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TOPIC HIGHLIGHT

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Cartilage repair techniques of the talus: An update

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Abstract

Symptomatic chondral or osteochondral defects of the talus reduce the quality of life of many patients. Although their pathomechanism is well understood, it is well known that different aetiologic factors play a role in their origin. Additionally, it is well recognised that the talar articular cartilage strongly differs from that in the knee. Despite this fact, many recommendations for the management of talar cartilage defects are based on approaches that were developed for the knee. Conservative treatment seems to work best in paediatric and adolescent patients with osteochondritis dissecans. However, depending on the size of the lesions, surgical approaches are necessary to treat many of these defects. Bone marrow stimulation techniques may achieve good results in small lesions. Large lesions may be treated by open procedures such as osteochondral autograft transfer or allograft transplantation. Autologous chondrocyte transplantation, as a restorative procedure, is well investigated in the knee and has been applied in the talus with increasing popularity and promising results but the evidence to date is poor. The goals of the current article are to summarise the different options for treating chondral and osteochondral defects of the talus and review the available literature.

Key words: Cartilage defect; Talus; Repair techniques; Arthroscopy; Marrow stimulation; Mosaicplasty; Autologous chondrocyte implantation

Core tip: The goals of the current article are to summarise the different options for treating chondral and osteochondral defects of the talus and review the available literature.

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INTRODUCTION

In contrast to other joints of the lower extremity, chondral and osteochondral lesions of the talus are frequently being recognised as being caused by traumata. The impact of shear and compression forces causes a cartilage contusion and is often transmitted to the subchondral bone, thus causing subchondral microfractures. In addition to trauma other causes include endocrine or metabolic factors genetic predisposition, vascular or synovial abnormalities, localised hyperpressure, or chronic microtrauma[1-3].

Irrespective of their aetiology, these lesions remain important problems (Figure 1), a consequence of the limited reparative potential of human cartilages. During

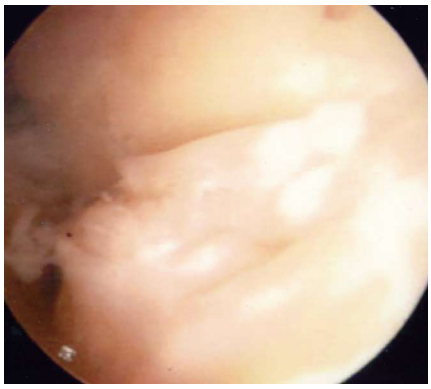

Figure 1 Arthroscopic view of an osteochondral lesion of the lateral shoulder of the talus.

repair, the cartilage usually produces a fibrocartilaginous tissue that has inferior mechanical properties and may deteriorate gradually[4]. For these lesions, diverse treatment options have been published in the last decades[5-10].

The goals of the current article are to summarise the different options for treating chondral and osteochondral defects of the talus and review the available literature.

Special characteristics of talar cartilage

Many recommendations for the management of talar cartilage defects are based on approaches for the knee. However, some well-known and important attributes clearly distinguish the cartilage of the talus from other cartilage, especially from that of the knee joint.

First, the ankle is a highly congruent joint, which is important to know when using different methods for cartilage repair, such as autologous osteochondral transplantation. Additionally, the nature of the joint will affect the development of pain in osteochondral defects of the talus[11]. Of note, the average thickness of the talar articular cartilage is approximately 0.89 mm whereas knee cartilage thickness reaches 6 mm[12,13]. Moreover, the tensile stiffness of healthy talar cartilage has only minimal topographical variability and the dynamical stiffness is higher than in the knee[14,15]. A further difference is the lower contact area and the lack of absorbability that makes the cartilage able to tolerate higher maximum loads[16]. Additionally, its metabolic activity appears to be greater than that of the knee, with a higher turnover as well as a higher level of proteoglycan synthesis[16].

Finally, the capability to maintain its mechanical properties more successfully during ageing appears to be more favourable in the talar articular cartilage compared to other joints[17].

TREATMENT OPTIONS

Conservative treatment

The intended purpose of a non-operative approach is to unload the injured cartilage and thereby allow the subchondral oedema to resolve, prevent osseous necrosis, or enable healing of a minimal detached fragment. Unfortunately, the reasons for choosing this treatment are not always clearly described[18]. Additionally, the overall results of the non-operative treatment of cartilage lesions of the talus indicate only a low success rate[19,20].

Despite this fact, conservative management may be considered and favourable for some types of lesions. Non-operative treatment is appropriate in fresh cartilage injuries that are non-displaced and have a potential for healing, depending on their size and location as well as on patient parameters, such as age, socio-professional context, or smoking[1]. Asymptomatic lesions, minimally symptomatic lesions that involve cartilage alone or show an intact cartilage surface, and low-grade osteochondritis dissecans lesions in children may recover using temporarily protected weight-bearing with or without joint immobilisation[1,3,21].

Surgical treatment

Marrow stimulation techniques: Human articular cartilage has a limited reparative capability because of its avascularity, among other reasons. Although the basic purpose of the surgical treatment is to re-vascularise the bony defect, many cartilage defects of the talus can be treated arthroscopically using bone marrow stimulation methods involving drilling or microfracture.

These techniques attempt to promote the development of a fibrocartilageous formation over the defect, which may suffice for small lesions. The principle is to breach the subchondral plate at multiple intervals to allow the subsequent inflow of serum factors as well as to stimulate chondroprogenitor cells of the marrow into the base of the defect site[22] (Figure 2A and B). The release of fatty drops from the created fracture apertures provides a clinical indicator that the depth of the microfracture is adequate. To remove the calcified layer and to obtain stable edges of vital cartilage, it is recommended that the procedure be supplemented by excision and curettage[23,24] (Figure 3).

Of note, a recent study of 2nd look arthroscopy at 12 mo postoperatively revealed incomplete healing of osteochondral lesions treated using these techniques in 40% of the patients[25]. Interestingly, good clinical results were achieved, which agrees with most series demonstrating pain relief and optimisation of function[26-28]. O'Driscoll[29] summarised that this technique may be best for the treatment of small (< 6 mm), shear-type lesions with minimal subchondral involvement.

Increased age has been considered to be an independent risk factor for a poor outcome, but has not been confirmed by recent studies[27,30]. In contrast, a higher body mass index, a history of trauma, and the presence of degenerative changes will certainly worsen the outcome[5,27]. Moreover, the defect's size is a predictor of clinical outcome: a defect dimension larger than 150 mm^2 appears to result in a significantly higher failure rate[5,31].

Tissue transplantation

Autologous osteochondral transplantation: The un-

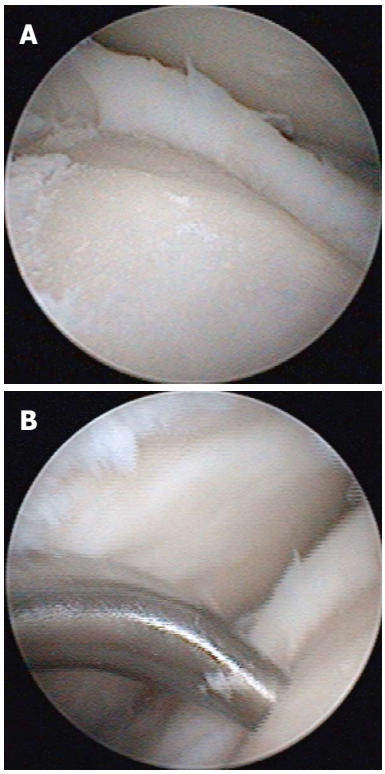

Figure 2 Chondral defect grade Ⅳ (A) of the lateral aspect of the talus, breaching the subchondral plate with an awl (B).

certain value of bone marrow stimulation techniques for defects larger than 150 mm^2 has encouraged the search for alternative resurfacing procedures, such as autologous osteochondral transplantation. This technique was developed principally to treat focal cartilage defects of the knee[32].

This procedure involves autologous grafting using one or more cylindrical components consisting of cartilage and its underlying bone. The components were harvested from a less weight-bearing part of the femur of the ipsilateral knee. Hangody *et al*[8] introduced this mosaicplasty to treat large cartilage defects using a one-step procedure. This can be performed using an open approach or, in special cases, arthroscopically. The size of the defect determines whether more than one osteochondral plug is needed: the plugs may vary in size and are placed in a side-by-side configuration into the prepared defect site. Distinctive cystic lesions could be treated using the osteochondral autograft transfer system (OATS)[3]. Several authors reported favourable results based on short- to mid-term follow-up[8,33-35]. Good results may be expected for a moderate talar dome defect of approximately 2 cm^2 in size and more than 5 mm in depth[36]. Others recommend this treatment for lesions that are 4 cm^2 or smaller[3].

In contrast to bone marrow stimulation the aim of osteochondral transplantation techniques is to resurface the defect with a viable hyaline cartilage. Therefore, this procedure attempts to reproduce the mechanical, structural, and biomechanical characteristics of the primary hyaline talar cartilage[18].

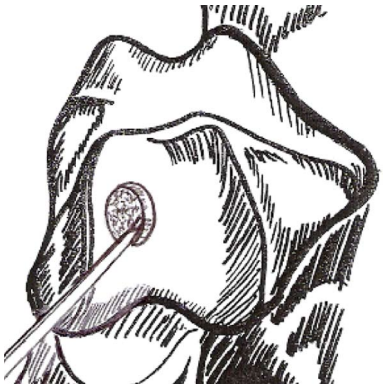

Figure 3 Schematic drawing: It is necessary to obtain a vertical and stable border of healthy cartilage after debridement of the cartilage defect.

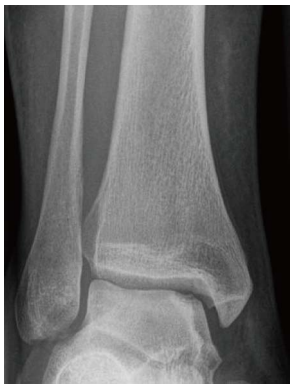

Figure 4 A.-P. radiograph of the ankle showing an osteochondral defect of the medial shoulder of the talus.

Despite these advantages, some disadvantages must be considered when planning osteochondral autografts. Only a circumscribed surface can be treated anatomically due to the limited number of suitable donor sites, which is primarily due to differences in the surface curvature between the graft and the host tissue[4] (Figure 4). Additionally, restoring lesions of the talar shoulder can be difficult[17]. Any type of surface incongruity or irregularity caused by differences in thicknesses of the grafts or differences between the size of the graft and the size of the defect should be carefully avoided. These surface differences often result in an uneven surface or the development of "dead spaces" between each graft that is filled only with a fibrous regrind. Therefore, circular lesions could often be resurfaced better than elliptical defects[17].

Based on the location of the lesion and depending on the approach needed a malleolar osteotomy is necessary. In some patients the use of an osteotomy may worsen the clinical outcome and affect the potential benefit of cartilage resurfacing[37], but this does not appear to cause widespread concern[38]. Several techniques were described for performing the osteotomy[39]. However, the surgeons have to be aware of potentially related problems. First, it is essential to be conscious of a proper level to avoid violating the articular surface as well as to gain optimal visibility of the defect[40]. Second, one must focus on a

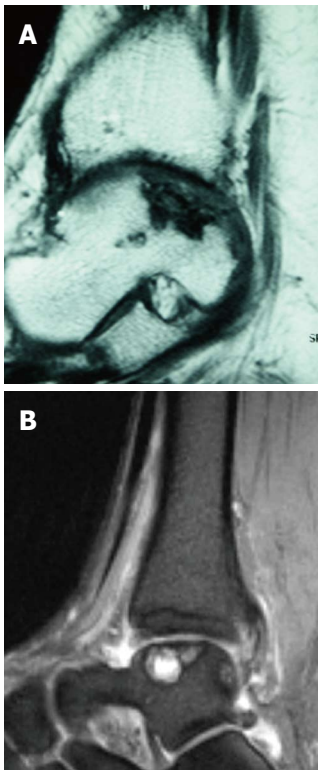

Figure 5 Sagittal T1 and T2-weighted magnetic resonance imaging scan. A: Sagittal T1-weighted magnetic resonance imaging scan demonstrating deep osteochondral defect of the posterior aspect of the talus; B: Sagittal T2-weighted magnetic resonance imaging scan showing the several cystic lesions of the talus in addition to an osteochondral defect.

precise reduction and sufficient fixation to avoid a fibrous non-union or malunion[3]. For example, Lamb *et al*[41] described a chevron-type medial malleolar osteotomy that appears safe and reduces the risk of non-union. At a median follow-up of 34.5 mo 94% of the patients were non-symptomatic. The median time to radiographic healing was six weeks.

Donor-site knee morbidity could pose problems for patients, but it is not discussed in any of the published series[17]. Therefore, some authors suggest harvesting the osteochondral plugs from the talus itself to avoid donor-site knee pain, stiffness, or even arthritic changes[42]. Two series specifically addressed donor-site morbidity[43,44]. In a retrospective study of 11 patients, Reddy *et al*[44] showed that the number of grafts obtained had no effect on clinical outcome. Paul *et al*[43] found that a high body-mass index influenced the outcome score negatively.

Osteochondral allograft transplantation: The use of fresh osteochondral allografts is a different technique especially designed to reconstruct massive osteochondral defects that have substantial loss or cystic degeneration of subchondral bone[40] (Figure 5). Indications for choosing this method for reconstruction are similar to those for osteochondral autologous transplantation, but without limitations based on size[36]. In patients with severe tibiotalar arthritis, the use of bipolar osteochondral allografts has been described[45].

In osteochondral allografts, a cadaver graft, consisting of both articular cartilage and its underlying bone, is transplanted into the defect site. An advantage of this technique is that the transplanted allograft can be tailored to match the shape of the defect precisely, which is particularly necessary due to the above-mentioned high congruity of the ankle joint. Therefore, even severe defects that involve the talar shoulder can be treated successfully[46]. Regardless, a malleolar osteotomy is required in some cases. A viable articular cartilage is provided and graft harvesting from a healthy knee joint is not needed; these are other advantages of this method.

Nevertheless, the success of such allografts is related to the percentage of chondrocytes that remain viable after graft procurement[47]. The storage of a fresh human allograft for more than fourteen days was revealed to substantially decrease the viability, cell density, metabolic activity of the chondrocytes, and lead to an approximately 30% decrease in viable chondrocytes after 28 d[47,48]. Despite these drawbacks, the biomechanical characteristics appear not to be affected by storage for this time interval[39]. However, many tissue banks need almost one month for screening to minimise the risk of disease transmission via the graft[36]. To date, the authors are not aware of any viral transmission via such allografts; however, the screening period is necessary and patients have to be informed of this hypothetical risk.

An immunologic reaction that adversely affects the chondrocytes, the limited availability of grafts, and the acceptance of costs may be further disadvantages[47]. Several authors have investigated the treatment of large osteochondral defects of the talus using osteochondral allograft transplantation in case series[7,46,49-52]. The overall clinical results were promising, especially considering the size of the defects. However, in certain of these studies, only a few patients were reported to be symptom-free[51]: some patients needed further surgical treatment, or the procedure failed[46,49,51].

In summary, the evidence for the use of osteochondral allograft transplantation has to be interpreted carefully. Most series included a small number of patients, studied patients retrospectively, had only a short- or mid-term follow-up, or presented no description of the underlying size of the defect[7,46,49,50,52,53]. Additionally, in several of these investigations, patients were lost to follow-up or were excluded because of graft failure[46,50,52].

Autologous chondrocyte transplantation/ implantation: Brittberg *et al*[54] implemented the technique of autologous chondrocyte transplantation in 1987. The first results were published in 1994 after treating chondral defects of the knee with this technique. Since then, it has become a promising tool for the repair of cartilage defects. Several long-term trials have provided strong evidence of the efficacy of this procedure, primarily studying its application in the knee[55-57]. Young patients suffering from a single focal cartilage defect with only a short duration of symptoms should expect good re-

Table 1 Indications and contraindications for autologous chondrocyte transplantation of the talus (modified to[61])

Indication	Contraindication
symptomatic full-thickness chondral/osteochondral lesions	Osteoarthritis/rheumatoid arthritis
focal lesion > 1.5 cm^2 in size	so-called kissing lesions
lesion with necrotic bone/fibrous tissue base	ligamentous instability (can be corrected in conjunction with the ACT procedure)
failed previous traditional surgery	axial malalignment
(*i.e.*, drilling or microfracture)	(should be previously corrected)
patients younger than 45 yr of age	children/teenagers
	patients older than 45 yr of age

ACT: Autologous chondrocyte transplantation.

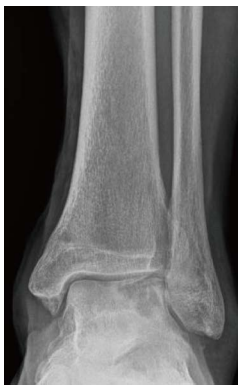

Figure 6 A.-P. radiograph of the ankle demonstrating a distinctive cystic lesion due to an osteochondral defect of the lateral shoulder of the talus.

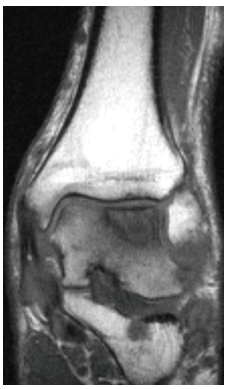

Figure 7 Sagittal T1-weighted magnetic resonance imaging scan demonstrating an osteochondral defect of the wholelateral aspect of the talus and a consecutive talar edema.

sults[58]. However, to our best knowledge, equivalent data do not exist regarding the treatment of the talus. Additionally, a clearly recommendation regarding the defect size in which this procedure works best cannot be given: reported defect sized vary between 2 cm^2 and 12 cm^2[59].

Autologous chondrocyte transplantation (ACT) is a cell-based, two-stage procedure that involves the transplantation of viable and cultured chondrocytes into a defect. In the first step, cartilaginous material is harvested from the knee or the ankle itself[10,40]. In some cases, the cartilage was harvested from a detached osteochondral fragment without any reported adverse effect on the chondrocytes' viability[60]. Usually, the second-stage of the procedure is performed after three to four weeks of cell culturing.

The aim of ACT is to promote the development of a regrind that meets the requirements of human hyaline cartilage or, at best, will facilitate a hyaline-like repair tissue. The ideal indication for an ACT is a full-thickness cartilage defect with an intact subchondral plate with stable edges of the surrounding cartilage[59]. The conditions for its application do not differ from that of the above-mentioned techniques: all pathologic cartilage should be carefully debrided to achieve vertical and stable edges surrounding the defect[10,61]. In case of an osseous deficiency (Figures 6 and 7), concomitant bone-grafting is suggested to provide a sufficient bony base[61]. Indications and contraindications are summarised in Table 1.

A method using a periosteum-covered ACT is called the first generation of this technique. A periosteal flap is harvested, *i.e.*, from the distal part of the tibia, and then placed over the defect with the cambium layer facing toward the aforementioned prepared bed[40,61]. Then, the cultured cell suspension is injected beneath the sutured flap. However, this technically demanding procedure induced complications, such as delamination, uneven distribution of cells within the defect, cell leakage, or periosteal hypertrophy[38].

Due to these complications, a second generation of ACT, using matrix-associated techniques, was developed. In matrix-induced autologous chondrocyte implantation/transplantation (MACI/MACT), cells are embedded into a bioabsorbable, porcine type- Ⅰ/Ⅲ collagen membrane[62]. In the second stage of the procedure this membrane is placed over talar cartilage defect. Advantages of MACI/MACT are the avoidance of periosteal graft harvesting and a more even cell distribution potentially delivering more viable cells to the defect[17].

Furthermore, a third-generation of ACT, a three-dimensional, biomaterial-free MACT with chondrospheres, is available[63]. To apply it entirely arthroscopically and therefore reduce morbidity is a further advantage. However, to date, it is unclear whether the chondrospheres will remain securely in the defect because they are placed without coverage.

Analysing of the literature reveals various trials of ACT of the talus[4,40,43,63,64]. Although, many of the reports publicised promising results, the available evidence is of poor quality. A recent meta-analysis showed that many

Table 2 Summary of treatment options for cartilage repair of the talus

Procedure	Concept	Indication	Potential Advantage	Worth knowing	Evidence
Conservative	Unload injured cartilage	Low-grade OD in children	Healing without surgical risk	Results in literature low but recommended first-line treatment in low-grade lesions	Poor
Marrow stimulation techniques	Recruits mesenchymal stem cells from bone marrow Stimulates differentiation of repair tissue	Lesions < 150 mm^2 with none/minimal subchondral involvement	Can be administered arthroscopically Can be done repeatedly	Fibrocartilaginous repair tissue Results deteriorate over time	Fair
Autologous osteochondral transplantation	Resurfaces defect with viable hyaline cartilage + underlying bone	Osteochondral defects (2-4 cm^2)	Reproduces mechanical, structural, biomechanical characteristics of primary cartilage One-stage procedure	Donor site morbidity Potential need for osteotomy	Fair
Osteochondral allograft transplantation	Resurfaces defect with viable hyaline cartilage + underlying bone	Large-volume/ cystic lesions	No limitations based on size of defect One-stage procedure	Potential decrease in viable chondrocytes due to disease screening	Poor
Autologous chondrocyte transplantation (ACT)	Cultured chondrocyte-like cells will stimulate a hyaline-like repair tissue	Second-line treatment in large defects (> 2 cm^2)	Nearly perfect fit with defect (no "dead spaces")	Adverse effects of 1st generation MACT with better cell distribution Osseous defect has to be grafted before ACT	Poor
Further treatment options (hyaluronic acid, PRP, mesenchymal stem cells)	Not clear May function as an biological adjunct	Not clear May be added to repair techniques	Not clear May improve final outcome	Mode of function not completely understood	Insufficient

ACT: Autologous chondrocyte transplantation; MACT: Matrix-associated autologous chondrocyte transplantation; OD: Osteochondritis dissecans; PRP: Platelet rich plasma.

publications address ACT of the talus[65]. However, only 16 of 54 studies could be included in this systematic review. Due to the use of several products for ACT, several "generations" of ACT, the low case numbers, inhomogeneous indications, and the use of different outcome parameters, it was not possible to draw any conclusion about what type of ACT is superior[65]. Additionally, there were no controlled studies available. Therefore, a safe and significant superiority of other techniques of cartilage repair could not be estimated until now.

Further treatment options

Further methods to optimise techniques for cartilage repair have been introduced, but most of them are in the early stages of development or are only described in isolated case series. In summary, there is insufficient evidence to support recommending their use. However, they are mentioned below for completeness.

Mesenchymal stem cells may be able to differentiate into articular cartilage and may be used as an adjunct to microfracture treatment[6]. However, to date, the only relevant investigations were either animal or uncontrolled trials[66,67].

Additionally, platelet-rich plasma (PRP) may function as a scaffold for cultured cells and provide a reservoir of growth-stimulating factors[9,68].

Finally, viscosupplementation therapy using of hyaluronic acid has great popularity despite the lack of convincing outcomes[3]. In a recent study, after arthroscopic debridement and microfracture in osteochondral defects of the talus, hyaluronic acid was added postoperatively. Functional and pain scores were significantly improved compared to the group treated with microfracture alone[53].

CONCLUSION

In summary, no technique appears to be superior to the others, and treatment of chondral/osteochondral lesions of the talus remains controversial. Patients should be analysed rigorously. Before selecting an appropriate procedure, the socio-professional context and the patient's compliance, as well as the characteristics of the patients job-related or sports activities, have to be considered.

Based on the evidence available as well as our own experience we agree with others that, depending on the lesion's size, arthroscopic treatment using marrow stimulation and debridement may be a reasonable strategy to treat these lesions effectively[3,18,38]. Therefore, this approach can be recommended as first-line treatment.

For larger lesions, autologous osteochondral transplantation can be utilised as primary treatment with good success as well. Moreover, it can be recommended as second-line treatment in cases in which the bone marrow stimulation technique fails.

Patients with large-volume or cystic lesions who cannot be treated with the standard autograft procedures due to evidence of poor quality results, should be chosen for osteochondral allograft transplantation carefully.

Finally, autologous chondrocyte transplantation techniques should be individualised and applied to cautiously selected patients in whom the above-mentioned first-line treatment methods have failed. Table 2 gives an overview

about the different treatment options.

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