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Biological reconstruction of large osteochondral lesions of the talar dome with a modified “sandwich” technique—Midterm results

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ABSTRACT

Background: Surgical treatment for large osteochondral lesions of the talar dome (OLTD) must restore the convexity and curvature of the talus. Here, we present midterm results and describe the modified “sandwich” reconstruction procedure. Bone defects were restored using a biological inlay consists of autologous bone chips that were mixed with bone marrow concentrate and fibrin glue and covered with a xenogeneic collagen membrane infiltrated with bone marrow concentrate and stabilized by fibrin glue.
Methods: Ten patients who were treated using a modified “sandwich” OLTD reconstruction were assessed after an average follow-up period of 46.4 (±18) months, using the clinical American Orthopaedic Foot and Ankle Society Ankle Hindfoot Scale (AOFAS) score and radiological magnetic resonance observation of cartilage repair tissue (MOCART) score.
Results: The mean AOFAS score increased significantly from 58.3 (±8.5) points to 81.8 (±15.5) points as well the mean VAS score reduced significantly from 5.58 (±0.97) to 1.83 (±0.93) points. The average MOCART score was 69.5% (±16.7%) in the final follow-up.
Conclusions: The presented modified “sandwich” technique permanently recreates the convexity and curvature in large osteochondral lesions of the talar dome with a single step surgical procedure.

1. Introduction

Osteochondral lesions of the talar dome may develop when there is idiopathic necrosis of cartilage and bone (osteochondritis dissecans—OCD), subchondral cysts, posttraumatic focal necrosis, trauma, or repetitive microdamages [1,2]. Small osteochondral lesions of the talar dome are successfully treated arthroscopically with a bone marrow stimulation technique (BMST). In case of traumatic fracture of a large osteochondral fragment, an arthrotomy and reimplantation of a broken piece of the articular surface is recommended [3–6]. More extensive lesions of the articular surface require the use of a regenerative method, which is based on covering the lesion with a matrix containing autologous chondrocytes (ACI) or bone marrow mesenchymal stem cells (MSCs) [5,7–9]. The large osteochondral defect of the talar dome is a difficult therapeutic problem, as it requires restoration of damaged layers of both bone and cartilage [10]. According to numerous authors, the treatment of large osteochondral lesions with osteochondral autologous transposition (OAT) gives very good results [11], but critics of this method are concerned that the healthy knee joint has to be breached to obtain the osteochondral graft, and that there will be problems obtaining the native curvature of the articular surface on the talar dome [12]. Another significant disadvantage of the OAT technique is a lack of full integration of the transplanted block with the surrounding bone and cartilage [10,12]. The dual-layer reconstruction of an osteochondral lesion that recreates the specific shape of the surface is known as the “sandwich” technique and involves the implantation of autologous bone chips and covering their surface with autologous chondrocyte cultures or an empty collagen matrix [13–15].

2. Materials and methods

Ten patients (six males and four females) were treated at our institution from January 2011 to August 2013. The average age at the time of surgery was 37 (±12.5) years. The average follow-up

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period was 46.4 (±18) months. The average BMI index of patients was 26.7 (±3.5) kg/m^2. There were seven right and three left ankle joints involved. The average calculated size of the defect was 132 (±59) mm^2. Two patients were treated unsuccessfully before the index procedure with arthroscopic microfracturation techniques. Clinical results were assessed with Visual Analog Score for pain evaluation (VAS) and American Orthopaedic Foot and Ankle Society Ankle Hindfoot Scale (AOFAS) [16]. Table 1 presents clinical and radiological variables of patients with osteochondral lesion of the medial talar dome. Bone healing of the osteotomy site was assessed in anteroposterior and lateral weight-bearing radiographs. The magnetic resonance observation of cartilage repair tissue (MOCART) score, which measures different variables to describe the constitution of the cartilage repair tissue and the surrounding structures, was used to evaluate the regenerative tissue fulfilling the talar defect [17]. In addition, patients were asked if they would undergo that procedure again or would recommend it to their relatives and family. All patients were treated using an identical surgical technique.

2.1. Surgical technique

The procedure started with aspiration of 30 ml of bone marrow from the iliac crest, using a set of MarrowStim (Biomet Warsaw, Indiana). After centrifugation and separation, about 4 ml of the bone marrow concentrate was obtained. Then, a 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 posterior tibial tendon had to be protected at the beginning of the osteotomy. Before debridement, it is recommended to use a piece of smooth material for joint protection against the falling tissue remnant. The cartilage around the lesion had to be cut perpendicularly to the bottom to form a vertical wall of healthy chondral tissue. To achieve vertical edges, according to Steadman's recommendation, a surgical knife blade number 11, a curette, and a small rounded chisel were used. 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 10 mm (Fig. 1A). Autologous bone was harvested from the tuberosity of the ipsilateral tibia by creating a little window in the tibial cortex. Harvested bone chips were effectively crushed, and then approximately 1 cm^3 of bone marrow concentrate was added. A first portion of the mixture was compacted in the bottom of the lesion (Fig. 1B). 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 (Fig. 2). 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. 3). Collagen membrane (Chondro-Gide, Geistlich Pharma AG, Wolhusen, Switzerland) was matched to the defect and infiltrated with bone marrow concentrate. Then, the membrane was placed on the bone chips seal, and the edges sealed with fibrin glue (Figs. 1C and 4). The joint was closed and the medial malleolus was stabilized by two lag screws with 4.5 mm diameters (Fig. 1D). Hardware removal from medial malleolus were performed 12 months after surgery in all patients, before MRI examination which were reviewed for the evaluation of remodeling and bone ingrowth of the biological inlay at 12th month and 2 years postoperatively.

2.2. Postoperative care

Postoperative care consists of immobilization using a short-leg, non-weight-bearing casting for 2 weeks postoperatively, subsequently a walker (Aircast Walker, DJO Global, Vista, California) and functional physiotherapy with 15 kg partial weight bearing, maximal range of passive motion of 20° and lymphatic drainage massage for the next 4–6 weeks. This initial phase is followed by an intensive rehabilitation phase with progression to full weight bearing and strengthening of the ankle joint stabilizing lower leg muscles and proprioception training for the following 6 weeks (up to 12 weeks). The patients were seen in the outpatient clinic in 6th and 12th week after the surgery for a clinical follow-up examination and conventional radiographs. Routine weight-bearing radiographs (anteroposterior mortise and lateral views) were obtained in 6th and 12th week postoperatively. After 6 weeks, light sports exercising (swimming and cycling) were allowed. Return to competitive sports was preferred after 5–6 months. After

Table 1
Clinical and radiological variables of patients with osteochondral lesion of the medial talar dome; AOFAS—American Orthopaedic Foot and Ankle Society hindfoot scale; VAS—visual analog scale; MOCART—magnetic resonance observation of cartilage repair tissue; pre—preoperative; post—postoperative; y—yes; n—no; M—male; F—female; R—right; L—left; Arthr. Mfx—arthroscopical microfracture; ATFL—anterior talofibular ligament; TP—tibialis posterior; CFL—calcaneofibular ligament.

Case	Sex	Age	Smoker	BMI	Previous trauma	OCL size mm^2	OCL volume mm^3	Side	Previous surgery	Add procedure	VAS pre	VAS post	AOFAS pre	AOFAS post	MOCART final follow-up
1	M	21	n	29.8	y	120	600	R		ATFL repair	4.6	1.2	62	98	60
2	M	53	n	29	y	91	728	R			7	4.2	35	66	55
3	M	56	n	29.7	y	84	420	R		ATFL repair	5	1.4	47	72	65
4	M	52	n	25.5	n	280	3920	L			4.1	1.5	69	85	50
5	F	36	y	23.8	n	176	1232	L			6.2	1.5	69	83	45
6	F	25	n	29	n	117	702	R	Arthr. Mfx	TP repair after iatrogenic cut	5.5	2.5	39	63	90
7	M	29	n	21.8	y	84	504	R			4.8	1	65	92	80
8	F	33	n	31.8	y	144	720	R		Achilles elongational "Z" tenotomy	6.5	2	59	75	75
9	F	38	n	22.4	n	104	624	L	Arthr. Mfx		6.6	1.6	76	100	90
10	M	28	n	24.2	n	117	585	R		ATFL, CFL reconstruction	5.5	1.4	62	84	85
Average	4F/6M	37.1	1y/9n	26.7	5y/5n	131.7	1003.5	7R/3L			5.58	1.83	58.3	81.8	69.5

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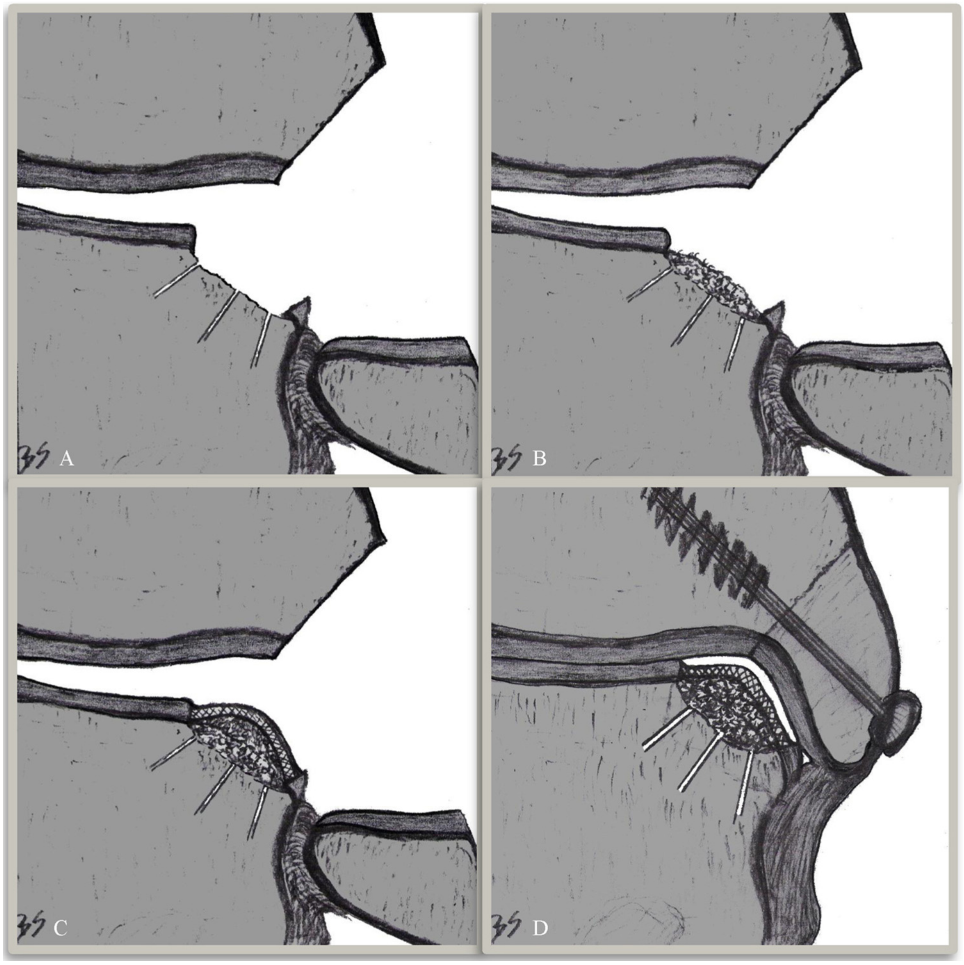

Fig. 1. The cross-sectional scheme of the right ankle joint after abrasion and drilling the bottom of the medial talar dome lesion (A); after implantation of the first portion of the mixture of bone chips and bone marrow concentrate (B); after implantation of the second layer of the bone chips mixture forming the convex seal, its surface covered by a piece of collagen matrix infiltrated with the bone marrow concentrate (C); and after medial ankle fixation using lag screws (D).

6 weeks, light sports exercising (swimming and cycling) were allowed. Return to competitive sports was preferred after 5–6 months.

2.3. Statistical methods

All data were collected and analyzed using Microsoft Excel software to determine the mean scores, range, and standard deviations. The normal distribution of each parameter was tested with the Shapiro–Wilk test. The Student's paired t-test was used to assess the mean scores pre and post treatment. Dichotomous data are presented as percentages. All continuous and interval variables are presented as the mean ± standard deviation. Statistical

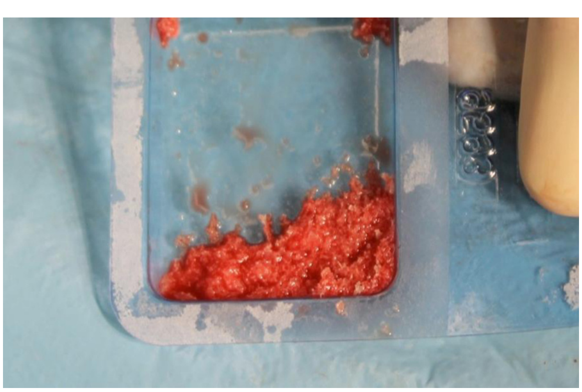

Fig. 2. Autologous bone chips mixed with bone marrow aspirate concentrate and fibrin glue before the implantation.

Fig. 3. Dry arthroscopic image of the osteochondral lesion of the medial talar dome, after debridement and drilling.

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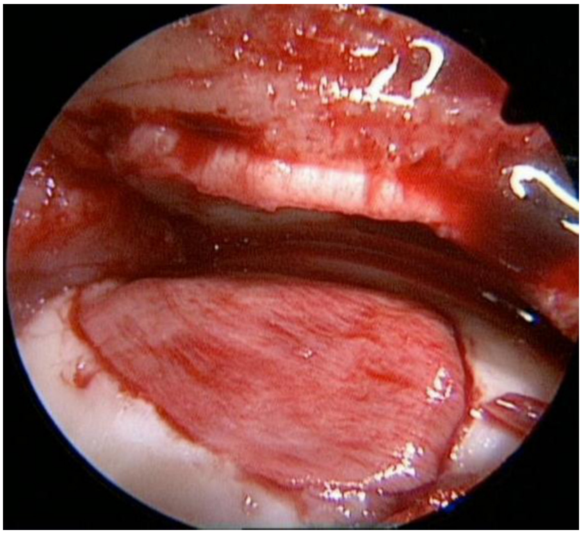

Fig. 4. Dry arthroscopic image of collagen matrix covering bone inlay soaked with bone marrow, matched closely to the shouldering cartilage of the talar dome lesion.

significance was set at $p < 0.05$. All statistical analysis was performed using Statistica 10, by StatSoft, 2013.

3. Results

The medial malleolar osteotomy site healed in every case. One patient sustained an iatrogenic lesion of the posterior tibial tendon during medial malleolar osteotomy that was repaired during the procedure. The mean VAS score reduced significantly from 5.58 ($\pm$0.97) to 1.83 ($\pm$0.93) points. The mean AOFAS score increased significantly from 58.3 ($\pm$8.5) points to 81.8 ($\pm$15.5) points ($p < 0.005$). The average MOCART score on MRI was 69.5% ($\pm$16.7%). Table 1 presents VAS and AOFAS scores before and after surgery, as well as the results of MOCART score. Fig. 5 illustrates MRI imaging of the ankle joint before and after surgery. Nine patients were completely happy with the surgery and would undergo it again and/or recommend it to other people. The patient with an iatrogenic posterior tibial tendon lesion was disappointed and would not undergo the surgery again. She received 39 points for the AOFAS score and 90 points for the MOCART score.

4. Discussion

Biological reconstruction of osteochondral lesions of the talar dome 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 [18]. The bone marrow stimulation technique is best used in small osteochondral lesions according to Zengerink et al. [19]. They argued that more complicated surgical techniques, such as the OAT or the transplantation of ACI, did not show superiority when assessed subjectively [19]. To date, the most commonly used treatment for large osteochondral lesions of the talar dome is OAT with a graft harvested form the knee [11,12,20,21]. That technique may produce symptoms of the knee joint related to donor site morbidity after osteochondral graft harvesting [22]. 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 [23]. Formation of bone cysts adjacent to the autograft was also reported [10,12,20]. So far, the most durable results for reconstruction of damaged cartilage are obtained from the ACI technique, which is also the most expensive among the current procedures. That two-step procedure is only suitable for regeneration of the damaged cartilage layer with shallow subchondral lesions [24]. Regeneration techniques for cartilage defects, such as the Autologous Matrix-Induced Chondrogenesis (AMIC) developed by Behrens, were successfully used in the treatment of defects of the knee since 1999. AMIC is a procedure similar to ACI, but without the culturing of chondrocytes. The collagen matrix used by Behrens is intended to keep a spatial arrangement of stem cells flowing with bone marrow from the holes created in the subchondral plate. Multipotent cells

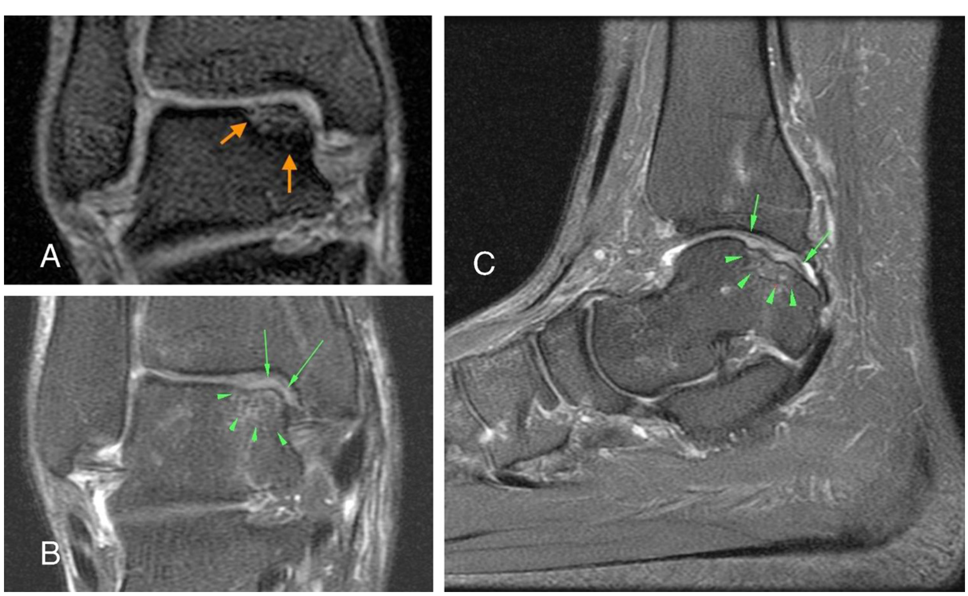

Fig. 5. MRI imaging of the ankle joint patient No 6; preoperative coronal slice (A), orange arrows indicate calcification at base of osteochondral lesion (Proton Density Fat Saturation, 1.0 tesla scanner); coronal (B) and sagittal slice (C) at 2 years follow-up; green arrowheads indicate osseous integration of bony inlay; green arrows indicate chondral surface layer congruent with surrounding articular cartilage (Proton Density Fat Saturation, 3.0 tesla scanner).

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should differentiate into chondroblastic or osteoblastic lines, depending on the surrounding environment [7]. Deeper defects need to be restored by the bone, which is mechanically resistant to the pre-load required for proper graft remodeling [22]. 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 curvature of the talar dome 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. Regeneration of the cartilage layer should be based on a spatial matrix that ensures the proper thickness of the regenerated tissue. Some authors advocate enhancing the remodeling processes of osteochondral grafts with biological factors, such as autologous bone marrow concentrate or platelet rich plasma [10,24].

Limitations of this pilot study include a small cohort of included patients, as well as the lack of a control group that underwent one of well-established techniques described in the literature. Such techniques include the original “sandwich” technique by Peterson or Mandelbaum [13], autograft bone blocks with matrix induced chondrogenesis by Valderrabano [15], or knee-to-ankle OATS [12]. With respect to this study, however, authors were focused on technical aspects of medial talar dome reconstruction in terms of restoring shape and proper ankle joint congruency. The main question posed by the authors was: does the “biological inlay” construct that consists of bone chips, bone marrow concentrate, and a few drops of fibrin glue covered with collagen matrix have the capability to maintain its convexity and integrate into the talar dome permanently? Most of the MRI examinations performed 2 years postoperatively showed very encouraging results.

A significant drawback of the described surgical technique is the need to perform a medial malleolar osteotomy, which may increase the risk of iatrogenic damage of the surrounding tissues, such as the articular cartilage surface of the tibia, or the nearby posterior tibial tendon. Lee observed iatrogenic cartilage damage in 9 out of 31 procedures [24]. Several studies of arthroscopic treatment of the talus showed good, or even better outcomes than the studies of those after arthrotomy. But still it is difficult to compare the results of different studies owing to the varying cohorts of patients, study periods, surgeons, techniques and equipment used in each study [25]. In recent years, the use of artificial osteochondral grafts has increased. Bone marrow derived cells and platelet rich fibrin loaded on hyaluronic acid membranes was effective in chondral surface regeneration of middle and shallow talar defects [8,9,26,27]. Many products are now entering the market after successful clinical trials, but in our experience, autologous biological material is the most appropriate for reconstruction of large osteochondral lesions.

5. Conclusions

Biological materials, such as autograft bone chips, bone marrow concentrate, fibrin glue, or collagen matrix have been used regularly in orthopedic surgery for many years. The presented modified surgical “sandwich” technique allows the talar convexity and curvature to be permanently and precisely recreated. Furthermore, the reconstruction was performed in one step. In the 4-year follow-up, none of the patients required revision of the surgical treatment, as described in the results. Except for one patient, all the patients were satisfied with the surgery. Most of the MRI examinations performed postoperatively showed very encouraging results. A significant drawback of this surgical technique is the need to perform a medial malleolar osteotomy, which may result in iatrogenic damage to the surrounding tissues. Currently, all surgical techniques for reconstruction of large osteochondral lesions of the talus require an approach that provides perpendicular access to the articular surface. Future treatments of osteochondral lesions of the talar dome should focus on minimally invasive surgical techniques that avoid malleolar osteotomy.

Conflict of interest

Authors declare that no conflict of interest with respect to the research, authorship and publication of this submitted article.

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