluronic acid-based scaffold (Hyalofast, Anika Therapeutics, Srl, Abano Terme, Italy) is appropriately size-matched to the defect dimensions to more easily contain the BMAC and apply it to the scaffold. The malleable HA-BMAC graft is created by combining BMAC with the hyaluronic acid-based scaffold.

46.3.2.3 Dry Arthroscopic Biologic Inlay Osteochondral Reconstruction Procedure

A fluid form the joint is drained from the knee and reevaluated the prepared osteochondral defect to confirm complete visualization. Prepared bone graft is applied to the base of the defect using the specialized applicator or a preferred chosen arthroscopic instrument (Fig. 46.5a). Bony deficiency at the base of the defect is reconstituted with the bone graft inlay using an arthroscopic paddle to contour and compress the graft. Recreation of the natural radius of curvature of the articular surface is a priority (Fig. 46.5a). Using a grasper or non-toothed forceps, HA-BMAC is inserted into the appropriate knee compartment via a valveless cannula or halfpipe, and the graft is placed into the repair site. Graft is securely press-fit within the defect, and the contour of the dual-layer repair structure is reexamined circumferentially to ensure that the expected radius of curvature has been achieved (Fig. 46.5b–d). Under arthroscopic visualization, the knee is gently cycled repeatedly to confirm secure seating of the BIOR construct. Fibrin glue may be added to the graft to provide greater security [23] (Fig. 46.5e). All surgical wounds are closed and covered by sterile dressings. The operative knee is immobilized in a brace set to correspond to the articular tibiofemoral contact angle (typically 40° of flexion) after the repair of osteochondral lesions within the medial or lateral compartments. The advantages/limitations of this surgical procedure are summarized in Table 46.1.

Step-by-Step Technique Summary

- Position patient supine; expose ipsilateral iliac crest and site of bone graft harvest (e.g., proximal tibia) in addition to operative knee.
- Examine the operative knee under anesthesia; prepare for treatment of associated pathology as indicated.
- Perform diagnostic arthroscopy, ensure complete visualization of cartilage lesion and affected subchondral bone, and confirm arthroscopic treatment is appropriate.
- Treat associated pathology or perform corrective osteotomy as indicated.

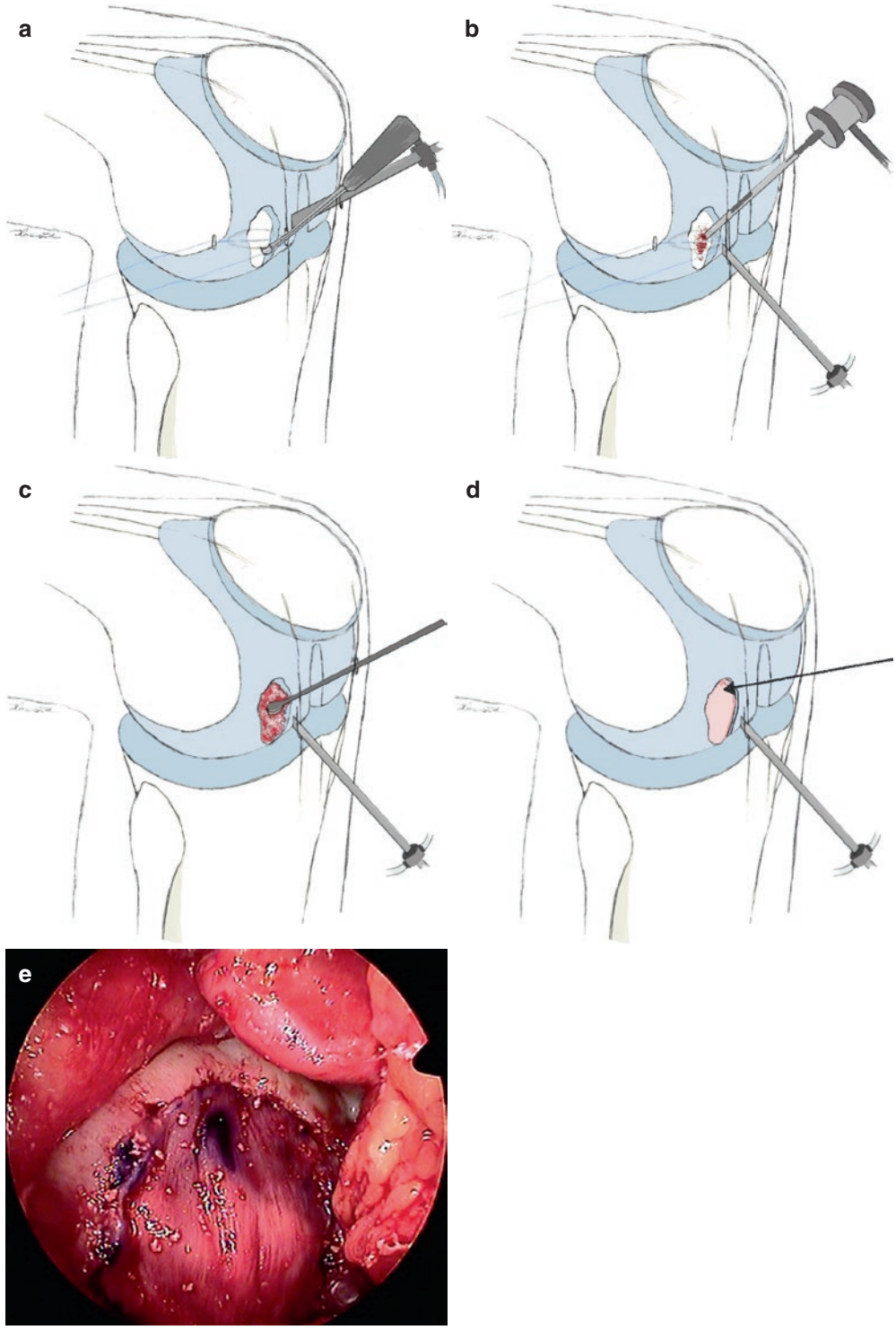

Fig. 46.5 Biologic Inlay Osteochondral Reconstruction: (**a**) cartilage debridement with chondrectomes - loose cartilaginous tissue removing, defect periphery preparing to obtain a wellshouldered cartilage walls; base of defect preparing (layer of calcified cartilage removing); subchondral bone debriding to expose healthy bone, (**b**) prepared bone graft is applied to the base of the defect using the specialized applicator, (**c**) arthroscopic paddle uses to contour and compress the graft (matching the natural radius of curvature of the subchondral surface), (**d**) HA-BMAC graft is securely press-fit into the defect (fibrin glue may be applied to the periphery of the graft to further secure the implant), (**e**) arthroscopic look of reconstructed OCL

Table 46.1. Advantages and limitations of biologic inlay osteochondral reconstruction

Advantages	• One-stage cartilage repair that is capable of addressing subchondral bone deficiency • More precise restoration of the condyle shape and convexity allows achieve higher congruency of the reconstructed articular surface • Arthroscopic technique provides magnification that enables detailed visualization of the defect and implantation procedure • Osteochondral defect is repaired without removing adjacent healthy tissue, as opposed to osteochondral transfer procedures that remove healthy cartilage and subchondral bone • HA-BMAC has been shown to provide durable cartilage restoration that is superior to standard techniques such as marrow stimulation • Minimally invasive approach that is low morbidity and encourages early recovery and rehabilitation • Favorable cost profile compared to other cell-based procedures of osteochondral repair such as autologous chondrocyte implantation with bone grafting
Limitations	• Surgical time in cases of multiple compartment cartilage lesions may be reduced with an open technique • Arthroscopic technique may not provide optimal visualization for larger osteochondral lesions • Long-term clinical outcome data for HA-BMAC used in conjunction with bone grafting is not yet available

- Debride cartilage lesion, remove loose cartilaginous tissue, and prepare defect periphery to obtain a well-shouldered, contained defect.
- Prepare base of defect; remove any layers of calcified cartilage, assess subchondral bone involvement, and debride base to expose healthy bone at sites of planned inlay.
- Measure prepared cartilage defect and record dimensions for size matching of hyaluronic acid-based scaffold.
- Aspirate bone marrow from iliac crest and harvest autologous cancellous bone from planned site.
- Prepare BMAC using chosen commercially available system.
- On a back table, prepare autologous bone graft by placing chips into box compartment of applicator, and add several drops of BMAC and fibrin glue.
- Load prepared bone graft into 10 mm barrel of applicator, or place into dish if specialized applicator is not used.
- Create size-matched hyaluronic acid-based scaffold appropriate for cartilage defect.
- Use BMAC and combine with scaffold to create HA-BMAC implant. Surgeon may elect to use BMAC that has not been clot-activated.
- Remove remaining fluid from joint space and confirm complete visualization of prepared osteochondral defect under dry arthroscopy.
- Apply the bone graft to the base of the cartilage defect and create a bony inlay that reconstitutes the bone deficit, matching the natural radius of curvature of the subchondral surface.
- Insert the HA-BMAC implant into the joint space, use a grasper or non-toothed forceps to place the graft into the cartilage defect, and press-fit securely.
- Fibrin glue may be applied to the periphery of the graft to further secure the implant.
- Gently cycle the knee while visualizing the graft to ensure stability of the construct.
- Close surgical wounds, apply sterile dressing, and immobilize operative knee in a brace set to 40° of flexion in order to maintain shape of graft until fibrous consolidation.

46.4 Ankle

46.4.1 Introduction

The ankle is characterized by more congruency than the knee resulting in thinner cartilage, which requires much more precision in chondral surface reconstruction. Biological treatment of osteochondral lesions of the talar dome (OLT) aims to restore layers of the defect using biological material that undergoes further remodeling and integration with the surrounding tissue. The purpose of the reconstruction is to effectively recreate the shape of the talar dome in each different location, especially on the medial edge, where the most common traumatic lesions are located [24]. Nowadays, the most commonly

used treatment for large osteochondral lesions of the talar dome is OAT with a graft harvested form the knee [25–28]. This technique may produce symptoms of the knee joint related to donor site morbidity after osteochondral graft harvesting [29]. Moreover, the osteochondral graft harvested from the knee rarely restores the talar surface properly, especially in terms of its curvature and the joint congruence. Some authors have reported incomplete integration of the OAT graft with surrounding tissues in relation to bone plug necrosis [30]. Formation of bone cysts after autograft transplantation was also reported [26, 28, 31]. Some authors propose the treatement of OCLT only with chondral procedures. However, it seems deeper defects need to be restored by the bone, which is mechanically resistant to the preload required for proper graft remodeling [29]. In our opinion, successful repair of the deeper talar dome osteochondral lesions requires a separate restoration of the bone layer and chondral layer. Filling the lesion should be adapted to the shape of the talar dome curvature in the same way as a dentist molds a tooth filling. The bone plug filling the defect should be formed and suitably concentrated, to carry the preload joint without collapsing the subchondral layer.

46.4.2 Surgical Technique

46.4.2.1 Approach and Cartilage Defect Preparation

The procedure started with aspiration of 30 ml of bone marrow from the iliac crest, using a set of MarrowStim (Biomet Warsaw, Indiana). The anteromedial approach of the ankle joint was performed if the defect had been accessible from anterior direction. When the defect is localized more posteriorly, then the medial malleolus Chevron osteotomy was performed. The direction of the malleolus osteotomy was planned based on a coronal scan using magnetic resonance or computer tomography to determine the most convenient approach to the defect. The cartilage around the lesion had to be cut perpendicularly to the bottom to form a vertical wall of healthy chondral tissue. The bottom of the lesion was abraded by burr shaver, to achieve superficial bleeding vessels in the subchondral opening bone. Next, three low-speed drills using a 1.6 mm diameter K-wire were made to a depth of about 5 mm (Fig. 46.5c).

46.4.2.2 Biological Inlay in the Talus

After previous bone marrow centrifugation and separation, about 4 ml of the bone marrow concentrate was obtained. Autologous bone was harvested from the proximal tibia of the ipsilateral tibia by creating a little window in the tibial cortex. Harvested bone chips were effectively crushed, and then approximately 1.0 ml of bone marrow concentrate was added. A first portion of the mixture was compacted in the bottom of the lesion (Fig. 46.5d). A second portion of bone chips and MSCs had been mixed and drained off, then two or three drops of Tisseel (Baxter, Deerfield, IL, USA) fibrin glue were added and mixed again just before the application of the mixture into the defect. The last portion of bone chips with MSCs and fibrin glue should reproduce the shape and curvature of the edge of the medial talar dome. This procedure is similar to creating a dental filling, which must be perfectly matched to the shape of the tooth. The formed seal was coated with a thin layer of fibrin glue. Dry arthroscopic imaging was used to provide an enlarged image and better visibility in this small operative area (Fig. 46.5e) [32]. Collagen scaffold (Chondro-Gide, Geistlich Pharma AG, Wolhusen, Switzerland) was matched to the defect and infiltrated with bone marrow concentrate. Then, the scaffold was placed on the bone chip seal, and the edges sealed with fibrin glue (Fig. 46.6). The joint was closed and the medial malleolus was stabilized by two 4.5 in. diameter lag screws (Fig. 46.7). Hardware removal from medial malleolus was performed 12 months after surgery in all patients before MRI examination which was reviewed for the evaluation of remodeling and bone ingrowth of the biological inlay at 12th month and 2 years postoperatively (Fig. 46.8).

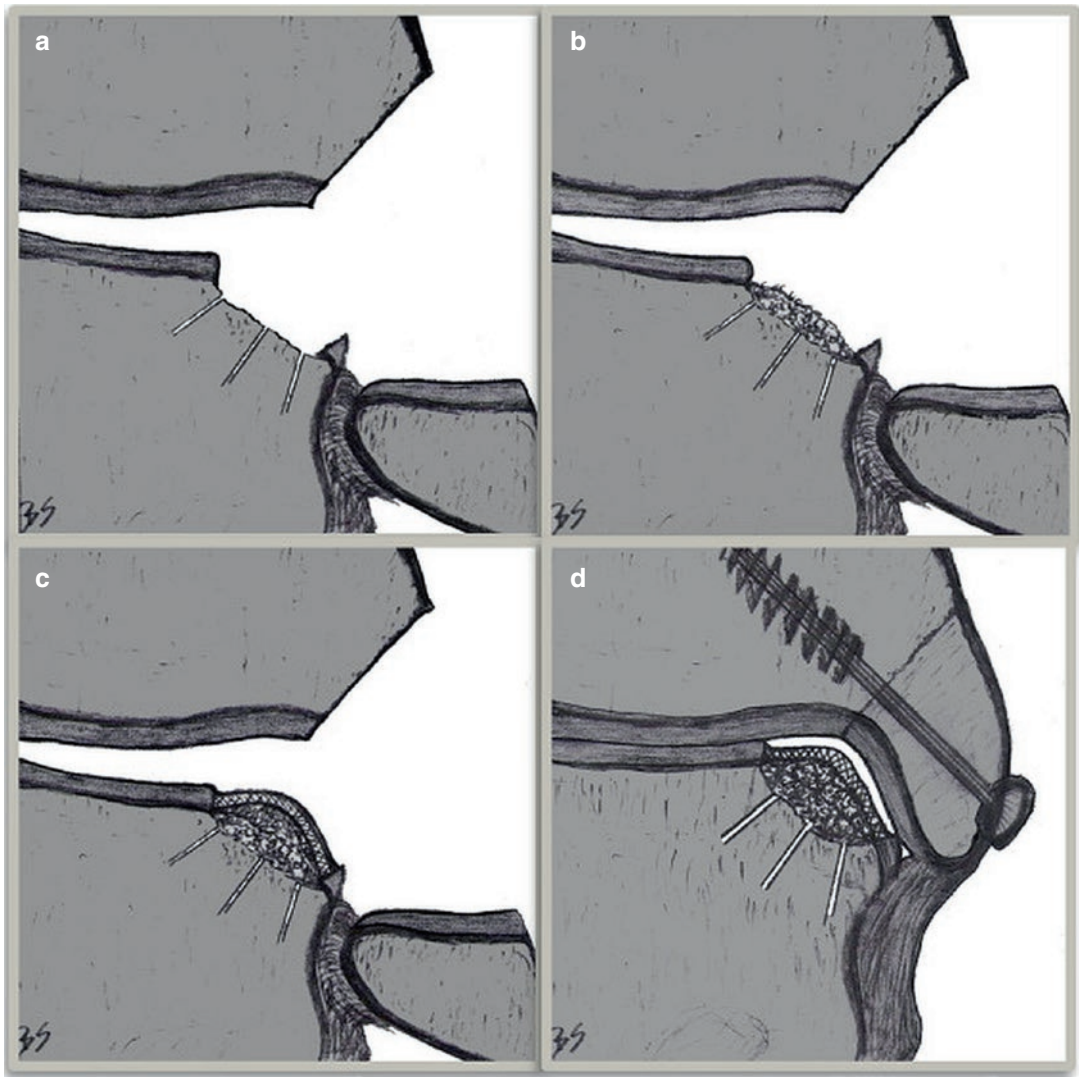

Fig. 46.6 (**a**) Low speed drilling using a 1.6 mm diameter K-wire were made to a depth of about 5 mm, (**b**) first portion of the bone mixture compacted in the bottom of the lesion, (**c**) scaffold placed on the bone chips seal and the edges fixed with fibrin glue, (**d**) joint closed and the medial malleolus stabilized by two 4.5mm in diameter lag screws

46.5 Summary

The treatment of cartilage injury associated with significant subchondral bone loss with the arthroscopic BIOR technique enables reconstruction of damaged osteochondral tissue, while providing a method to restore the natural anatomic contour of the articular surface, in a minimally invasive fashion. The one-step cell-based cartilage technique of HA-BMAC has been used at our institutions with success using both open and arthroscopic methods to treat cartilage defects of varying dimensions and in cases of multicompartmental knee cartilage injury. The arthroscopic BIOR technique combines HA-BMAC cartilage repair with a malleable bony inlay to provide a bilayer autologous reconstruction of the osteochondral unit, with minimal morbidity (Fig. 46.9a–d).

It should be noted that although good to excellent medium-term outcomes have been demonstrated with use of HA-BMAC to treat cartilage

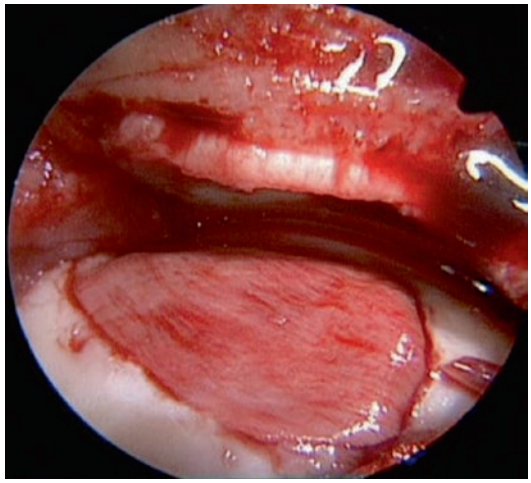

Fig. 46.7 Dry arthroscopic imaging was used to provide an enlarged image and better visibility in this small operative area

injury within the knee, similar outcome analysis is not yet available for use of this technique in conjunction with a bony inlay to reconstitute subchondral bone loss. With regard to the choice of scaffold, a type I/III collagen graft, or similar material, may be used in place of the hyaluronic acid-based scaffold. In our experience, the hyaluronic acid-based scaffold is preferred for arthroscopic use, due to the malleable and adherent nature of the HA-BMAC graft, allowing precise manipulation and placement of the graft within the cartilage defect.

The Biologic Inlay Osteochondral Reconstruction technique of osteochondral repair has the capability to treat a wide range of lesion sizes, with varying depths of subchondral bone loss. In addition, lesions of irregular shape may be repaired without sacrificing healthy adjacent tissue, as opposed to reconstruction procedures that involve circular-shaped osteochondral grafting. Furthermore, while osteochondral autograft or allograft procedures require graft implantation from a near-90° approach, the BIOR technique may be used to restore the natural anatomic radius of curvature of articulating surfaces from a wide variety of angles. This single-stage, dual-layer, cell-based cartilage repair procedure with bony inlay is a versatile technique that has an attractive cost profile and may be used in minimally invasive fashion for a variety of joint cartilage injuries that involve subchondral bone deficiency.

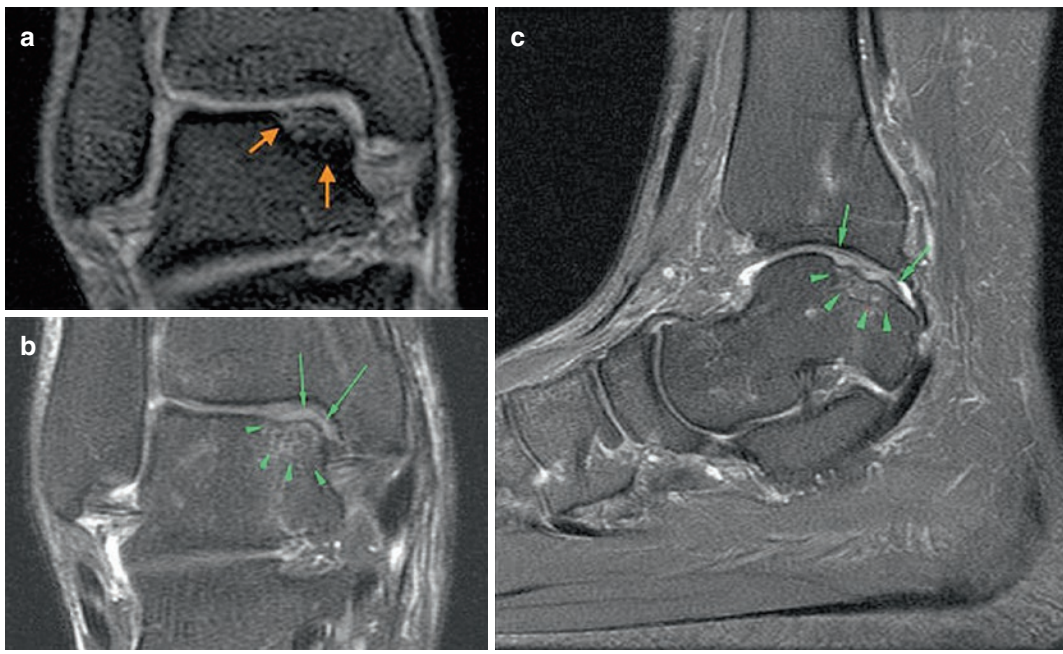

Fig. 46.8 After 12 months MRI 3,0T scans od reconstructed OCT (**a**) *orange arrows* – bone margin of the reconstructed OCL talus, (**b**, **c**) *green arrows* – cartilage regenerate, *green arrowheads* – bone part of the reconstructed OCL talus

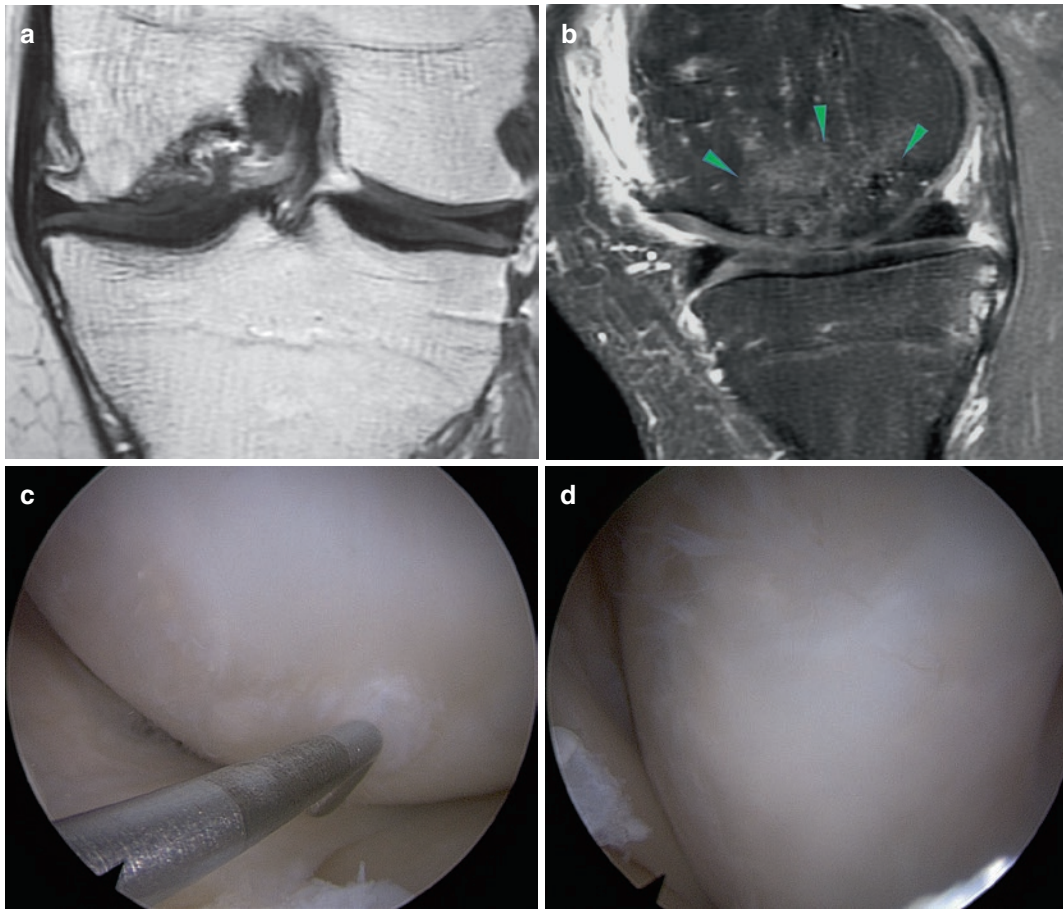

Fig. 46.9 (**a**) Coronal and (**b**) sagittal MRI slices (Proton Density Fat Saturation, 3.0 tesla scanner), *green arrowheads* – base of the reconstructed OCL, (**c**) arthroscopic view the lower part and (**d**) upper part osteochondral lesion of the medial femoral condyle 4 years after BIOR treatment

Biological materials, such as bone autograft, bone marrow concentrate, fibrin glue, and collagen matrix, have been used regularly in orthopedic surgery for many years. The presented modified surgical "sandwich" technique allows the talar convexity to be precisely recreated to match the anatomic radius of curvature of the articular surface. Furthermore, the reconstruction is performed as a one-step procedure. In the 4-year follow-up of our 22 patients, none of the cohort required revision surgery. Except for one patient, all patients were satisfied with the procedure. Postoperative MRI examinations typically demonstrated good quality repair tissue. A notable drawback of this surgical technique is the requirement to perform a medial malleolar osteotomy in a substantial number of cases (10 of 22 patients), which has the potential to increase procedure morbidity.

Currently, all surgical techniques for reconstruction of large osteochondral lesions of the knee or the talus require an approach that provides perpendicular access to the articular surface, thereby allowing the implantation of bone blocks, osteochondral grafts, or synthetic scaffolds. Moreover, there is less tolerance of articular incongruity in the ankle joint compared to the knee, and so surgical techniques to treat articular injury are more demanding. In our opinion, the focus of future treatments of osteochondral lesions should be to develop minimally invasive, or even arthroscopic, techniques that

are appropriate for routine use. Such techniques would enable the restoration of anatomic articular congruence within the ankle joint, while minimizing postoperative morbidity. A specific focus should be on developing techniques that avoid the need for malleolar osteotomy, which remains a disadvantage of current regenerative surgical methods.

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