14 One-Stage Treatment for Osteochondral Lesion of the Talus

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14.1 Cartilage Restoration Considering Ankle Joint Congruency

In order for weight-bearing joints to remain functional and 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 relatively to each other should articulate over the functional range with the smallest frictional forces possible in order to minimize trauma to the opposing surfaces and avoid overheating. 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 pressure and peak loads on the weight-bearing surfaces; these are important factors to minimize the destructive mechanical forces that lead to progressive degenerative joint injury. Given that the ankle joint is the most dynamic human weight-bearing joint, it is crucial that there is proper matching of adjacent articular surfaces over the full range of motion.

The ankle is characterized by higher congruence than the knee with thinner cartilage, and this is why it requires much more precision in chondral surface reconstruction. Surgical 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 every location, especially on the medial edge, where the majority of traumatic lesions are located [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 osteophytes, restoration of anatomic surface geometry is accomplished with a shaver or burr that can be used to mill the subchondral bony protuberance. In cases of large osteochondral defects involving deep areas of subchondral bone deficiency, careful reconstitution of the bone deficit is needed. Special attention must be paid to restore the natural subchondral surface geometry, necessary for optimal adjacent cartilage regeneration.

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G. L. Canata et al. (eds.), *Sports Injuries of the Foot and Ankle*,
https://doi.org/10.1007/978-3-662-58704-1_14

Until now the most commonly used single-stage treatment for large osteochondral lesions of the talar dome was OAT with a graft harvested from the knee [2–5]. Unfortunately, that technique may cause symptoms related to donor site morbidity in the knee after osteochondral autograft harvesting [6]. 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 as well as bone plug necrosis [7].

Biological scaffolds are frequently used to restore chondral tissue and can be implanted as cell-free or cell-embedded scaffolds. Second- or third-generation autologous chondrocyte implantation procedures have been developed to provide cartilage restoration in treatment of significant chondral injury. In cases of cartilage injury that are associated with significant subchondral bone loss, a dual-layer restoration procedure may be used, originally described by Peterson in 2003 as a "sandwich" technique.

Of the available techniques described, the dual-layer, cell-based technique has the greatest potential to restore articular congruity. This is achieved 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 development of three-dimensional scaffolds that are more malleable and therefore more stable 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 biological scaffolds, as described by Gobbi [8, 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. Bone layer of the defect is usually restored by a calcaneus bone plug taken from iliac crest or bone chips compacted into the defect before covering its surface with a chondrogenic matrix [10–12].

14.2 Single-Stage Surgical Treatment of the Osteochondral Lesion

Recent advances in arthroscopic instrumentation have enabled the provision of minimally invasive procedures to treat chondral and osteochondral injury by a one-stage, single- or dual-layer, cell-based reconstruction techniques [13]. These developments in instrumentation and biomaterials have greatly reduced the need for aggressive, open procedures in the treatment of chondral and osteochondral defects.

One of the examples of new one-stage procedures is the arthroscopically assisted approach in surgical repair of osteochondral lesions of the talus using biological inlay osteochondral reconstruction (BIOR) (Fig. 14.1) [14]. In our opinion, successful repair of the deeper osteochondral lesions of the talar dome requires a separate restoration of the bone layer and chondral layer. Filling of the lesion should be adapted to the shape of the curvature of the talar dome in the same way as a dentist molds a tooth filling. The bone plug filling of the defect should be formed and suitably concentrated, to carry the joint preload without the risk of subchondral layer collapse. Due to the limited accessibility to the articular surface of the talar bone, BIOR implantation can be made only through three minimally invasive portals. The classic approach through a medial malleolar osteotomy is advised in cases of larger lesions situated in the talar dome center. Due to a narrow joint space and deep location of the lesion, this arthroscopy assisted and minimally invasive approach may only be performed with the help of a skillful assistant surgeon.

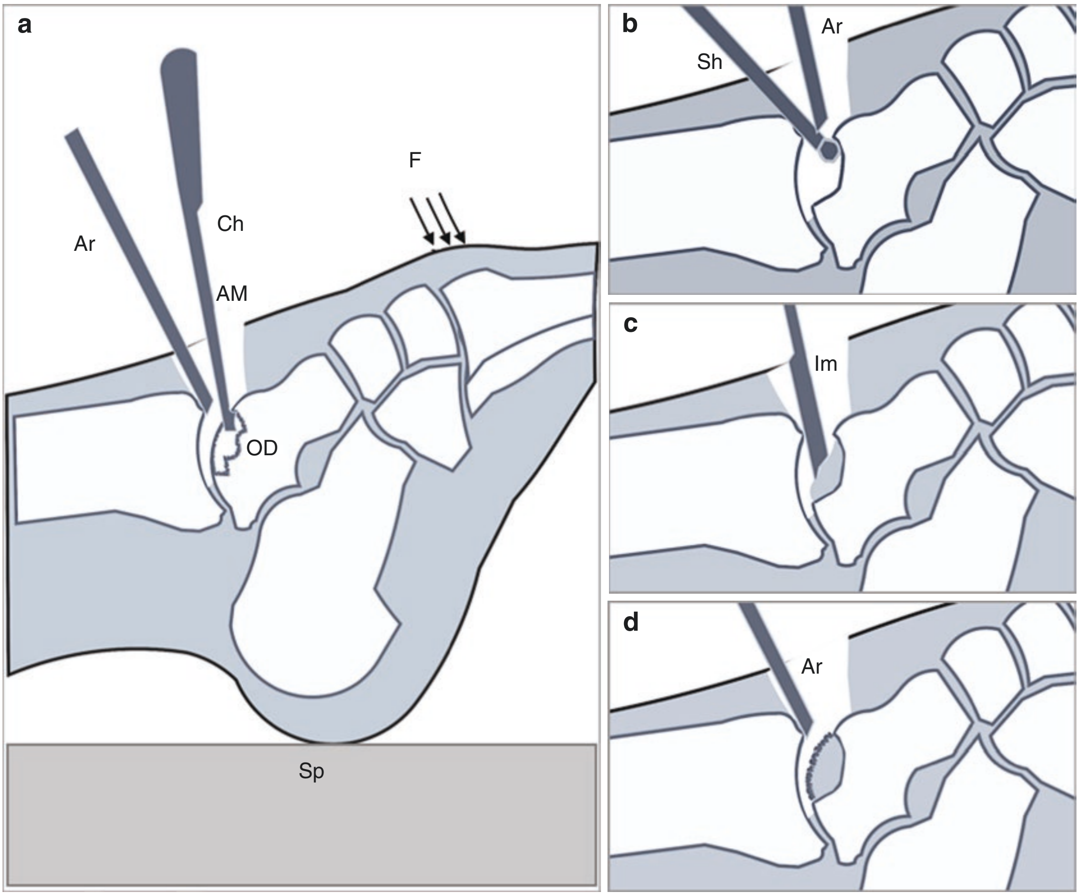

Fig. 14.1 Minimally invasive anteromedial approach to the talar dome with an arthroscope visual assistance for osteochondral defect biological inlay reconstruction (BIOR): AM, anteromedial approach; *Ar* arthroscope, *Ch* chondrectome, *F* force manually applied by an assistant, *OD* osteochondral defect, *Sp* heel support point, *Sh* "burr"-type shaver, *Im* barrel implantation device for bone chips. Biological Inlay Osteochondral Reconstruction step by step: (**a**) osteochondral defect removal using chondrectome or curette; (**b**) refreshing sclerotic bone plate on the bottom and walls of the defect; (**c**) bone chips inlay implantation using barrel implantation device; (**d**) bone chips inlay covered with matrix immersed with BMAC

14.3 Approaches to the Talar Osteochondral Lesion

An arthroscopic approach is useful in the cases of shallow osteochondral or chondral lesions treated by defect debridement and bone marrow stimulation technique. In favorable conditions, an arthroscopic matrix implantation might be achievable, although a minimally invasive open technique is much easier for that purpose. Osteochondral reconstruction of a deep lesion needs to be performed with an open approach.

14.3.1 Anteromedial Approach

The anteromedial approach that requires skin incision from 3 to 4 cm long directly above the joint line, medially to the tibialis anterior tendon, is the most often used technique for addressing lesions localized on the anterior and central surface of the medial talar dome. The patient is positioned supine, as for standard ankle arthroscopy. Up to 50% of the medial talar dome surface can be visualized arthroscopically after synovium removal and excessive plantar flexion of the foot.

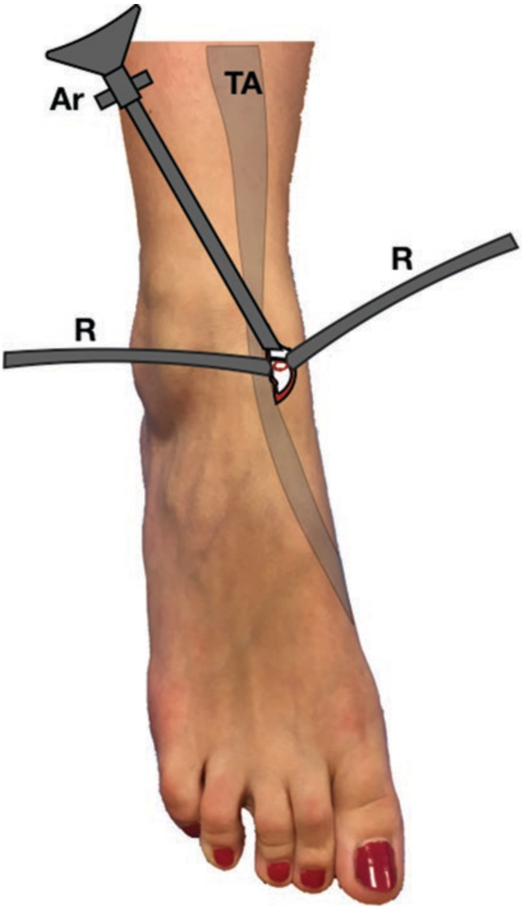

Fig. 14.2 Anteromedial arthroscopic approach to the ankle joint. *Ar* arthroscope, *R* retractor, *Ta* tibialis anterior tendon

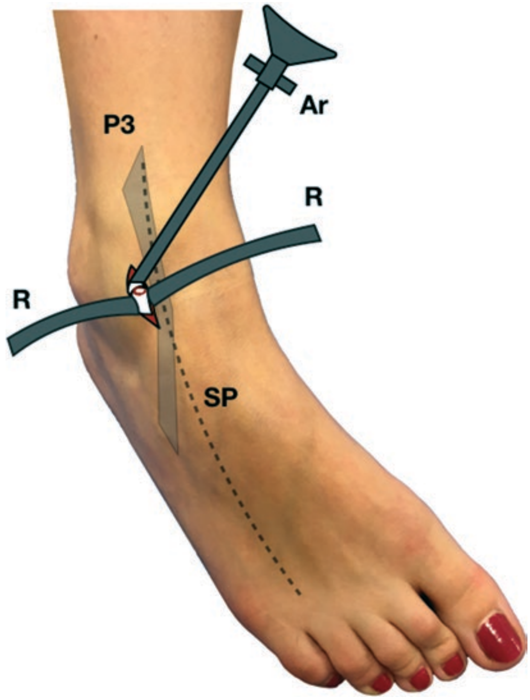

Fig. 14.3 Anterolateral approach to the ankle joint. *Ar* arthroscope, *R* retractor, *P3* peroneus tertius tendon, *SP* superficial peroneal nerve

Treatment of the lesion and implantation in such a narrow space is possible with the assistance of an arthroscope, controlled by an assistant, while the work of the second assistant should be focused on maneuvering the foot (Fig. 14.2).

14.3.2 Anterolateral Approach

In the case of a lesion localized in the anterolateral part of the talus, an analogous technique may be applied from the anterolateral approach. It is performed on the anterior edge of the lateral malleolus with the retraction of the third tendon of the sagittal muscle in the medial direction. Also in this situation, two assistants are required to perform the implantation. Special attention must be paid to not damage the intermediate dorsal cutaneous nerve, which should remain intact either on the lateral or medial side of the incision (Fig. 14.3).

14.3.3 Posterolateral Approach

If the defect is located in the lateral part, it is accessible from an incision located on the posterolateral side of the joint, near a lateral border of the Achilles tendon. The incision is made at the level of a standard posterolateral portal; the cut should be extended by 1.5 cm proximally and 1.5 cm distally. The patient is placed on their side, and the operated limb is turned upward with knee bent to 90°. This position relaxes the tension of the calf muscles and allows the Achilles tendon to be pulled toward the medial side. The dorsal flexion of the foot held by the assistant makes it possible to visualize 20% of the surface of posterolateral edge of the talus. Also here, the use of

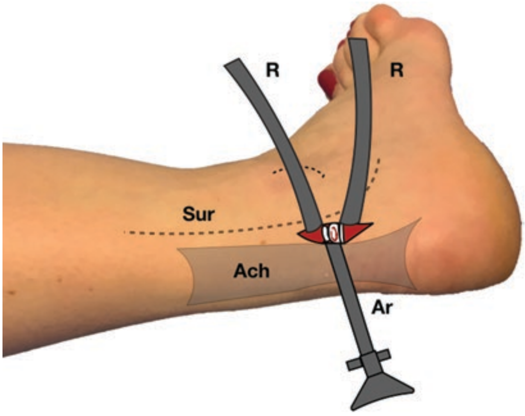

Fig. 14.4 Posterolateral approach to the ankle joint. *Ach* Achilles tendon, *Ar* arthroscope, *R* retractor, *Sur* Sural nerve

an arthroscope to visualize the operating field is necessary (Fig. 14.4).

14.3.4 Standard Approach Through the Medial Malleolus Osteotomy

Approach to the lesion located in the posteromedial-central part is possible only through the osteotomy of the medial malleolus, which is the most common and well-known approach, used and described by many authors [1, 3, 5].

14.4 Postoperative Management and MRI Monitoring

Deep osteochondral defects of the talus are more often seen at the outpatient clinic than chondral ones, which require only bone marrow stimulation technique or chondral scaffold implantation. Deep osteochondral defects are much more demanding and should be treated with surgical techniques considering reconstruction of both bone and chondral layers of the defect. Expected time of graft remodeling and healing is longer when compared with treatment of a chondral defect. Thus the type of surgical reconstruction method implies specific postoperative treatment and what is more important the rehabilitation protocol should be individually modified. In our opinion, the best way to properly control the osteochondral graft maturation is periodically checking of the graft status. In our center, after undergoing osteochondral regeneration procedures, patients are followed up with a monitoring MRI protocol, 6 weeks then 6 and 12 months postoperatively. Depending on the bone and subchondral lamina quality, patients are allowed more or less physical activity. Slow maturation process of the graft indicates a modified pharmacotherapy or/and physiotherapy.

The rehabilitation protocol after biologic surgical treatment of osteochondral injury is based on the size and location of the osteochondral defect and the contact angle (CA). CA is the angle of the reconstructed articular surface that stays in contact with the opposite articular surface during ankle movement. This crucial information allows the physiotherapist to determine a safe ROM in exercise progression.

In the authors' experience, the individual rehabilitation strategy should be planned carefully, taking into consideration these three key issues:

- Restricted joint motion in the initial phase of graft integration (first 7–10 days), in order to allow graft integration and the formation of a fibrous hematoma on its interface, and then progressively increasing joint motion up to full range, applying passive mobilization with the joint distraction.
- MRI graft maturation monitoring at 3 or 6 weeks and then 6 and 12 months after the surgery.
- Orthopedic equipment should be individualized, depending on the size, location, and CA of the osteochondral reconstruction.

In all cases, the rehabilitation process should be modified depending on the joint status as swelling, adhesion, additional procedures or injures, as well as MRI assessment.

In the first 7–10 days, we recommend limited joint motion, in order to encourage successful integration of the repair tissue and the formation of a fibrous hematoma. After this period, range of motion exercises should be undertaken in conjunction with joint distraction. Partial weight-bearing should begin 4 or 5 weeks after surgery, with expected unrestricted weight-bearing by weeks 6, 7, or 8, depending on MRI assessment at week 6. It is important for a physiotherapist to understand that a predefined ROM is necessary to restore the anatomic curvature of the talus. To optimize postoperative monitoring of the healing process and formation of repair tissue, it is recommended that patients undergo MRI at 6 and 12 weeks after surgery. At 3 months, patients progress to straight-line running, with an emphasis on strength, endurance, and aerobic training. Sport-specific training typically begins at 8 months, with expected return to competition by 10 months postoperatively.

Most of the rehabilitation centers use standard postoperative rehabilitation protocols after ankle osteochondral lesion surgical treatment. Management can be various, depending on lesion size and localization, comorbidities, and patient age. The late postoperative management, considering various physical activities of the patients, should be administered with functional tests and graft maturation rate in MRI. Various graft maturation dynamics in MRI assessment can be seen (Figs. 14.5, 14.6, 14.7). There is noticeably slower graft rebuilding rate in older patients. The biological osteochondral reconstructions of the talar dome seem to be slower in maturation comparing to the knee. There is no universal postoperative protocol after osteochondral reconstruction, due to the fact that biological healing of the graft is not well defined and uncontrolled in vivo.

14.5 Summary

The treatment of cartilage injury associated with significant subchondral bone loss with the arthroscopic BIOR technique enables reconstruction of damaged osteochondral tissue and restoration of 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 various dimensions and also multi-compartmental 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.

The biological inlay osteochondral reconstruction technique of osteochondral repair has the capability to treat a wide range of lesion sizes, with various 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 articulating surface curvature, 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.

Biological materials, such as bone autograft, bone marrow concentrate, fibrin glue, and collagen matrix have been used 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 were satisfied with the outcome. Postoperative MRI examinations typically demonstrated good quality repair tissue. A notable drawback of this surgical technique was a need to perform a medial malleolar osteotomy in a substantial number of cases (10 of 22 patients), which theoretically may increase procedure morbidity.

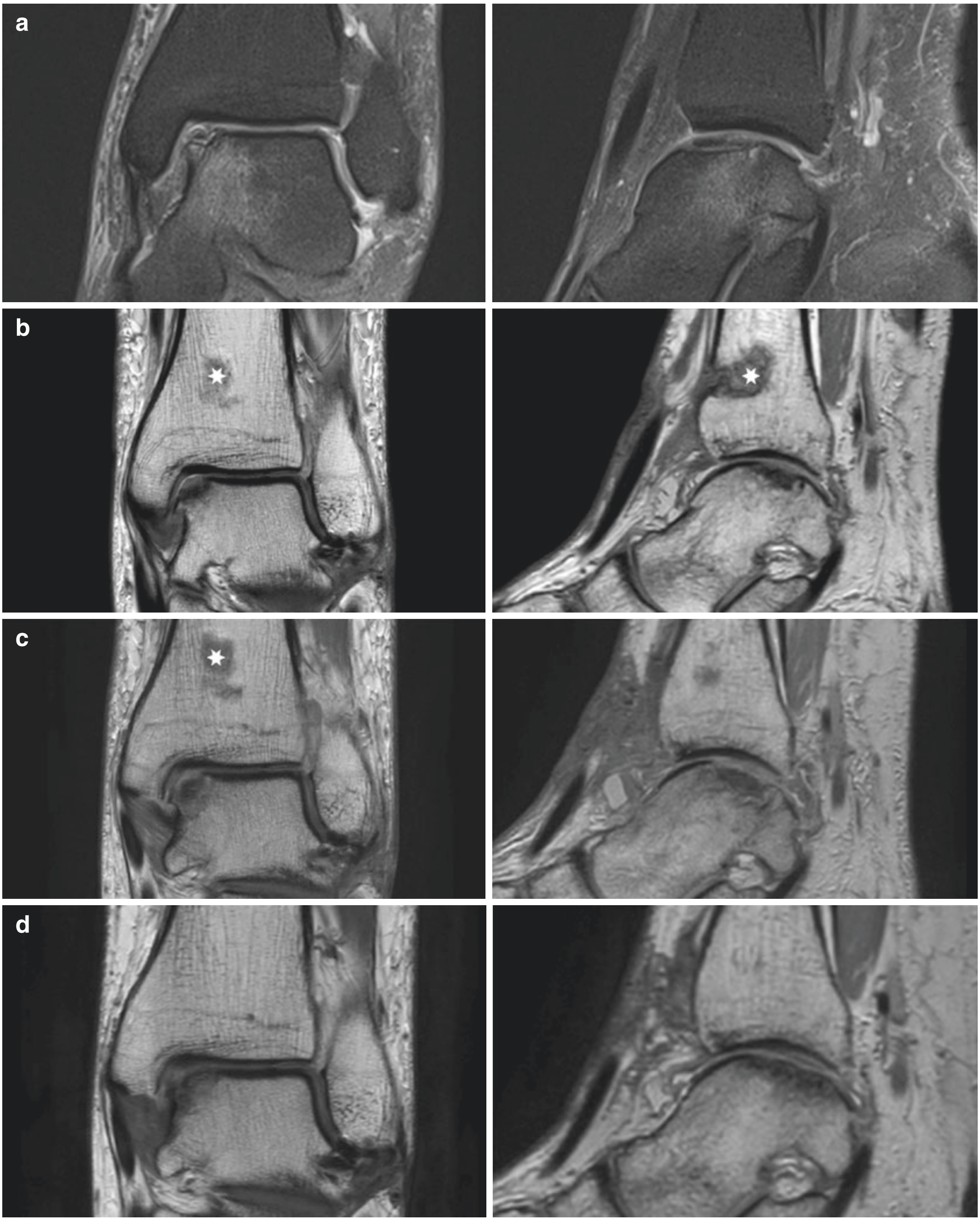

Fig. 14.5 An example of slow remodeling of the biological inlay of medial talus. MRI evaluation of the left ankle of a 48-year-old female regarding the stepwise remodeling of the subchondral lamina and chondral surface: (**a**) osteochondral defect grade III of the medial aspect of the talar dome, preoperatively; (**b**) biological osteochondral inlay (asterisk indicates donor site of a spongiosa bone graft), 3 months postoperatively; (**c**) 6 months postoperatively, a border of subchondral lamina and chondral surface are clearly visible, bone edema slightly decreased; proton density (PD) with or without fat saturation (FS) (m-SPIRE, 3.0 Tesla digital scanner) and sagittal and coronal scans shape of the talar dome properly formed (3 months postoperatively); (**c**) still proper shape of the talar dome, subchondral lamina not visible yet (12 months postoperatively); (**d**) subchondral lamina and chondral layer visible (24 months postoperatively); PD (proton density) with or without fat saturation (m-SPIRE, 3.0 Tesla digital scanner); sagittal and coronal scans

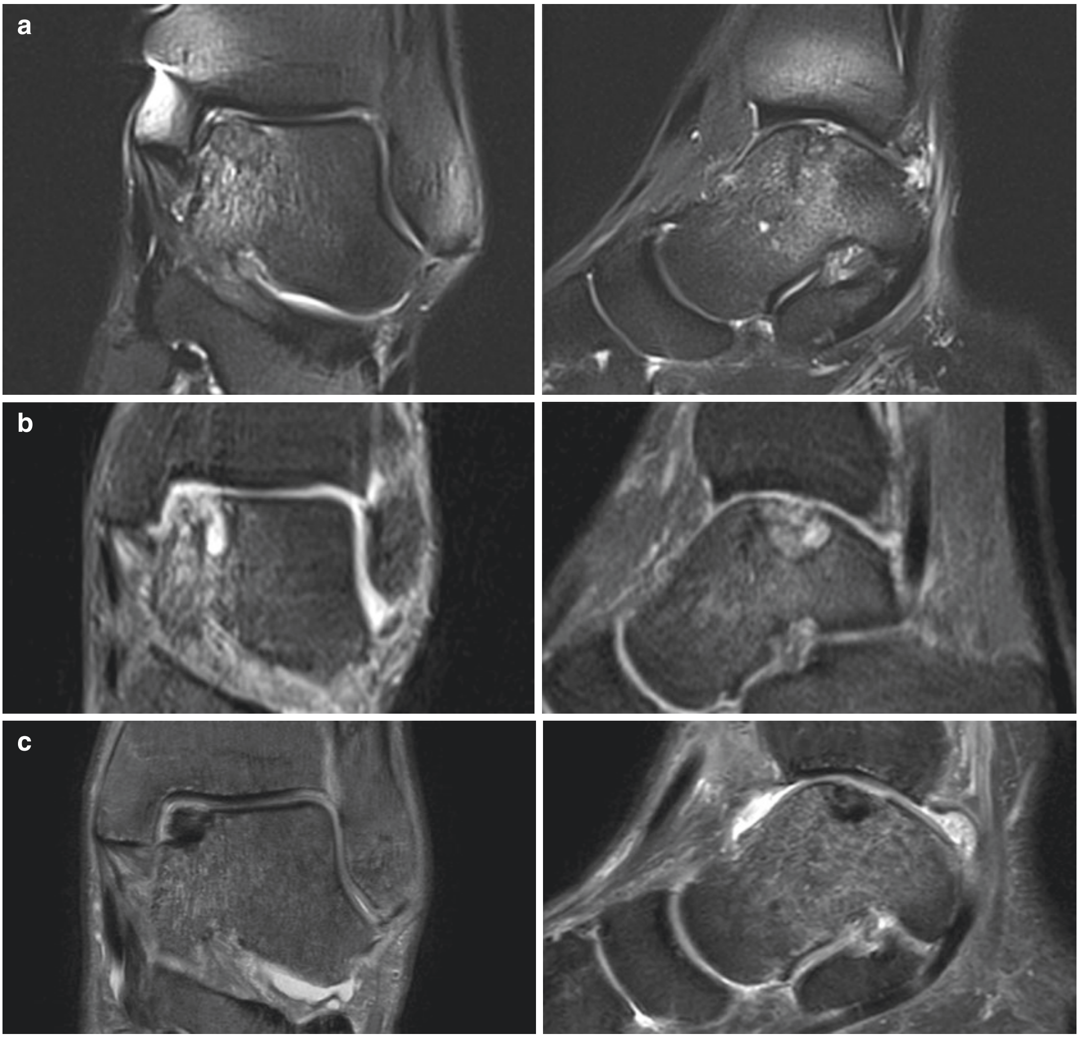

Fig. 14.6 Natural history of OLT: (**a**) the first MRI at the beginning of the ankle pain (2 years before surgery), only chondral lesion and subchondral bone edema can be seen on the medial boulder of the talus; (**b**) MRI scans 2 months before surgery, chondral lesion and edema extended, and several pseudocysts appeared in the region of talar edema. MRI 2 months after OLT reconstruction with BIOR technique; (**c**) talar dome curvature and structure were restored; PD (proton density) with or without fat saturation (m-SPIRE, 3.0 Tesla digital scanner) and sagittal and coronal scans

Currently, all surgical techniques for reconstruction of large osteochondral lesions of 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. It should be specifically focused on the development of a technique that avoids the malleolar osteotomy, which remains a disadvantage of current regenerative surgical methods.

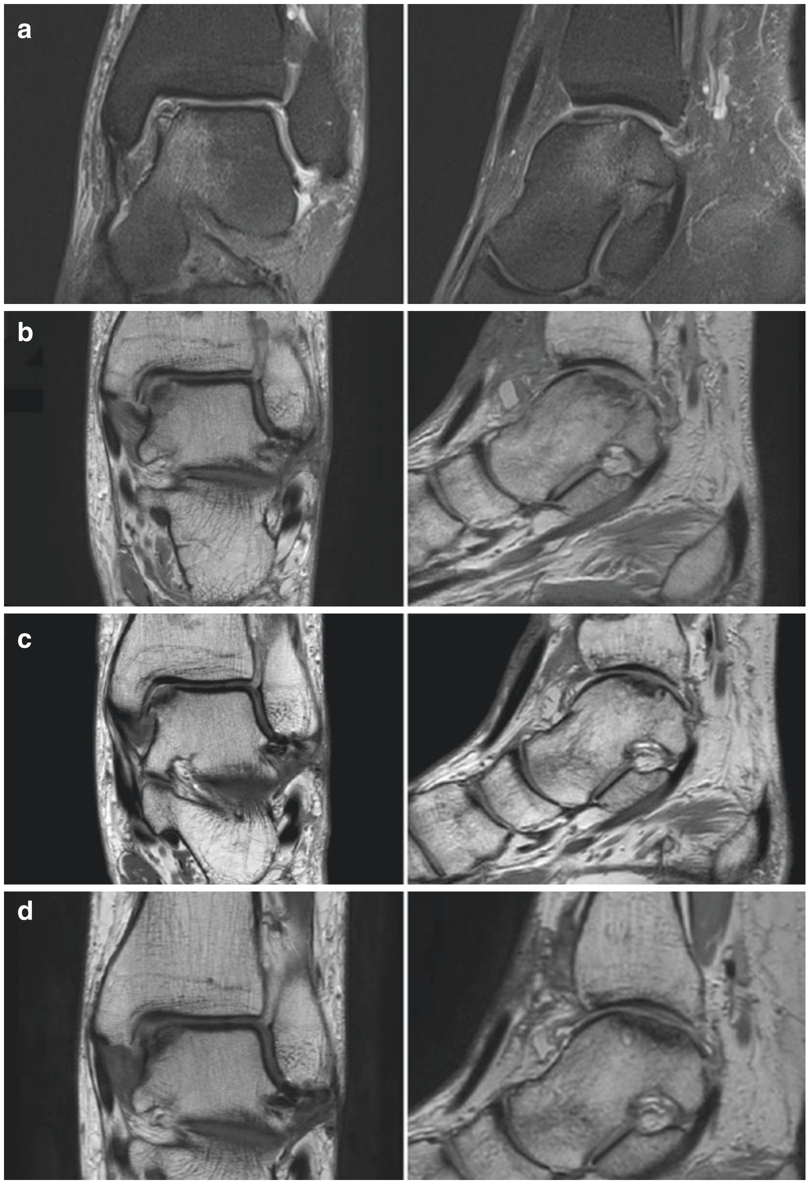

Fig. 14.7 A 45 year old female treated for OCD of the talus - BIOR procedure was performed through miniarthrotomy from antero-medial approach, additionally ATFL and CFL reconstruction was done. MRI scans show the lesion preoperatively (**a**), and a slow maturation process of the graft: 1 month postoperative (**b**), 3 months postoperative (**c**) and 18 months postoperative (**d**)

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