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Operative management of osteochondral lesions of the talus: 2024 recommendations of the working group 'clinical tissue regeneration' of the German Society of Orthopedics and Traumatology (DGOU)

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- The working group 'Clinical Tissue Regeneration' of the German Society of Orthopedics and Traumatology (DGOU) issues this paper with updating its guidelines.
- Literature was analyzed regarding different topics relevant to osteochondral lesions of the talus (OLT) treatment. This process concluded with a statement for each topic reflecting the best scientific evidence available with a grade of recommendation. All group members rated the statements to identify possible gaps between literature and current clinical practice.
- Fixation of a vital bony fragment should be considered in large fragments. In children with open physis, retrograde drilling seems to work better than in adults, but even there, the revision rate reaches 50%. The literature supports debridement with bone marrow stimulation (BMS) in lesions smaller than 1.0 cm^2 without bony defect. The additional use of a scaffold can be recommended in lesions larger than 1.0 cm^2. For other scaffolds besides AMIC®/Chondro-Gide®, there is only limited evidence. Systematic reviews report good to excellent clinical results in 87% of the patients after osteochondral transplantation (OCT), but donor site morbidity is of concern, reaching 16.9%. There is no evidence of any additional benefit from autologous chondrocyte implantation (ACI). Minced cartilage lacks any supporting data. Metallic resurfacing of OLT can only be recommended as a second-line treatment. A medial malleolar osteotomy has a minor effect on the clinical outcome compared to the many other factors influencing the clinical result.

Keywords: ankle; cartilage; operative; osteochondral; osteochondrosis dissecans; osteonecrosis; talus; review

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Introduction

Osteochondral lesions of the talus (OLT) affect the talar dome with varying involvement of the articular cartilage and subchondral bone. In 2017, the working group 'Clinical Tissue Regeneration' of the German Society of Orthopedics and Traumatology (DGOU) published the first recommendation for treating osteochondral lesions of the talus (1). As much further research has been done within the last 6 years, the rationale behind the update was to include recent results and the latest knowledge on the treatment algorithms and update the guidelines with the new literature. Due to a lack of evidence, in 2017, many of the recommendations were based on expert opinion. Meanwhile, more concepts are supported by an increasing number of scientific studies. Besides the continuous discussion within the working group, the development was also driven by several consensus meetings, including the 'International Consensus Meeting on Cartilage Repair of the Ankle' in Pittsburgh in 2017 (2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12) and Dublin in 2019 (13). Since these meetings, many additional studies have been published.

The working group on 'Clinical Tissue Regeneration' of the DGOU issues the present article. It represents the best evidence available in 2023 for managing OLT and updates its guidelines published in 2017 (1).

Table 1 Abbreviations and definitions.

AOFAS	American Orthopedic Foot and Ankle Society
ACI	Autologous chondrocyte implantation (scientifically neutral term, includes protected trademarks like MACI®)
DGOU	German Society of Orthopedic and Trauma Surgeons
BMS	Bone marrow stimulation (scientifically neutral term, includes protected trademarks like MFx®, Microfracture®, Nanofracture®, Microdrilling®)
M-BMS	Matrix-associated bone marrow stimulation (scientifically neutral term, includes protected trademarks like AMIC®, Chondro-Gide®, HYAFF®, Hyalofast®)
FAAM	Foot and Ankle Ability Measure
FADI	Foot and Ankle Disability Index
FAOS	Foot and Ankle Outcome Score
MSC	Mesenchymal stem cell
OA	Osteoarthritis
OCT	Osteochondral transplantation
OLT	Osteochondral lesion of the talus
ORIF	Open reduction and internal fixation
MOCART	Magnetic resonance observation of cartilage repair tissue
PRP	Platelet-rich plasma
LDFF	Lift, drill, fill, and fixation of an osteochondral fragment
VAS	Visual analog scale

This article focuses on the operative management of OLT. Abbreviations are defined in Table 1.

Methodology

The working group 'Clinical tissue regeneration' of the German Society of Orthopedics and Traumatology (DGOU) brought together 60 orthopedic and trauma surgeons with a particular interest in treating articular cartilage lesions. According to their subspeciality, a subgroup of 29 had a special focus on foot and ankle surgery. Under the leadership of the first author, literature was analyzed regarding different topics relevant to OLT treatment (PUBMED, Cochrane, Web of Science, Scopus, MEDLINE, University Library Munich). The relevant papers were collected for each topic, and the main conclusions were brought together. This process concluded with a statement for each topic reflecting the best scientific evidence available for a particular diagnostic or therapeutic concept. The level of evidence for each study was analyzed. Based on the evidence, each statement was assigned a grade recommendation (Tables 2 and 3) (14, 15, 16).

In the second step, the 29 group members were asked to rate the statements according to their clinical practice. The goal was to identify possible gaps between clinical experience and evidence in the literature. Blinded electronic surveys were distributed to all group members. The participants could agree or disagree with the statements, comment on the statements, and provide additional references. Based on the participants' input, statements were revised if additional literature was provided and sent for a second vote. The process ended with a statement on the different topics, based on the best evidence available, together with a grade of recommendation based on the quality of the studies supporting each statement. In addition, agreement among the experts was given, reflecting the current clinical practice and experience (17).

Different surgical treatment strategies

Fragment fixation

Large and vital osteochondral fragments, especially after ankle trauma, are suitable for fixation based on the principles of open reduction and internal fixation (ORIF) (18). After ankle trauma, fragments of the talar shoulder can be fixed with screws, while large, unstable, or detached OLTs can also be addressed with this treatment concept. It is crucial to debride all soft tissue that might have developed between the talus and the fragment. The bed of the defect is perforated with a drill bit or a K-wire to stimulate bony healing. Additional bone grafting can be considered for bony defects and

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Table 2 Grades of evidence.

A1	Multiple (two or more) level I RCTs with similar findings or a meta-analysis
A2	A single level I RCT
B1	Prospective cohort study
B2	Any comparison group that is not level I (e.g. a case–control study)
C	Case series
D	Case report
E	Expert opinion/basic science

chronic lesions (19). Importantly, any sclerotic wall should be perforated several times. This treatment strategy is also described by the abbreviation LDFF (lift, drill, fill, fix) (20).

The advantages of absorbable screws have been reported (21, 22), while there are some data on magnesium-based absorbable screws (23, 24) and polylactide polymer products (25, 26). Although there are no significant concerns regarding the safety of those products (23, 27, 28), the literature does not allow general recommendations. Most papers are case reports or small case series, reporting the results of osteochondral fragment fixation in various body regions.

In a retrospective study, Rak Choi *et al.* (29) reviewed the data of 26 patients with OLT treated with internal fixation, noting that 77% of the patients achieved bony union on postoperative CT scans. There was no statistically significant difference in clinical outcomes between patients with skeletally immature ankles and those with skeletally mature ankles. Haraguchi *et al.* (19) reported on 44 patients who had the osteochondral fragment reduced and fixed with bone harvested from the osteotomy site, with excellent results regardless of size and/or chronicity. The technique can also be considered in unstable and detached fragments in children after failed conservative treatment, which is the primary choice in patients with open physis (30, 31). Although a malleolar osteotomy is often the only way to approach the defect, it has the potential for secondary problems and it needs special attention. Bull *et al.* reported some displacement in a CT follow-up after a medial malleolar bi-plane chevron osteotomy stabilized with two lag screws in over 38%; in 30%, the offset was more than 2 mm (32). They found that using a buttress plate can eliminate postoperative osteotomy displacement.

The minimal critical size of the fragment for its successful fixation seems to be 10 mm in diameter and 3 mm in thickness (9). Whenever possible, the use of at least 2 pegs/screws is recommended to provide sufficient stability and compression (33).

Statement: Fixation of a vital bony fragment should be considered in OLT with a large enough bony fragment. In chronic lesions, an additional bone graft seems to be beneficial. Fixation is not recommended for isolated cartilage lesions. Fixation of an osteochondral fragment should also be considered in children not responding to conservative management. A disadvantage is the need for a malleolar osteotomy in most patients.

Grade of Recommendation: C

Arthroscopic debridement with the injection of adipose tissue-derived mesenchymal stem cells

In 2021, the first case report was published on the effect of autologous adipose-derived mesenchymal stem cell (MSC) therapy in treating osteochondral lesions in the ankle (34). Freitag *et al.* (34) reported on a patient with a history of multiple arthroscopies in an unstable OLT and onset of early osteoarthritis (OA). They performed arthroscopic debridement of the unstable cartilage and bone in combination with three ultrasound-guided intraarticular injections of adipose-derived MSCs at 6-month intervals. Besides improving the Foot and Ankle Disability Index (FADI), the MRI T2 mapping showed successful hyaline-like cartilage regeneration. So far, this is the first report on the use of adipose-derived MSCs in osteochondral lesions of the talus while any further data are missing. In Germany, current regulations prevent the use of this method although regulations can be different in other countries.

Statement: The use of adipose-derived MSCs in OLT treatment is experimental. So far, there is no information provided by the literature to support the use of adipose-derived MSCs in OLT treatment.

Grade of Recommendation: I

Retrograde drilling

Retrograde drilling can be considered in subchondral lesions with intact cartilage (1, 8). The significant advantage of this technique is no harm to the cartilage surface. Arthroscopy is recommended to evaluate the

Table 3 Grades of recommendation.

A	Good evidence (level I studies with consistent findings) for or against recommending an intervention.
B	Fair evidence (level II or III studies with consistent findings) for or against recommending an intervention.
C	Conflicting or poor-quality evidence (level IV or V studies) not allowing a recommendation for or against an intervention.
I	There is insufficient evidence to make a recommendation.

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cartilage surface as small lesions might be missed by MRI (35). The drilling can be performed with X-ray control, special guide instruments, or computer-based navigation (36, 37, 38, 39, 40, 41). Electromagnetic navigation reduces radiation exposure compared to fluoroscopy (41).

Although there are many articles on technical issues of retrograde drilling, there is a lack of literature on the clinical results (38, 39, 41, 42, 43). The indication of retrograde drilling is limited to an undetached stage I or II (Berndt and Harty) lesions. Especially in children with open physis, retrograde drilling seems to work better than in adults (41). However, even in pediatric and adolescent patients, Körner *et al.* (44) found a 50% revision rate after retrograde drilling. The control group with higher staged cartilage lesions was treated with debridement and microfracture (BMS). Although the control group's cartilage lesions were more severe, the revision rate was significantly lower.

Hyer *et al.* (45) reported on eight adults with a 2-year follow-up. Although they found a significant improvement in the AOFAS score, the median AOFAS score was only 56 (range: 52–68) at the last follow-up. Kono *et al.* (46) compared transmalleolar drilling vs retrograde drilling in grade 0 and I lesions (Pritsch classification, see Table 4 (47)). After retrograde drilling, they noted better results when evaluated in a second-look arthroscopy 1 year after the primary procedure. However, in their cohort, only three lesions (27.2%) improved from I to grade 0, while most eight lesions (72.8%) remained unchanged during the follow-up.

A careful arthroscopic examination of the cartilage surface is mandatory to avoid missing small tears and detached cartilage areas. The sensitivity of MRI was 91%, and specificity was 55% for the Outerbridge grading scale in a study performed by Staats *et al.* (35). For the Berndt and Harty classification system, sensitivity was 91% and specificity was 28%. An intact cartilage surface reported by the radiologist in MRT is not necessarily the truth.

Retrograde drilling alone may cause adverse effects in patients with cystic lesions (48). In addition, the presence of a cystic lesion is always suspicious that the cartilage surface is not intact, even if the radiologist does not see the lesion in the MRI (49).

Statement: Retrograde drilling can be performed in lesions with intact cartilage surfaces (Pritsch grades I and II) without cysts. However, the data on clinical results are limited, and the results published are inferior to other treatment options, with revision rates over 50%. The only advantage of retrograde drilling is the minimal trauma of the procedure. Arthroscopy and/or electromagnetic navigation can reduce radiation exposure and increase accuracy compared to fluoroscopy alone. Once the cartilage surface is disrupted, other treatment concepts should be preferred.

Table 4 Pritsch classification, and Pritsch classification modified by Takao.

Pritsch classification	Pritsch modified by Takao	Arthroscopic evaluation
I	0	Intact overlaying cartilage
II	I	Soft cartilage
III	II	Frayed overlaying cartilage
	III	Detached fragment is in place
	IV	Dislocated fragment

Grade of Recommendation: B

Retrograde cancellous bone grafts or bone substitutes

Retrograde grafting targets a subchondral bone cyst combined with an intact cartilage surface. The idea was to provide a technique to fill the cyst without damaging the cartilage. Although it is debatable whether a cystic lesion at the talar shoulder can develop without a cartilage lesion (34), some literature deals with this treatment concept (37, 50, 51, 52).

The established concept to implant a bone graft into the void without touching the cartilage surface is to create a retrograde drill hole of 3.5–4.5 mm (50), and then a k-wire is placed into the defect. After having checked the position of the wire, it can be used as a guide for a canulated drill (51). Cysts can be filled with autologous or allogenic cancellous bone grafts or bone substitutes (52). A modification of this technique uses retrograde osteochondral plugs (37).

Beck *et al.* (49) assessed the effectiveness of retrograde endoscopic core decompression in seven patients, drilled a tunnel, debrided the cystic lesion and necrotic bone, and then filled the defect with an injectable bone substitute. After 3 months, they reported a significant improvement in the clinical scores with good bone remodeling. Even lesions larger than 150 mm^2 showed good clinical scores with medial talar dome contour restoration in radiographic imaging. Anders *et al.* (53) reported that among 38 patients treated by fluoroscopy-guided retrograde core drilling and autologous cancellous bone grafting stage I and stage II lesions (Pritsch classification (47)) tended to have better results.

Statement: Retrograde drilling with bone graft or bone substitute can be used in lesions with intact cartilage surfaces. No studies have compared cancellous bone grafting and bone graft substitutes. Some limitations must be estimated in the quality of debridement of the cystic lesions and necrotic bone since it appears

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unlikely that all the soft tissue from a cystic lesion can be reached and removed through a small drill hole.

Grade of Recommendation: C

Debridement with bone marrow stimulation (microfracture, micro-drilling)

The literature well supports the debridement of unstable cartilage combined with bone marrow stimulation (BMS) (microfracture, micro-drilling). The procedure can be performed arthroscopically.

Takao *et al.* (54) analyzed 69 patients with ankle instability and grade 3 or 4 OLT (Pritsch classification modified by Takao). One group underwent arthroscopic drilling to preserve the cartilage at the lesion site; the other was treated with arthroscopic drilling and debridement of the unstable cartilage. The authors found that removing the unstable cartilage at the lesion site improved the cartilage condition at a second look arthroscopy 1 year later.

The technique, however, has limitations in bony defects. Angermann *et al.* (55) examined patients after removing loose bony fragments and reported that half of the patients had pain with activity 9–15 years following debridement and drilling, and 28% had significant swelling.

In the recommendations from the group 'Clinical Tissue Regeneration' of the DGOU in 2017, debridement with BMS was recommended for lesions smaller than 1.5 cm^2 and a depth less than 5 mm (1).

During the last few years, there has been an ongoing debate about the critical size to justify invasive procedures and the additional use of scaffolds or autologous chondrocyte transplantation. The success rate of debridement and BMS in literature is between 46% and 100% (with an average of 85%) (54, 56, 57). Some studies followed athletes treated with debridement and BMS. The reported rate of return to sports at the previous level was between 60% and 100%. The overall return to sports rate was between 77% and 100% (58, 59, 60, 61). It should be noted that these studies have an age and lesion size bias, as the average age of the patients was 30–40 years, with an average lesion size of less than 1.5 cm^2 (62).

Ramponi *et al.* (63) found in a systematic review that the currently available data suggest that BMS may best be reserved for OLT sizes less than 107.4 mm^2 in area and/or 10.2 mm in diameter. One study by Migliorini *et al.* (64) with a 5-year follow-up compared M-BMS (matrix-associated BMS) using Chondro-Gide® against BMS, and they reported significantly better results with the additional scaffold in lesions sized between 2 and 3 cm^2. In a systematic review and meta-analysis, Wen *et al.* (65) included studies comparing microfracture alone against microfracture with additional biological augmentation such as scaffolds, hyaluronic acid, platelet-rich plasma (PRP), bone marrow aspirate concentrate, and MSCs. They concluded that augmented microfracture is superior to microfracture alone in treating talar OLTs based on the AOFAS, MOCART, VAS score, complication rate, and revision ratio. Tan *et al.* (66) confirmed the results with a similar methodologic approach.

There are also discussions on the best BMS technique. Kraeutler *et al.* (67) concluded after a systematic review and meta-analyses that there is still limited basic science available, whether deep drilling or microfracture leads to better clinical results. Regardless of the BMS technique, the overall quality of the cartilage repair tissue created with this technique was poor and did not achieve the characteristics of native articular cartilage.

Statement: Good results are reported for BMS in small lesions, including a high rate of return to sports. Unstable cartilage and small bony fragments should be removed. There is no particular advantage of microfracture vs micro-drilling. Increasing evidence shows that the results are less favorable in more extensive lesions. The additional use of biological augmentation seems beneficial, but the data are still limited. It is not possible to compare different biological augmentations.

Grade of Recommendation: B

Anterograde transmalleolar drilling

It was suggested that lesions of the medial malleolus, which cannot be reached arthroscopically, can be drilled through the medial malleolus. Kono *et al.* (46) compared patients with anterograde transmalleolar drilling to patients with retrograde drilling. After transmalleolar drilling, they found an unchanged lesion in 58% of the patients, while 42% had deteriorated one grade (Pritsch classification (47)). They concluded that transmalleolar seems to be an unsuitable technique to improve OLTs. Robinson *et al.* (68) performed debridement and transmalleolar drilling in 22 patients with a high rate of persistent medial malleolar pain and moderate clinical results. Their conclusion was to stop transmalleolar drilling as a treatment concept.

Statement: Anterograde transmalleolar drilling is no longer recommended.

Grade of Recommendation: B

Debridement and bone grafting

Draper and Fallat (69) published that bone grafting of a cystic lesion yields better long-term clinical results than curettage plus drilling alone. However, a bone

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graft without coverage against the joint space was always of some concern. Kolker *et al.* (70) followed 13 patients after autologous bone grafting of OLTs. They saw a revision rate of 46% of patients and an overall satisfaction rate of 46.2%. The authors have been reluctant to recommend this treatment concept.

Gu *et al.* (71) reported significantly better results in patients with stage V OLT (Hepple classification, see Table 5 (72)) with a modified approach. After debridement of the defect, they grafted the cavity with cancellous bone and added PRP. At the last follow-up, the MRI demonstrated a complete regeneration of the subchondral bone and cartilage in all patients. The average AOFAS score was 86.2 ± 6.4, therefore better than the results published for grafting alone. The study's primary limitation was that a control group was missing. Therefore, it remains unclear if the addition of PRP together with a bone graft influenced the clinical outcome.

Statement: Debridement and bone grafting alone lack good support from clinical studies. Compared to the articles published for bone grafting together with scaffolds, the results for bone grafting alone seem to be inferior.

Grade of Recommendation: B

Debridement, bone grafting, and scaffolds

Different scaffolds can be used to support cartilage regeneration after debridement and bone grafting of OLTs. The need to cover any bone graft is supported by the work of Kolker *et al.* (52), who reported a revision rate of 46% among patients who had undergone bone grafting alone. While there is a variety of scaffolds available, the majority of the peer-reviewed literature, whether a clinical study, metanalysis, or systematic review, has evaluated outcomes with the bilayer type I/III collagen membrane (Chondro-Gide®, Geistlich Pharma AG, Wolhusen) in the M-BMS technique (64, 73, 74, 75, 76, 77).

While the first studies used arthrotomy with a malleolar osteotomy (78), many scaffolds are now implanted with an arthrotomy alone (79). Depending on the localization of the lesion, a ventromedial, ventrolateral, dorsomedial, or dorsolateral approach allows access to approximately 85% of the surface of the talus without malleolar osteotomy (79, 80). Sripanich *et al.* (81, 82) published a systematic review on the limitations of accessibility of the talar dome with different open surgical approaches. The conclusion was that the talus's central dorsal area is challenging to reach without osteotomy, with otherwise good options, especially if no perpendicular access is needed. Usuelli *et al.* (83, 84) described an all-arthroscopic technique. Geyer *et al.* (85) presented the first arthroscopic results from a study that enrolled 23 patients with a minimum follow-up of 24 months. Limitations of arthroscopic techniques can be the radical debridement of extended cystic lesions and bone grafting.

Table 5 Hepple classification (MRI).

Stage	MRI characteristics
I	Articular cartilage damage only
IIA	Cartilage damage with underlying fracture and surrounding bony edema
IIB	IIA without bony edema
III	Detached but undisplaced fragment
IV	Detached and displaced fragment
V	Subchondral cyst formation

Results of M-BMS with Chondro-Gide® are available with follow-up as long as 8 years (77), while several papers report 5-year results, including prospective cohort studies (64, 73, 86). Two meta-analyses and systematic reviews have analyzed studies dealing with this treatment concept (75, 87). Compared to the studies dealing with Hyalofast®, the lesions treated with M-BMS using Chondro-Gide® are more extensive, and bone grafting is routinely performed in lesions deeper than 3–4 mm. Multiple studies have confirmed that the treatment of OLTs with M-BMS significantly improves patient outcome scores, compared to the preoperative values, with stable results at least 5 years postoperatively. Richter *et al.* (88) reported the 5-year follow-up in 100 patients with high, validated outcome scores.

Migliorini *et al.* (64) compared M-BMS and microfracturing in borderline-sized defects of the talus. The mean follow-up of the retrospective study was 43.5 months. The mean defect size was 2.7 cm^2. No difference was found between the two cohorts regarding the length of symptoms prior to surgery and follow-up, mean age and BMI, sex, side, and defect size. The clinical scores (AOFAS, VAS, Tegner) were significantly better, and the failure rate was significantly lower in the M-BMS group than in the microfracture group. Becher *et al.* (89) compared two groups with articular cartilage defects of the talus (lesion size average 1.1 cm^2), treated arthroscopically via BMS with or without an additional bilayer type I/III collagen membrane. Although the mean and average scores in the group treated with the additional scaffold outperformed the group treated with BMS alone, the difference did not reach any significance in the 5-year follow-up. While the difference between M-BMS and BMS is consistent with reports for other joints, such as the knee (90), comparisons to ACI for talar OLT have been rare. A recent systematic review compared outcomes between M-BMS and matrix-induced autologous chondrocyte implantation (MACI®) (91). The authors concluded that although M-BMS exhibits similar clinical results to MACI®, M-BMS involves only one surgical procedure and neither articular cartilage harvesting nor expansion of cells in

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a lab. Therefore M-BMS may be preferred over MACI®. Richter *et al.* (92) published a 5-year follow-up of M-BMS using Chondro-Gide® plus peripheral blood concentrate with good clinical results. So far, no comparative studies are looking at Chondro-Gide® with BMS and Chondro-Gide® in combination with other cell sources.

Recent studies reported the results of the biodegradable, hyaluronan-based (HYAFF®) scaffold (Hyalofast®). Bajuri *et al.* (93) reported on seven patients treated with Hyalofast®, all with an anterior-medial incision and a medial malleolar osteotomy. The OLT was then excised and debrided, microfracture was performed, and the scaffold was applied directly to the defect. Fibrin glue was used to ensure the adherence of the scaffold to the defect (93). SF-36, AOFAS, and VAS showed a significant improvement. The major problem with this article is that the authors did not mention the defect size. Moreover, discussing the results in the context of other scaffolds is impossible, as all results are given as relative postoperative changes and not as absolute values.

Yonta *et al.* (94) followed 20 patients with OLTs smaller than 1.5 cm^2 and deeper than 7 mm after arthroscopic debridement and treatment with Hyalofast®. They noted a significant improvement in AOFAS and the VAS score at the final 6.2 months or more follow-up. The authors reported no postoperative complications related to the surgery. It should be noted that none of the studies dealing with this cell-free hyaluronic acid scaffold used bone grafting.

Statement: The additional use of a scaffold can be recommended to stabilize the bone graft in cystic OLT. Early studies supported the benefit of M-BMS in larger lesions compared to microfracture alone. So far, data indicate that the smaller the defect, the less likely the benefit of an additional scaffold. The critical cutoff seems closer to 1.0 cm^2 than 1.5 cm^2. For other scaffolds besides AMIC®/Chondro-Gide®, there is only limited evidence. Few studies on Hyalofast® deal with a small number of patients, a short follow-up, and small lesions treated. AMIC®/Chondro-Gide®, as well as Hyalofast®, can be used in an arthroscopic procedure. Arthroscopy's technical limitations include radical debridement of cystic lesions and bone grafting. While there is a paucity of clinical data for most scaffolds used in M-BMS, the preponderance of data for Chondro-Gide®, as measured by the volume of peer-reviewed literature, supports its role as an essential element in treating osteochondral lesions of the talus.

Grade of Recommendation: B

Osteochondral transplantation and mosaicplasty

Hangody *et al.* (95) published the results of transferring osteochondral plugs from the knee to an OLT in patients after failed BMS. They treated defects up to 4 cm^2 and showed promising results for the medial and lateral talar shoulder lesions, while limitations were observed for OLTs located at the central talus. Similarly, good results have also been reported by other groups (96, 97, 98, 99, 100).

A technical modification is the transplantation of a single osteochondral plug (OCT – osteochondral transplantation). After debridement of the unstable cartilage, the size of the defect can be estimated. The diseased cartilage and bone are removed with a punch, and an osteochondral plug with healthy cartilage is inserted. Several companies provide instruments to prepare the plugs with a perfect press fit.

Shimozono *et al.* (101) published a systematic review and reported good to excellent clinical results in 87% of the patients, with good restoration of the articular surface in MRI and minimal evidence of osteoarthritis.

There is still a lack of literature on the perfect donor site and the use of osteochondral autograft (3), as there are some concerns about the donor site morbidity at the knee joint. Andrade *et al.* (102) published a meta-analysis examining donor site morbidity at the knee and reported that osteochondral harvesting often results in considerable morbidity. The donor site morbidity for the knee-to-ankle procedure was calculated at 16.9%, based on data from 22 studies. In a more recent meta-analysis, Shimozono *et al.* (103) estimated the donor-site morbidity after autologous OCT to range from 6.7% to 10.8%. There are inconsistent data on correlations between donor site morbidity, defect size, and the number and size of the plugs (102, 104, 105, 106). It is hypothesized that there might be an underreporting of donor site problems in papers dealing with OCT so the problem might be underestimated (105).

Other autologous donor regions include the proximal tibiofibular joint (107) and non-weight-bearing areas of the talus (108). Pereira *et al.* (109) performed a systematic review on using fresh osteochondral autograft as a source for OCT. Based on 12 studies, they found an aggregated graft survival rate of 86.6% and considered fresh osteochondral autograft as a suitable concept to avoid donor site problems. However, this option is currently not available in Germany.

OCT requires an orthogonal approach to the lesion (80). Although Muir *et al.* found that only 17% (range, 10%–24%) of the medial talar dome and 20% (range, 16%–25%) of the lateral talar dome cannot be accessed perpendicular without osteotomy, the majority of OLT at least partially extend to that 'inaccessible' areas (108, 110). To our knowledge, there are no papers published on OCT or mosaicplasty performed without malleolar osteotomy. So far, no studies compare OCT to the use of scaffolds.

Statement: Donor site problems and the mandatory need for malleolar osteotomy increase the risk of

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potential complications of OCT. OCT is suitable for treating OLTs after failed BMS. Good or excellent results are reported in up to 87% of the patients.

Grade of Recommendation: B

Autologous chondrocyte implantation (ACI)

ACI is discussed as an alternative for treating larger OLT (111). Niemeyer *et al.* (112) concluded in a meta-analysis, which included 16 studies and 213 cases, that evidence concerning the use of ACI is still elusive. Although clinical outcomes seemed promising, superiority or inferiority to other techniques, such as OCT or microfracture, could not be determined. The first version of the guidelines discussed ACI as a possible treatment option for OLT (1).

The downside of ACI is the two-step approach (harvesting the cartilage cells in a first surgery prior to definitive treatment with the implantation) and the high cost of cell culture. Based on the missing proof of superiority in combination with the high cost, ACI was excluded from healthcare insurance reimbursement in Germany (Gemeinsamer Bundesausschuss der Krankenkassen – BGA) in 2009, and this situation has remained unchanged. In a recent systematic review, Migliorini *et al.* (91) compared M-BMS against ACI. They found that M-BMS exhibits similar clinical results to ACI but underscored the advantage of M-BMS as a single surgical procedure with no donor-side morbidity. Some papers have presented medium- to long-term results after ACI (113), and a recent meta-analysis confirmed that using ACI could provide a relatively high success rate and improve the AOFAS score. However, the outcome scores were not compared to other treatment concepts (114). Because of the reimbursement situation, ACI is currently not in the scope of clinical research in Germany.

Statement: There is some evidence for good results with ACI. There is no evidence of any additional benefit compared to acellular scaffolds in the talus.

Grade of Recommendation: B

Minced cartilage

The implementation of vital chondrocytes harvested from the OLT was first suggested for the knee (115). Osteochondral fragments are often covered with cartilage containing many vital cartilage cells (116). The cartilage cells from the osteochondral fragment can be harvested and cut into small pieces with better cell vitality after manual harvesting with the scalpel than machined harvesting (116). In this procedure, the small cartilage particles are mixed with PRP and fibrin glue and re-implanted into the defect. The construct can then be covered with a collagen membrane to improve stability. Until now, most studies discussing this technique deal with cartilage defects at the knee joint (115).

At this stage, there are still many open questions regarding minced cartilage. Cells from the osteochondral fragments have also been proposed as a source for cell culture in ACI, although there is an international consensus that articular chondrocytes for ACI should be removed from unaffected, lesser weight-bearing areas of the joint (117). There are also some fundamental questions regarding minced cartilage. Adult human cartilage cells usually cannot proliferate. If they are forced to proliferate, each proliferation cycle increases cell dedifferentiation toward fibroblast (118) although it was possible to stimulate an *in vitro* proliferation of cartilage cells in an animal model (119). Moreover, the cutting process during the mincing procedure induces chondrocyte death at the edges of the minced fragments (120). There are still many open questions on the behavior of minced cartilage in the human joint (116, 121, 122).

Although two papers have been published using minced cartilage for OLT (123, 124), both papers are technical notes without clinical results.

Statement: Minced cartilage is another approach for the treatment of OLT. So far, clinical results for the application at the ankle joint are missing. There are no data on which defects may benefit from adding minced cartilage. It cannot be excluded that minced cartilage may also lead to inferior results compared to other established techniques.

Grade of Recommendation: I

Metallic implants

In 2007 the first metallic implants were developed to fill a bony defect at the talus (HemiCap™). The product was recommended for revisions to compensate for insufficient biological healing. The initial clinical and radiological results of a prospective cohort study with a follow-up of 2 years have been promising (125). Meanwhile, three other working groups have analyzed the results of this concept (126, 127, 128). Ettinger *et al.* (128) reported a revision rate, during a 43.5 ± 35.51 months follow-up, of 70% due to persistent pain, even though 60% of the patients stated they would do the operation again instead of fusion or total ankle replacement.

The most comprehensive study on HemiCap™ was published by Ebskov *et al.* (126), in which they followed 31 patients up to 81 months (mean 50 months) in which they stated there was no revision surgery, while the AOFAS score improved from 47.6 ± 16.1 to 79.1 ± 14.7.

The most recent paper included 12 patients (127) and reported that the AOFAS score improved from 55.92 ± 9.52 to 74.67 ± 13.1 while the VAS decreased

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from moderate-to-mild pain. Based on these results, the authors concluded that metal resurfacing might be considered a valid option for OLT treatment after a failed previous surgery. Current research is focused on improving the fit of the metal implant by individually manufactured products based on CT scans.

Statement: Based on the current literature, metallic resurfacing of OLT can be considered after failed primary cartilage treatment when other options are limited to ankle fusion or total ankle replacement. Creating a realistic expectation for the patient of what can be achieved with this treatment concept seems essential.

Grade of Recommendation: C

Effect of medial malleolar osteotomies on the clinical outcome

The need for malleolar osteotomies in the treatment of OLTs varies between different techniques. As long as there is no need for an orthogonal approach, most talus areas can be reached with an arthrotomy (79, 129). If perpendicular access is mandatory, malleolar osteotomies are needed in most cases. A 6% rate of late complications of medial malleolar osteotomies was reported by Leumann *et al.* (130). Bull *et al.* (32) found an offset of more than 2 mm in 30% of the patients on CT scans after medial malleolar osteotomies with a 38.3% loss of correction compared to the postoperative images. Kim *et al.* (131) performed second-look arthroscopies after medial malleolar osteotomies. They found a close correlation between irregularities in the osteotomy area and inferior clinical results.

Two studies have examined the effect of medial malleolar osteotomies on the clinical outcome of OLT treatment. Gottschalk *et al.* (132) presented a study based on the data of the German cartilage registry, including patients treated for OLT lesions with BMS plus an I/III collagen scaffold with and without medial malleolar osteotomy. They reported a significant improvement in patients' outcome scores (FAAM – Foot and Ankle Ability Measure, FAOS – Foot and Ankle Outcome Score, VAS – visual analog scale). However, no statistically significant difference was noted between the groups with and without a medial malleolar osteotomy. Although the difference was not statistically significant, a closer look at the data showed that in all subcategories of the scores, the average results of patients with medial malleolar osteotomy were less favorable than those seen in patients without medial malleolar osteotomy.

Similar results were reported by Sadlik *et al.* (133). They compared patients treated arthroscopically to patients treated using the medial malleolar osteotomy to reach the OLT. Although statistically insignificant, the mean AOFAS, VAS, and MOCART scores have been less favorable after osteotomy.

Statement: A medial malleolar osteotomy will likely have a minor effect on the clinical outcome. The effect seems small compared to many other factors influencing the clinical result. A malleolar osteotomy can be justified if needed to address the lesion sufficiently.

Grade of Recommendation: B

Ankle instability and malalignment

Based on the German cartilage registry data, Koerner *et al.* (134) could show that OLT with additional chronic ankle instability worsens the patients' quality of life. Ackermann *et al.* (74) performed a matched-pair cohort study that evaluated 26 patients treated for OLT via M-BMS using Chondro-Gide® with or without ankle instability. Concurrently performed M-BMS and lateral ligament stabilization resulted in clinical outcomes comparable with isolated M-BMS if postoperative ankle stability was achieved. Residual ankle instability was associated with worse postoperative outcomes.

Unfortunately, there is little literature on alignment correction in combination with OLT treatment. In the knee, overload through malalignment increases the risk for cartilage degeneration, while unloading diminishes it and shifts the articular cartilage and subchondral bone phenotype to normal (135).

Malalignment may cause overloading of specific areas at the ankle and increase the risk for the development of ankle OA (136). Correcting osteotomies can normalize the cartilage load and restore biomechanics (137, 138) but most studies on alignment correction deal with posttraumatic or congenital malalignment (139). In cartilage reconstruction, there is often limited information on additional procedures.

Statement: Ankle instability should be addressed in any surgical treatment concept for cartilage lesions. Persistent ankle instability is related to inferior results. Although there is limited literature on alignment correction combined with the treatment of OLT, the evidence available from other cartilage problems and other joints supports alignment correction.

Grade of Recommendation: B

All group members (n = 29) voted on the statements to detect possible differences between evidence in the literature and clinical practice (Table 6). The lowest grade of the agreement was seen in the statement regarding autologous chondrocyte implantation (46% totally agree, 38% somehow agree). None of the group members 'totally disagreed' with the statements.

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Table 6 Statements, grade of recommendation (GOR), level of evidence (LOE) of the best study on the topic and agreement on the statements among the experts (29 votes).

			Expert agreements (%)				
Statement	**GOR**	**LOE***	TA	SA	NE	SD	TD
Fixation of a vital bony fragment should be considered in OLT with a large enough bony fragment. In chronic lesions, an additional bone graft seems to be beneficial. Fixation is not recommended for isolated cartilage lesions. Fixation of an osteochondral fragment should also be considered in children not responding to conservative management. A disadvantage is the need for a malleolar osteotomy in most patients.	C	IV	85	11	0	4	0
The use of adipose-derived mesenchymal stem cells in OLT treatment is experimental and currently not approved in Germany. However, the approach is worth closer examination in the future.	I	IV	88	8	4	0	0
Retrograde drilling can be performed in lesions with intact cartilage surfaces (Pritsch Grade I and II) without cysts. The procedure is safe. However, the data on clinical results are limited, and the results published are inferior to other treatment options. The significant advantage of retrograde drilling is the minimal trauma of the procedure. Arthroscopy and/or electromagnetic navigation can reduce radiation exposure and increase accuracy compared to fluoroscopy alone. Once the cartilage surface is disrupted, other treatment concepts should be preferred.	B	III	81	19	0	0	0
Retrograde drilling with bone graft or bone substitute can be used in lesions with intact cartilage surfaces. No studies have compared cancellous bone grafting and bone graft substitutes. Some limitations must be estimated in the quality of debridement of the cystic lesions and necrotic bone since it appears unlikely that all the soft tissue from a cystic lesion can be reached and removed through a small drill hole.	C	IV	84	12	0	4	0
Good results are reported for BMS in small lesions, including a high rate of return to sports. Unstable cartilage and small bony fragments should be removed. There is no particular advantage of microfracture versus micro-drilling. Increasing evidence shows that the results are less favorable in more extensive lesions. The additional use of biological augmentation seems beneficial, but the data are still limited. It is not possible to compare different biological augmentations.	B	II	73	23	0	4	0
Anterograde transmalleolar drilling is no longer recommended.	B	III	84	8	4	4	0
Debridement and bone grafting alone lack good support from clinical studies. Compared to the articles published for bone grafting together with scaffolds, the results for bone grafting alone seem to be inferior.	B	III	69	23	4	4	0
The additional use of a scaffold can be recommended to stabilize the bone graft in cystic OLT. Early studies supported the benefit of M-BMS in larger lesions compared to microfracture alone. So far, data indicate that the smaller the defect, the less likely the benefit of an additional scaffold. The critical cutoff seems closer to 1.0 cm^2 than 1.5 cm^2. For other scaffolds besides AMIC®/Chondro-Gide®, there is only limited evidence. Few studies on Hyalofast® deal with a small number of patients, a short follow-up, and small lesions treated. AMIC®/Chondro-Gide®, as well as Hyalofast®, can be used in an arthroscopic procedure. Arthroscopy's technical limitations include radical debridement of cystic lesions and bone grafting. While there is a paucity of clinical data for most scaffolds used in M-BMS, the preponderance of data for Chondro-Gide®, as measured by the volume of peer-reviewed literature, supports its role as an essential element in treating osteochondral lesions of the talus.	B	II	58	35	0	7	0
Donor site problems and the mandatory need for malleolar osteotomy increase the risk of potential complications of osteochondral transplantation. Osteochondral transplantation is suitable for treating OLTs after failed BMS. Good or excellent results are reported in up to 87% of the patients.	B	II	85	15	0	0	0
There is some evidence for good results with ACI. There is no evidence of any additional benefit compared to acellular scaffolds in the talus.	B	II	46	38	16	0	0
Minced cartilage is another approach for the treatment of OLT. So far, clinical results for the application at the ankle joint are missing. There are no data on which defects may benefit from adding minced cartilage. It cannot be excluded that minced cartilage may also lead to inferior results compared to other established techniques.	I	V	77	23	0	0	0
Based on the current literature, metallic resurfacing of OLT can be considered after failed primary cartilage treatment when other options are limited to ankle fusion or total ankle replacement. Creating a realistic expectation for the patient of what can be achieved with this treatment concept seems essential.	C	IV	57	35	4	4	0
A medial malleolar osteotomy will likely have a minor effect on the clinical outcome. The effect seems small compared to many other factors influencing the clinical result. A malleolar osteotomy can be justified if needed to address the lesion sufficiently.	B	III	77	15	8	0	0
Ankle instability should be addressed in any surgical treatment concept for cartilage lesions. Persistent ankle instability is related to inferior results. Although there is limited literature on alignment correction combined with the treatment of OLT, the evidence available from other cartilage problems and other joints supports alignment correction.	B	III	96	4	0	0	0

*Highest LOE.

NE, neither agree not disagree; SA, somewhat agree; SD, somewhat disagree; TA, totally agree; TD, totally disagree.

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Seven percent somehow disagreed with the statement regarding the use of scaffolds.

Discussion

The surgical treatment algorithm for OLT published by Aurich *et al.* (1) in 2017 was modified (Fig. 1). The literature now supports many statements primarily based on expert opinion. Some new treatment modalities, like minced cartilage, have been proposed. Especially for more extensive defects, there is increasing evidence that the additional use of scaffolds may improve the clinical outcome, and the threshold for the use was reduced to 1.0 cm^2. Much data are available for the bilayer collagen I/III membrane (Chondro-Gide®), including follow-up as long as eight years, while there is a paucity of data regarding other scaffolds.

In addition, two papers have demonstrated the negative effect of persistent ankle instability on clinical results. Therefore, joint mechanics should be addressed when treating cartilage defects. In smaller lesions, the additional scaffolds did not change the clinical outcome. However, patients benefit from biological support (65, 66).

The published literature on the operative management of OLT shows increasing evidence for the different treatment options. However, the maximum grade of recommendation never exceeds level B – fair evidence. The evidence is poor or missing for some approaches, like minced cartilage or adipose-derived MSCs resulting in a grade of recommendation 'I.' However, none of the recommendations reaches a grade of recommendation A. Hopefully, ongoing register studies as supported by the research group may contribute in the future to fill this gap. The first studies from this register are available and provide valuable data for the conclusions (132, 134, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150).

Although the group members developed all statements, the statement on autologous chondrocyte transplantation had the lowest percentage of agreement (46% totally agree, 38% somehow agree, 16% neither agree nor disagree). A possible reason for this result might be the limited experience with this treatment modality due to the reimbursement situation for ACI in the talus, which is different in the knee. Surgeons may have good experience with ACI in the knee and may want to use ACI also in the talus.

The other statement, with only 58% of agreement, was on the role of scaffolds. About 35% somehow agreed, and 7% somehow disagreed. The voting may reflect the high dynamic of this treatment modality, where the latest clinical developments are always ahead of the scientific literature.

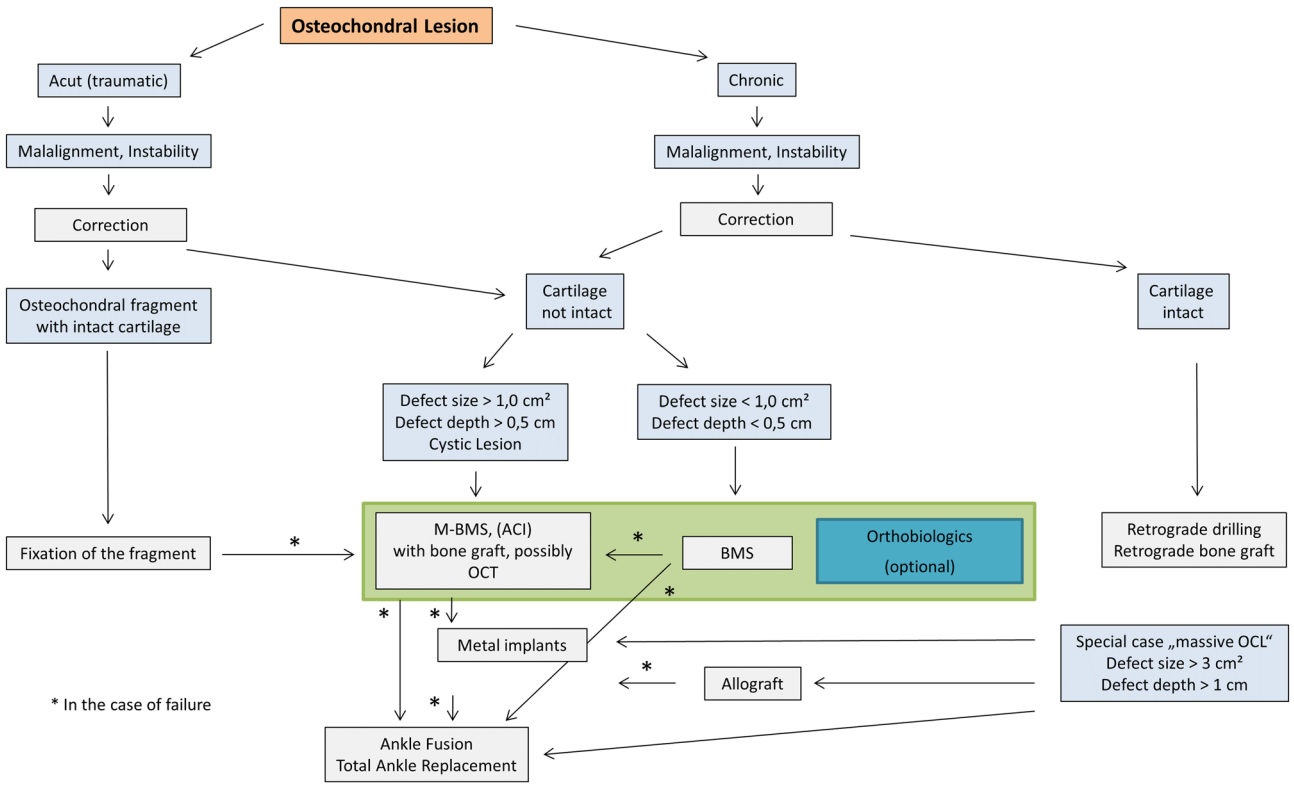

Figure 1

Operative treatment algorithm for OLT.

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Other statements with some limitations regarding agreement were debridement with bone grafting alone (69% totally agreed) and BMS (73% totally agreed). All other statements could be developed until the wording finally reached a total agreement rate of around 80% or more.

There are several key messages regarding operative treatment. The statements are, in general, supported by the expert group. However, the most inhomogeneous opinion was seen on the topics 'scaffolds' and 'autologous chondrocyte transplantation':

- Fixation of a vital bony fragment should be considered in large fragments (18, 21, 22). The procedure is also abbreviated in literature with LDFF (20). Defects need to be debrided and filled with a bone graft. The technique has also shown good to excellent results in instable and detached fragments in children after failed conservative treatment (30).
- Retrograde drilling should be limited to subchondral lesions with intact cartilage without bony defects (1, 8). There is a lack of literature on the clinical results, and few case-control studies report limited results (45). In children with open physis, retrograde drilling seems to work better than in adults (41), but even there, the revision rate reaches 50% (44).
- Few studies, all with moderate results, support retrograde cancellous bone grafts or bone substitutes (52, 151). A modification of this technique uses retrograde osteochondral plugs (37). The concept should be limited to patients with an intact cartilage surface (53).
- The literature supports debridement with BMS in lesions smaller than 1.0 cm^2 without bony defect (63). The literature's debridement and BMS success rate is between 46% and 100% (average 85%) (54, 56, 57).
- Anterograde transmalleolar drilling is no longer recommended.
- The treatment concept of debridement and bone grafting lacks good support from clinical studies (69, 70). Compared to the articles published for bone grafting together with scaffolds, the results for bone grafting alone seem to be inferior.
- The additional use of a scaffold can be recommended to stabilize the bone graft in cystic OLT. So far, data indicate that the smaller the defect, the less likely an additional scaffold is of benefit. The critical cutoff seems to be closer to 1.0 than to 1.5 cm^2. While there is a substantial body of clinical data concerning AMIC®/Chondro-Gide®, there is limited evidence for all other scaffolds.
- Systematic reviews report good to excellent clinical results in 87% of the patients after OCT (101). In a meta-analysis, donor site morbidity is of concern (78), reaching 16.9%. In addition, the need for malleolar osteotomy increases the risk of potential complications. Although the clinical outcome of OCT seems to be similar to the treatment with bilayer collagen I/III membranes, possible side effects made this technique a second-line treatment.
- ACI has shown promising results; however, there is no evidence of any additional benefit compared to acellular scaffolds. High cost, lack of reimbursement, and missing evidence of additional benefit compared to acellular scaffolds limit ACI use.
- So far, no clinical results support the application of minced cartilage at the ankle joint.
- Based on the current literature, metallic resurfacing of OLT can only be recommended after failed primary cartilage treatment to avoid ankle fusion or total ankle replacement. The results are inferior to those seen after biological reconstruction.
- A medial malleolar osteotomy seems to have a minor effect on the clinical outcome (132, 133). The effect is small compared to many other factors influencing the clinical result. A malleolar osteotomy can be justified if needed to address the lesion sufficiently.
- Persistent ankle instability leads to inferior results in OLT treatment (74, 134) and needs to be addressed.

Declaration of generative AI and AI-assisted technologies in the writing process

The authors did not use AI tools while preparing this work.

ICMJE Conflict of Interest Statement

All authors are members of the Working Group on Tissue Regeneration of the German Association of Orthopedic and Trauma Surgery (DGOU). Markus Walther and Oliver Gottschalk worked as paid speakers at Geistlich workshops.

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