Joints

Treatment of osteochondral lesions of the talus in athletes: what is the evidence?

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Abstract

Purpose: ankle injuries make up 15% of all sports injuries and osteochondral lesions of the talus (OLTs) are an increasingly frequent problem in active patients. There exist no widely shared guidelines on OLT treatment in the athletic population. The aim of this paper is to review all the existing literature evidence on the surgical treatment of OLTs in athletes, in order to determine the current state of the art in this specific population, underlining both the limits and the potential of the strategies used.

Methods: a systematic review of the literature was performed focusing on the different types of surgical treatment used for OLTs in athletes. The screening process and analysis were performed separately by two independent researchers. The inclusion criteria for relevant articles were: clinical reports of any level of evidence, written in English, with no time limitation, or clinical reports describing the treatment of OLTs in the athletic population.

Results: with the consensus of the two observers, relevant data were then extracted and collected in a single database to be analyzed for the purposes of the present manuscript. At the end of the process, 16 papers met the selection criteria. These papers report a total of 642 athletic patients with OCTs.

Conclusions: the ideal treatment for cartilage lesions in athletes is a controversial topic, due to the need for an early return to sports, especially in elite players; this need leads to extensive use of microfractures in this population, despite the poor quality of repair associated with this technique. None of the surgical strategies described in this paper seems to be superior to the others.

Level of evidence: systematic review of level IV studies, level IV.

Keywords: cartilage, osteochondral lesion, ankle, athletes, sport.

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Introduction

Ankle injuries make up 15% of all sports injuries and osteochondral lesions of the talus (OLTs) are an increasingly frequent problem in active patients, often being subsequent to ankle sprains or repetitive microtraumas (1). Cartilage defects are present in about 50% of acute ankle sprains and in 23% may be linked to lateral chronic instability of the ankle, resulting in persistent pain even after ligament reconstruction (2). Statistically, OLTs are observed, as collateral events, in 2-6% of ankle sprains, and in athletes as many as 28-45% of OLTs can be associated with ligamentous lesions. Since chondral tissue has poor healing abilities (3), the damage may be irreversible leading to chronic symptoms or osteoarthritis (4, 5).

Of all the different sports, football has one of the highest frequencies of OLTs, as the ankle is subjected to continual stress during sprinting, sudden changes of direction (“cutting-in”), tackling and kicking. During normal deambulation the ankle joint supports up to five times the weight of the body, whereas during sprinting, cutting-in or stumbling these forces increase to up to 13 times the body weight (6, 7). Of all these mechanisms, tackling is the one most commonly involved in ankle sprains (8), resulting in chronic sequelae that include mechanical instability, osteochondral lesions and impingement (anterolateral and anterior) (9).

There exist no widely shared guidelines on OLT treatment in the general population (10-12) and the ideal treatment for cartilage lesions in athletes is an even more controversial topic, due to the need for an early return to sports, especially in elite players; this need leads to extensive use of microfractures (MFs) in this population, despite the poor quality of repair associated with this technique (2, 13, 14).

The aim of this paper is to review all the existing literature evidence on the surgical treatment of OLTs in athletes, in order to determine the current state of the art in this specific population, underlining both the limits and the potential of the strategies used.

Methods

A systematic review of the literature was performed focusing on the different types of surgical treatment used for OLTs in athletes. The PubMed database was searched on February 10th, 2015 using the following formula: (Athletes) AND (Ankle OR Tibio-tarsal OR Talar) AND (Chondropathy OR Chondral lesions OR Osteochondral lesion OR Osteochondral fracture OR Osteochondritis dissecans) AND (Treatment). The Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines were used (15). The screening process and analysis were performed separately by two independent researchers. First, the articles were screened by title and abstract, using the following inclusion criteria for relevant articles: clinical reports of any level of evidence, written in English, with no time limitation, or clinical reports describing the treatment of OLTs in the athletic population. Exclusion criteria were: articles written in other languages, no indications of sports activity in the selected population, animal trials, and reviews. Moreover, articles not reporting clinical results were excluded.

Reference lists from the selected papers were also screened. With the consensus of the two observers, relevant data were then extracted and collected in a single database to be analyzed for the purposes of the present manuscript. At the end of the process, 16 papers met the selection criteria. These papers are summarized in **Table 1**.

Results

Several different types of treatment are described for OLTs in athletes. Arthroscopic bone marrow stimulation is a widely used first-line treatment, while restorative techniques, such as autologous osteochondral grafting, are indicated in larger lesions.

Microfractures

Saxena and Eakin (2) applied the MF technique in 44 high-demand (athletic) patients (46 OLTs), while individuals performing only activities of daily living were excluded from the series. Patients with stage 2 through 4 OLT (26 patients), rated using the Hepple classification, received MFs. Patients affected by a stage 5 OLT were treated with autogenous bone grafting (BG group, 20 patients). Preoperatively, the cohort consisted of 15 runners and another 12 patients who played either soccer or basketball (6 for each sport). Eighteen patients had a high level of activity (more than recreational), including collegiate sports and marathon running. Of these 18 patients, 17 were still participating at a high level (the one who was not had opted out for family reasons). The remaining patients engaged in multiple sports recreationally, including aerobics, dance and cross-training. All but two of the recreationally active patients in this study were able to get back to their level of pre-injury activity. One of these patients had additional surgery, consisting of an allograft ankle arthroplasty, and the other was diagnosed with Charcot-Marie-Tooth disease. The entire group had a mean American Orthopaedic Foot and Ankle Society (AOFAS) score of 50.9±9.7 preoperatively, and a postoperative score of 94.0±11.9 ($p < 0.0001$). The MF group's preoperative score was 54.6±8.4, and their postoperative score was 94.4±6.2 ($p < 0.0001$), while the BG group's preoperative score was 46.1±14.6 *versus* a postoperative score of 93.4±10.2 ($p < 0.0001$). The difference between the two groups was not statistically significant. Return to activity (RTA) was achieved after 15.1±4 weeks in the

Table 1. Papers fulfilling our criteria of selection.

Author(s)	Level of evidence	Number of patients	Mean size of lesion	AOFAS pre-op	AOFAS post-op	AOFAS increase	Follow-up	RTA	Satisfactory Results
Saxena et al. [2]	4, Prospective Case series	46 (26 MF, 20 ABG)	ND	MF =54,6 ABG =46,1	MF =94,4 ABG =93,4	MF =39,8 ABG =47,3	2 to 8 years	Total= 17.0±5.3 MF= 15.1±4.0 ABG= 19.6±5.9 (weeks)	96%
Chuckpaiwong et al. [16]	4, Prognostic case series	105 MF	8,84 mm	41	68	27	31.6±12.1 months	16 to 30 (weeks)	70%
Ferkel et al. [17]	4, Case series	50	ND	ND	84	ND	71 months	9 months	72%
Corominas et al. [19]	Case report	1	14 mm	ND	90 at 2 years 100 at 5 years	ND	5 years	3 for jogging, 6 for full range of sports (months)	100%
Doornberg et al. [20]	Case report	1	ND	ND	90 at 2 years	ND	ND	ND	100%
Giannini et al. [23]	4, Case series	10	3,1 cm²	37,9±17,8	92,7±9,9	54,8±7,9	119±6,5 months	ND	90%
Giannini et al. [24]	4, Case series	46	1,58 cm²	57.2±14.3	89.5±13.4	32,3±0,9	36 months	ND	82,5%
Magnan et al. [25]	4, Case series	30	2,36 cm²	36,9	83,9	47	45 months	15 RTA in 2 months; 8 failed RTA for pain; 7 failed RTA for non clinical related reasons	83,4 %
Giannini et al. [26]	4, Case series	48	2.1 cm²	64.4 ± 14.5	91.4 ± 7.7	27	24 months	4.4 low impact sport; 11,3 high impact sport (months)	72,9 %
Giannini et al. [27]	4, Case series	49	2.24±1.23 cm²	63.73±14.13	82.19±17.04	18.46±2,91	48±6,1 months	ND	ND
Cavallo et al. [28]	case report	1	176 mm²	64	100	36	36 months (1 year after second surgery)	1 year	100%
Draper et al. [29]	Retrospective	14 auto grafts 17 curettage and subchondral drilling	Debridement =85.2±58.7 mm² ABG= 156.4 ± 69.4 mm²	ND	graft, 6.9± 1.6, curettage + drilling, 4.5±1.9 [1-10]	ND	71.5±21.1 months	ND	ND
Hangody et al. [30]	4, Case series	39	1,7 cm²	63 (HHS)	91 (HHS)	28 (HHS)	9,6 years	ND	ND
Sammarco et al. [31]	4, Case series	12 autograft	61,6 mm²	64.4	90.8	26.4	25,3 months	9 months	95%
Paul et al. [32]	4, Case series	131 autograft	ND	Pain VAS 6,3±3 mean Lysholm score for this study group was 88 ±18 points	VAS 2,7±2,6	ND	60±28, 4 months	ND	ND
Valdebarrano et al. [33]	4, Case series	12 autograft (mosaicplasty)	135 mm²	45.9	80.2	35.3	72 months	ND	92%

MF group *versus* 19.6±5.9 weeks in the BG group. Malleolar osteotomy in patients undergoing bone grafting affected the RTA (RTA at 20.4±6.2 weeks *versus* 15.6±4.2 weeks in patients who did not have an osteotomy). The results in this series showed that the use of MFs for resurfacing ankle osteochondral defects can be effective even in high-demand patients at up to 55 months of follow-up and no significant differences were found between the results obtained by the BG and MF groups.
Chuckpaiwong et al. (16) reported the results of 105 patients (73 men and 32 women) treated with MFs. No failures were reported in lesions smaller than 15 mm. By contrast, only 1 patient in the group with lesions greater than 15 mm met the criteria for success. Repeat debridement and MFs were performed in 17 patients in the unsuccessful group at a mean of 7.2 months after the first surgery. Although the AOFAS score in this subset of patients improved by a mean of 17.2 points postoperatively, none of these cases met the criteria for a successful result. It was reported that 7 of these patients ultimately underwent ankle fusion and have all done well. Partial weight bearing was advised 1 to 2 weeks after surgery. This report contains very few indications regarding sports. The patients were allowed to resume low-impact sport 4 months after surgery, while a gradual return to high-impact disciplines was permitted after 6 months, depending on muscle strength, although the level of activity of the patients and the factors influencing the RTA are not indicated.

Retrograde drilling/antegrade drilling
In a long-term study published by Ferkel et al. (17), 50 patients with chronic sports-related OLTs were treated arthroscopically. The treatment consisted of either drilling of the OLT *in situ* (n=4), excision of the fragment and abrasion arthroplasty (n=6), or excision of the fragment and drilling (n=40). The patients had an average age of 32 years, and the average follow-up was 71 months. There were 72% excellent/good results and 20% fair results on the Alexander scale. In 35% of the patients, the results showed a deterioration over time. Postoperatively, all the patients returned to their pre-injury sports activity level, although 12% had to modify their activities. Thirty patients were able to return to their pre-injury activity as high school (n=15), college (n=9), and professional (n=6) athletes. Five patients underwent a total of seven additional surgeries, including a second arthroscopy with debridement (n=6) and ankle fusion (n=1). One patient had three additional procedures. Additional surgery was required in all 5 patients who suffered persistent or recurrent pain. One patient developed a cystic lesion in the medial malleolus in the area of the transmalleolar drilling and required curettage and local bone grafting of the lesion.
Kono et al. (18) reported on 30 patients affected by osteochondral lesions of the talar dome without detachment of the cartilage. Nineteen patients underwent transmalleolar drilling (TMD group), and 11 patients underwent retrograde drilling (RD group). Ankle arthroscopy was performed 1 year postoperatively to evaluate cartilage conditions. Arthroscopic findings revealed that in the TMD group, 11 lesions (57.9%) were unchanged (grade I), and 8 lesions (42.1%) had deteriorated from grade 0 to I; in the RD group, 3 lesions (27.2%) had improved from grade I to 0, and 8 (72.8%) were unchanged (2 grade 0 lesions and 6 grade I lesions). There was a significant difference between the 2 groups in the distribution of cases that had improved, were unchanged, or had deteriorated ($P < .0001$).
In an interesting case report, Corominas et al. (19) treated a 14-year-old soccer player with retrograde percutaneous drilling after unsuccessful conservative treatment consisting of rest and bracing. The patient's lesion was classified as a chronic stage 0 lesion according to Giannini's classification. The patient was able to return to full activity 9 months after surgery and remained asymptomatic throughout a five-year observation period.

Fragment fixation
Doornberg et al. (20) treated a young soccer player with curettage and drilling of the osteochondral defect followed by fixation of the articular fragment with screws. Healing was uneventful. Eighteen months postoperatively hardware removal was performed arthroscopically. The player returned to his pre-injury competitive level without restrictions or complaints.

Autologous chondrocyte implantation
Following initial promising studies reporting autologous chondrocyte implantation (ACI) in the knee (21,

22), Giannini et al. (23) were among the first to apply the ACI procedure in treatment of the ankle, and they did so in a small group (n=10) of young, active patients. The first procedure consisted of arthroscopy of the ipsilateral knee. Cartilage samples were harvested from the superolateral femoral condyle. In the second procedure, a medial or lateral arthrotomy was performed depending on the site of the lesion. The malleolus was reflected to permit inspection of the lesion. Radiographic and traditional magnetic resonance imaging (MRI) evaluations were performed at established intervals in all the cases. At the final follow-up, MRI T2 mapping evaluation was performed in six cases. Only coronal MRI views were considered for this purpose. Complete weight bearing was allowed at 3 months, while low-impact sports activity was resumed at 6 months after surgery. After 10 to 12 months, running and progressive training for high-impact activities, such as tennis and soccer, were permitted. Before surgery, the mean AOFAS score was 37.9±17.8 points, while at final follow-up (119±6.5 months) it was 92.7±9.9 ($p < 0.0005$). MRI showed well-modeled restoration of the articular surface. The overall scores at final follow-up were excellent in 7 cases (70%), good in two (20%) and fair in one (10%). At 12-month follow-up, 5 of the patients who played sports had resumed their sports at the same level as before, and 2 at a lower level, while 1 patient had given up sports. The professional aerobics instructor was able to resume her previous activity.

Matrix-induced autologous chondrocyte implantation (MACI)

Giannini et al. (24) reported a series of 46 patients with post-traumatic lesions sustained during sports activities. All the patients were affected by chronic type II (0-5 mm deep) or IIA (>5 mm deep) post-traumatic talar dome lesions. In all these patients, OLT treatment consisted of MACI. Twenty-nine patients practiced some kind of sports activity: contact sports (soccer, basketball) in 16 cases and noncontact sports (volleyball, tennis, swimming, cycling, ballet, aerobics) in 13 cases. Twenty-five practiced sports at a recreational level, while 4 were professionals. The procedure involved initial cartilage harvesting from the detached osteochondral fragment, culturing of chondrocytes on a Hyalograft C scaffold, and subsequent arthroscopic implantation of the three-dimensional scaffold. Partial weight bearing increasing to full weight bearing was permitted from 6 to 8 weeks after surgery; subsequently, at 4 months after surgery, low-impact sports activity could be resumed. After 10 to 12 months, running and progressive training for high-impact activities, such as soccer and tennis, were permitted. The patients were followed up prospectively for 36 months and showed a significant mean AOFAS score improvement, from 57.2 points preoperatively to 89.5 points postoperatively. The overall scores at 36 months were excellent in 25 cases (55.0%), good in 13 (27.5%), fair in 6 (12.5%), and poor in 2 (5%). Hyaline-like cartilage regeneration was identified histologically in samples obtained at second-look arthroscopy in 3 patients at an average of 18 months after surgery. At final follow-up, 20 patients had resumed their previous sports activity at the same level as before, 3 had resumed the same sport at a lower level, 2 had switched to a non-contact sport, and 4 had given up sports. The 4 professionals were all able to resume their previous activity.

Recently, Magnan et al. (25) evaluated 30 patients with a mean lesion size of 2.3 cm^2 who were treated with MACI. Standard X-rays and an MRI were performed preoperatively and lesions were classified as type 2 or 2A according to Giannini's classification (12). The mean AOFAS score improved from 36.9 points preoperatively to 83.9 points at a mean follow-up of 45 months; 15 patients (50%) returned to their previous sports within 2 months of the surgery; in 8 of the 30 cases (26.7%) sporting activities were no longer possible due to ankle pain, while in 7 cases patients (23.3%) the failure to return to sport was not related to the clinical outcome. The patient subjective satisfaction rating was excellent in 11 cases (36.7%), good in 13 (43.3%), fair in 5 (16.7%), and insufficient in 1 (3.3%).

Bone marrow-derived cell transplantation

Giannini et al. (26, 27) described the clinical application of an arthroscopic one-stage technique involving autologous mesenchymal stem cells, platelet-rich plasma and either porcine collagen powder or hyaluronic acid (HA) membrane.

The first trial (26) involved 48 patients (mean age 28.5 years) affected by focal lesions (mean size 2.1 cm^2) who were evaluated at 6, 12, 18 and 24 months of follow-up using the AOFAS score. A significant increase in this parameter was recorded 6 months after the surgical procedure. The mean AOFAS score was 64.4±14.5 preoperatively and it improved to 83.3±8.7 at 6 months, 88.9±8.2 at 12 months, 89.7±8.5 at 18 months, and 91.4±7.7 at 24 months. The rate of return to high-impact sports activity was satisfactory: 45 of the 48 patients (94%) participated in a low-impact sports activity at a mean of 4.4 months after the surgery, while 37 of the 48 (77%) participated in a high-impact sports activity at a mean of 11.3 months. The overall findings suggested that this novel approach could stimulate tissue regeneration with promising clinical efficacy, providing results that may even be comparable to those of ACI while avoiding the double surgical time and inherent stress for the patient.

In a further follow-up of the original case series, increased to 49 patients in this paper, the patients underwent clinical evaluation at 4 years (27). Among the 36 patients (73%) doing sports activities (soccer, basketball, skiing and general fitness classes), the large majority (28 patients, 78%) had been able to resume these activities at the same level as before, while the remaining 8 patients (22%) had resumed them at a lower level, or had preferred to switch to a lower-impact activity. The overall AOFAS score improved significantly, with the best results recorded at the 24-month follow-up. The clinical score was found to decrease significantly between 24 and 36 months postoperatively, and between 24 and 48 months.

On evaluation of the 20 patients who had undergone T2 mapping MRI two years previously, there emerged a significant relationship between the AOFAS score at 48 months and the percentage of regenerated cartilage with hyaline features (T2 values of 35-45 ms). Patients with hyaline-like regenerated cartilage in more than 80% of the treated area had a more predictable and stable result.

Cavallo et al. (28) presented a case report of a 15-year-old male, who underwent a first bone marrow-derived cell (BMDC) transplantation on a hyaluronate membrane to treat a deep osteochondral lesion (16x11x8 mm). No bone graft was used to fill the lesion. The procedure failed: at follow-up the patient still presented clinical pain and a non-satisfactory result with an enlarged subchondral bone cyst. Two years after the first operation, the same procedure was performed by grafting the lesion with demineralized bone matrix and using a collagen membrane with BMDCs and platelet-rich fibrin (PRF). After one year, the patient had an AOFAS score of 100, and MRI showed complete filling of the defect. Four months after the surgery, the patient was able to return low-impact sports, like swimming and cycling, without any complaints. The ankle pain was extinguished, and the range of motion (ROM) was close to normal. One year after the treatment, the ankle was not painful and the ROM was complete. Due to the good clinical outcomes, high-impact sports activities (soccer, competitive level) were gradually introduced one year after the operation. The AOFAS score at one year was 100 points.

Autologous graft and mosaicplasty

Draper and Fallat (29) performed a retrospective comparative study of the long-term outcome of two groups of patients affected by OLT, one made up of patients treated with autogenous bone grafts (n = 14), and the other of patients treated with curettage and subchondral drilling (n=17). The mean final follow-up duration was 71.5±21.1 months. Age, lesion stage and gender did not differ between the groups, but the mean fracture area was smaller in the curettage and drilling group (85.2±58.7 mm^2 *vs* 156.4±69.4 mm^2). This study showed better results in terms of pain reduction, ROM and sports activities in the group of patients treated with autografting: 6.9±1.6 *vs* 4.5±1.9 points (on an eight-point scale); p = 0.001. However, although the patients receiving bone grafts showed a trend to self-rate their performance higher than the curettage plus drilling group (satisfactory results were recorded in 93% *vs* 76%), the postoperative subjective assessment did not show differences either for total score or individual categories.

Mosaicplasty was used by Hangody et al. (30) to treat professional athletes with OLTs. The study was a multicenter prospective evaluation involving three different institutes. A total of 404 mosaicplasty procedures was performed, including 39 in the ankle joint; 354 competitive elite level athletes (67 soccer players, 46 handball players, 43 basketball players, 36 volleyball players, 34 track and field athletes, 32 water polo players, 32 wrestlers, 26 gymnasts, 19 tennis players, 8 downhill skiers, 4 modern pentathlon athletes, 3 ice hockey players, and 3 table tennis players) were followed up, but is unclear which of these underwent treatment of the ankle joint. At 2 years after mosaicplasty, the average Hannover ankle score was found to have increased to 91 from the preoperative value of 63; 63% of the whole series, mainly young adults (<30 years), resumed the same level of sports activity; 5 patients (2 gymnasts, 1 handball player, 1 wrestler and 1 water polo player) participated in the four most recent Olympic Games (1996, 2000, 2004, 2008); 28% of the patients, mostly older adults (>30 years), were able to return to a lower level of sports activity (including recreational sports), whereas 9% of the operated patients had to give up sports activity entirely (30).

Sammarco and Makwana (31) described a new technique for harvesting the osteocartilaginous graft directly from the affected talar dome. This technique involves mobilization of a bone block from the anterior tibial plafond. Twelve patients, including eight involved in sports activities, (2 baseball, 2 aerobic walking, 1 aerobic dancing, 1 running, 1 motor cross and 1 basketball) were treated with this technique, and recorded a statistically significant improvement of the AOFAS score from 64.4 preoperatively to 90.8 postoperatively, without postoperative complications. However, since, with this technique, the width of the graft taken cannot exceed 8 mm, the method can be used only for small lesions.

Paul et al. reported a series of 131 patients followed up retrospectively for a mean of 60 months (32). The frequency and the duration of sports activities did not significantly change after surgery: 1.7±2.0 (range, 0-8) and 4.2±3.8 hours (range, 0-30 hours), respectively. The number of different sports disciplines practiced was unchanged in comparison to the year before surgery (3.7±2.9; range, 0-12).

Similar results were published by Valderrabano et al. (33), who evaluated 12 patients after a mosaicplasty treatment. While the AOFAS ankle score increased significantly from 45.9 to 80.2 points ($p < 0.0001$), with good or excellent results recorded in 92% of cases, the sports activity score was significantly decreased preoperatively (0.4) and also at follow-up (1.25) in comparison with the pre-injury score (2.3). At final follow-up, sports activity was increased compared with the preoperative level, but the difference was not statistically significant. While 4 patients reached their pre-injury sports activity level, overall sports activity remained significantly reduced ($p = 0.035$) compared with the pre-injury level.

Discussion

OLTs are recognized as an increasingly common injury in athletes, and may occur in up to 50% of acute ankle sprains and fractures (2). Approximately 5 out of 10,000 athletes per day suffer an ankle injury (34) and this number can be higher (9.35 per 10,000 athlete exposures) (35) in the setting of active competition. Sports-related injuries causing inversion, forced dorsiflexion, plantarflexion or lateral rotation of the tibia may lead to traumatic lesions. Currently there is no single treatment strategy; indeed, numerous therapeutic possibilities are described in athletes. The literature contains very little evidence on rehabilitation and return to play, and outcomes may be influenced by many confounding factors. Youth, small lesions and a lower body mass index have been suggested to be positive prognostic factors for an early resumption of sport (36).

Conservative treatment is not recommended in athletes for several reasons. Indeed, this choice is indicated only in asymptomatic and incidentally-discovered lesions, which must be low-grade OLTs. These lesions, especially in the pediatric population, may resolve completely with protected weight bearing, since immature articular cartilage has been shown to have a much higher cellular density, increased proteoglycan content and a greater proportion of type II and type IX collagen compared to mature articular cartilage (37-39), as well as an increased proliferation rate and an overall enhanced ability to produce extracellular matrix (37-39). However, spontaneous healing is far less frequently observed in adult patients (40). In a review of 14 studies, Tol et al. (41) found that conservative treatment was effective in alleviating clinical symptoms in 59% of patients affected by early-stage OLTs.

Bone marrow stimulation, being a simple and cost-effective procedure associated with a low complication rate and low postoperative pain compared with more invasive procedures (42), is a widely used first-line treatment for OLTs. Since articular hyaline cartilage is avascular and has poor regenerative capabilities, injuries that do not penetrate the subchondral plate have no stimulus for an inflammatory reaction and healing. However, bone marrow stimulation involves the formation of fibrous cartilage, which lacks the favorable biomechanical properties of normal articular hyaline cartilage. In case of smaller lesions, microfracturing may be an appropriate choice. It has been suggested that 150 mm^2 is a critical defect area size for optimum clinical outcome (43). Chuckpaiwong et al. (16) reported a 100% success rate in patients with lesions smaller than 15 mm in diameter, but an only 3% success rate in patients with larger lesions. According to Ferkel et al. (19), arthroscopic treatment should be the gold-standard technique for chronic symptomatic OLTs; it resulted in good clinical outcomes in the majority of their patients and return to previous sports activity in nine months. However, the mean lesion size in these patients was not stated, and the Authors found a deterioration of the results in 35% of their patients, due to persistence of pain and functional limitation, especially in those in whom an unstable osteochondral defect was detected at the time of arthroscopy. However, with larger lesions, fibrocartilage may not provide adequate support for the joint. Therefore, the majority of recently developed treatment approaches are aimed at providing a method for replacing the damaged articular cartilage with a tissue that more closely resembles hyaline cartilage. These have included, primarily, transplantation of osteochondral autograft plugs from distant donor sites, allograft transplantation, or harvesting and culturing of chondrocytes that are later transplanted into the site of the osteochondral defect. Saxena and Eakin (2) demonstrated the validity of MFs in athletes as long as 55 months after surgery, although not in large and deep lesions, as well as the validity of autologous bone grafts; however, this was a non-comparative study, and the Authors used different techniques in different types of lesions.

Evaluation of arthroscopic *versus* open management of talar lesions reveals no significant differences. Patients undergoing bone grafting had a longer RTA time than MF-treated patients (approximately 5 *versus* 4 months), but both groups had similar postoperative AOFAS scores. Patients with anterolateral lesions had the fastest RTA and highest AOFAS scores. Conversely, Draper and Fallat (29) found that their patients who underwent bone grafting had better overall results than those treated with curettage and drilling. They hypothesized that the autologous bone grafting technique helps to restore the weight-bearing architecture of the talar dome, and therefore helps to reduce the onset of osteoarthritis of the ankle joint.

The role of autologous osteochondral transplantation procedures in returning patients to sports activities has also been investigated by Paul et al. (32). These Authors reported a full return to sports activities in 131 patients after autologus bone grafting surgery, with no statistically significant changes in sports frequency and duration of activities; some patients tended to modify their level of activity, especially if they were involved in high-impact sports. Similar results are published by Valderrabano et al. (33), although these Authors found a decreased sports activity score at one year of follow-up compared with the preinjury level in 12 patients treated with mosaicplasty. However, mosaicplasty is a technically demanding technique that can lead to donor site morbidity. ACI has been extensively applied for treating OLTs, with successful clinical outcomes (90%) (44). Although no clear superiority has been established, ACI is considered the gold standard among the regenerative procedures (44). There is less donor site morbidity compared with the mosaicplasty technique. In addition, a nearly perfect fit with the cartilage defect can be achieved, leaving no "dead spaces". The technique involves harvesting a small amount of cartilage arthroscopically from the ipsilateral knee for chondrocyte cultures, which are grown *in vitro* for approximately 30 days. The OLT is debrided and filled with autologous cancellous bone harvested from the ipsilateral distal tibial metaphysis. Periosteum is harvested from the ipsilateral proximal tibial metaphysis to cover the transplant area and is fixed with resorbable sutures. The chondrocytes are injected while the flap is still unsutured; after the injection the flap is fully sutured down and sealed with fibrin glue. This method involves two-stage surgery: the first procedure is necessary to remove the fragment containing vital chondrocytes, which are subsequently expanded; the second is necessary for the transplantation of the expanded chondrocytes. MACI is similar to ACI; it differs from traditional ACI in that the chondrocytes are not placed under the periosteal patch but rather embedded in a type I/III porcine-type collagen membrane bilayer. As with ACI, the membrane is placed in the defect, but sutures are not required. The membrane bilayer is secured using fibrin glue. Several Authors (24, 25, 45) believe that these aspects constitute advantages of MACI over ACI. Moreover, MACI delivers more viable cells to the lesion, and this will lead to better long-term results

(46). Three prospective studies (23-25) evaluated 86 patients after these two surgical techniques; the patients had a mean lesion size of 2 cm^2. Although satisfactory results were achieved in 84% of the patients, at 12 months after surgery only 40 were practicing their sports activity at the same level as prior to the injury. Despite promising results with the ACI technique, patients should be counseled thoroughly with regard to the need for two-stage surgery and other potential risk factors, such as those associated with periosteal harvesting.

BMDCT is an osteochondral regeneration technique based on the use of mesenchymal stem cells (26, 44). These cells have the capability to differentiate into articular cartilage and induce the formation of subchondral bone. Several investigators have employed concentrated bone marrow aspirate clinically; however, since these were uncontrolled studies, their usefulness in delineating the exact efficacy of this technique in the treatment of OLTs is limited. Nevertheless, clinical results at mid-term follow-up are encouraging, with excellent outcomes even in athletes (26, 27). Hyaline cartilage regeneration has been observed in biopsy samples and qualitative MRI assessments (26, 27). BMDCT may be performed in the same surgical session with good results, even in degenerated joints (26, 44). In the one-step technique, the cells are harvested from the iliac crest using a bone marrow needle. The aspirated material is processed through the use of a machine able, contemporaneously, to concentrate and separate the cells; this is done with the aim of increasing the proportion mononuclear cells. While the cells are being concentrated, a standard arthroscopy of the ankle is performed, and the defect is debrided. The cell concentrate is loaded on a collagen (or hyaluronate) membrane and then implanted in the joint using specific instrumentation. Thereafter, a layer of PRF is sprayed onto the biomaterial, to improve the growth, differentiation and stability of the implant. Although a longer follow-up is needed to confirm the validity of the repair over time, the arthroscopic one-step technique represents an advance in osteochondral regeneration, resulting in the achievement of high clinical scores with the formation of repair tissue, and without the major disadvantages of previous techniques. BMDCT could be preferred to the ACI surgical technique (currently considered the state of the art) as it is a single-step procedure that is also less costly than ACI, while able to provide similar clinical and histological results (47).

Several studies have investigated the role of biological adjuncts, such as HA or PRP, used to promote hyaline-like tissue development and improve the biological environment in which cartilage can heal, both in conservative (48) and in surgical (49) treatments, but none of these concerned the athletic population.

This systematic review concerns 642 athletic patients with OLTs; several treatments are described, but no clear conclusions regarding resumption of sports activity can be drawn, due to the use of different score systems and also to the fact that the time from surgery to RTA is often not declared. None of the surgical strategies described in this paper seems to be superior to the others. Therefore, only careful choice of the surgical technique, taking into account the pathoanatomy and causative factors, can ensure the best results.

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