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Preexisting and treated concomitant ankle instability does not compromise patient-reported outcomes of solitary osteochondral lesions of the talus treated with matrix-induced bone marrow stimulation in the first postoperative year: data from the German Cartilage Registry (KnorpelRegister DGOU)

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Abstract

Purpose The purpose of this study was to compare the subjective ankle function within the first year following matrix-induced bone marrow stimulation (M-BMS) of patients with a solitary osteochondral lesion of the talus (OCLT) with and without concomitant chronic ankle instability (CAI).

Methods Data from the German Cartilage Registry (KnorpelRegister DGOU) for 78 patients with a solitary OCLT and a follow-up of at least 6 months were included. All patients received M-BMS for OCLT treatment. The cohort was subdivided into patients with OCLT without CAI treated with M-BMS alone ($n=40$) and patients with OCLT and CAI treated with M-BMS and additional ankle stabilisation ($n=38$). The Foot and Ankle Ability Measure (FAAM), the Foot and Ankle Outcome Score (FAOS), and the Numeric Rating Scale for Pain (NRS) were used to assess patient-reported outcomes (median (minimum–maximum)).

Results From preoperatively to 12 months postoperatively, patients with OCLT without CAI treated with M-BMS alone had a significant improvement of all subscales in the FAAM [activity of daily living 64.3 (10–100) to 88.1 (39–100); sports 34.4 (0–100) to 65.6 (13–94), functional activities of daily life 50 (0–90) to 80 (30–100), functional sports 30 (0–100) to 70 (5–100)] and FAOS [pain 61.1 (8–94) to 86.1 (50–100), symptoms 60.7 (18–96) to 76.8 (29–100), activities of daily living 72.1 (24–100) to 91.9 (68–100), sport/recreational activities 30.0 (0–70) to 62.5 (0–95), quality of life 31.3 (6–50) to 46.9 (19–100)]. Within the first year, patients with OCLT and CAI treated with M-BMS and ankle stabilisation also showed significant improvement in the FAAM [activity of daily living 68.8 (5–99) to 90.5 (45–100); sports 32.8 (0–87.5) to 64.1 (0–94), functional activities of daily life 62.5 (25–100) to 80 (60–90), functional sports 30 (0–100) to 67.5 (0.95)] and the FAOS [pain 66.7 (28–92) to 87.5 (47–100), symptoms 57.1 (29–96) to 78.6 (50–100), activities of daily living 80.1 (25–100) to 98.5 (59–100), sport/recreational activities 35.0 (0–100) to 70.0 (0–100), quality of life 25.0 (0–75) to 50.0 (19–94)]. The pain level decreased significantly in both groups. No significant difference was found between both groups regarding the subscales of FAAM, FAOS and the NRS 1 year postoperatively.

Conclusion Improvements in subjective ankle function, daily life activities and sports activities were observed within the first year following M-BMS. Our results suggest that preexisting and treated ankle instability did not compromise subjective outcome in patients treated with M-BMS in the first postoperative year.

Level of evidence Level IV.

Keywords Osteochondral lesion · Ankle · Talus · Ankle instability · Cartilage · Cartilage registry · Knorpelregister

Abbreviations

AS	Ankle stabilisation
M-BMS	Matrix-induced bone marrow stimulation
AOFAS	American Orthopedic Foot and Ankle Society
BHL	Berndt–Harty–Loomer

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CAI	Chronic ankle instability
FAAM	Foot and Ankle Ability Measure
FAOS	Foot and Ankle Outcome Score
FU	Follow-up
ICRS	International Cartilage Repair Society
NRS	Numeric Rating Scale for Pain
OCLT	Osteochondral lesion of the talus
PROM	Patient-reported outcome measure

Introduction

Ankle sprains lead to chronic ankle instability (CAI) in 10–30% of patients [7]. Osteochondral lesions of the ankle are associated with chronic ankle instability (CAI) [8, 14]. Rates of osteochondral lesions of the ankle in patients with acute and chronic ankle instability vary from 16 to 95% [2, 7, 9, 12, 16, 20]. It is unclear, whether the osteochondral lesion occurs during the acute trauma or if it is the result of repeated microtraumas resulting from instability.

Patients with isolated an osteochondral lesion of the talus (OCLT) differ from those with concomitant CAI regarding demographics, lesion- and therapy-related factors [6, 10]. Patients with OCLT and concomitant ankle instability treated with matrix-induced bone marrow stimulation (M-BMS) and ankle stabilisation had worse preoperative scores in the *Quality of Life* subscale of the Foot and Ankle Outcome Score (FAOS) compared to patients with OCLT alone. The rate of laterally located OCLT is higher in patients with CAI compared to patients without CAI [10, 13]. It is not yet clear what influence CAI has on the size of OCLT.

M-BMS is an established method in the operative treatment of osteochondral lesions of the ankle [4, 21–23, 25]. A membrane is placed into the cartilage defect after microfracture, nanofracture, or drilling of the subchondral bone. M-BMS can be combined with bone grafting in case of a bony subchondral defect. M-BMS is recommended in OCLTs greater than 1 cm^2 [17].

Patient self-reported outcomes measures (PROM) gain increasing importance in clinical practice and research [18]. To the best of our knowledge, no study has yet investigated the subjective outcome of patients treated with M-BMS for OCLT and additional ankle stabilisation for CAI.

The purpose of this data analysis based on the German Cartilage Registry was to describe the subjective outcomes after operative treatment of patients with solitary OCLT with or without concomitant CAI. All OCLTs were treated with M-BMS. Patients with concomitant CAI received ankle stabilisation. It was hypothesized that the combined operative treatment (M-BMS plus ankle stabilisation) of patients with OCLT and concomitant CAI showed comparable results to isolated M-BMS in patients without CAI.

Materials and methods

The data used in this study were obtained from the *German Cartilage Registry (KnorpelRegister DGOU).* Approval was given by the institutional review board (IRB) at every participating clinical centre. The identification number of the IRB of the study coordination centre at the University Hospital of Freiburg, Germany is B-F-2013-075#A1. All patients gave their written, informed consent prior to inclusion.

The registry (February 2020) included data of 841 adult patients with osteochondral lesions of the ankle undergoing surgery between 2014 and 2020 in 52 clinical centres. The data were prospectively collected using a web-based data entry system. Inclusion criteria were solitary OCLT treated with M-BMS. Exclusion criteria were any previous surgery on the ankle, any concomitant surgery besides M-BMS and CAI-treatment (e.g. corrective osteotomies) and more than one treated osteochondral lesion. A total of 130 patients with a solitary OCLT with or without ankle stabilization were found. Of these patients, further 52 patients were excluded due to missing preoperative data ($n=8$), or less than 6 months follow-up ($n=44$). Therefore, 78 patients treated in 12 different centres were included. 38 patients had an OCLT with CAI and were treated with M-BMS and ankle stabilization. 40 patients had an OCLT without CAI and underwent M-BMS alone.

Patient characteristics and outcome measures

Clinical data were achieved preoperatively, 6 months and 12 months postoperatively. The German versions of the *Foot and Ankle Ability Measure (FAAM)* [16], the *FAOS* [2], and the *Numeric rating scale for pain (NRS)* [8] were used. The NRS score consists of values from 0 (no pain) to 10 (pain as bad as you can imagine).

In accordance with Koerner et al. [10], patients demographics (age, gender, body mass index (BMI)), aetiology of the OCLT (traumatic (trauma within 12 months before surgery) vs. posttraumatic (more than 12 months before surgery) vs. degenerative (no trauma in patient's history)) were obtained. The location of the OCLT (medial vs. lateral, anterior vs. central vs. posterior) was documented. The OCLT was classified according to Berndt–Harty–Loomer classification [15], and International Cartilage Repair Society (ICRS). The approximated lesion size (multiplication of lesion length by width) was measured. Surgical details were recorded: approach to the ankle, presence and type of a concomitant ankle stabilization and additional bone grafting.

Statistical analysis

Patient characteristics were analysed descriptively. Continuous variables were reported as mean ± SD (minimum–maximum), nominal and categorical variables as *n* (%). The four subscales and the overall functional subscale of the FAAM, the four subscales of the FAOS and the NRS were descriptively reported as median (minimum–maximum) at baseline, 6-month follow-up (FU) and 12-month FU. The number of patients recorded for each subscale at different time points could differ, as subscales of included patients were analysed if a preoperative baseline value and either a 6-month FU or a 12-month FU value were available.

Data were screened regarding normal distribution using the Shapiro–Wilk test. Paired Wilcoxon signed-rank test was calculated between the baseline and the 12-month FU to analyse differences of FAAM, FAOS, and NRS within the first year following surgery. The level of significance was set to $p = 0.05$ for all statistical tests. Patients were analysed regarding risk factors for a poor subjective outcome 1-year postoperatively. A poor subjective outcome was defined by patient self-assessment in the FAAM overall functional subscale as 'severely abnormal' or 'abnormal'. Odds ratios (OR (95% CI)) were calculated for patient demographics, lesion-related, and therapy-related parameters.

The cohort was stratified into two groups. Patients in group A ($n = 38$) had OCLT combined with CAI. They received M-BMS for OCLT treatment and additional ankle stabilisation (AS). Patients in group B ($n = 40$) had an OCLT without CAI and underwent M-BMS alone. Patient demographics and lesion-related factors were tested regarding difference between both groups. Reported FAAM and FAOS subscales in the 12-month follow-up were tested between both groups to find significant differences using the Mann–Whitney U test.

The study data were analysed with JMP® (SAS Institute Inc., version 14.2, Cary, NC, USA) and STATA® (Stata Corporation, version 15.0, College Station, TX, USA).

Results

Different collagen matrices for M-BMS were used. 54 patients received AMIC® using Chondro-Gide® (Geistlich Pharma, Wolhusen, Switzerland), 21 patients received Hyalofast® (Plasmaconcept, Köln, Germany) and 3 patients received other matrices. Patients with combined M-BMS and stabilization of ligament instability received a lateral stabilization according to Broström ($n = 24$), Broström–Gould ($n = 3$), or an other stabilization technique ($n = 3$). Additional eight patients had a combined medial and lateral stabilisation.

Table 1 shows patient demographics, lesion-related and therapy-related characteristics of the total cohort and for each subgroup. Patients demographics (age, gender, BMI), duration of symptoms and lesion-related parameters (lesion-size, grade of OCLT according to ICRS and Berndt/Hardy/Loomer, location, bone grafting) did not differ significantly between both patient groups.

All patients showed a significant improvement of all subscales of the FAAM between preoperative baseline and the 12-month follow-up (Table 2). The distribution between categories of the FAAM functional overall subscale changed over time: the number of patients assessing their subjective function as *normal* or *nearly normal* between baseline and follow-up increased, while the number of patients who assessed their function as *abnormal* or *severely abnormal* decreased. Seven out of 36 patients assessed their function in the overall FAAM subscale as "abnormal" 1 year postoperatively. No significant risk factors regarding patient's demographic and treatment selection were found. But all seven patients with abnormal function had a defect graded ICRS 4. In five out of seven patients, the OCLT was degenerative, and in five out of seven patients, bone grafting was performed (Table 3). All FAOS subscales improved significantly (Table 4). Moreover, the pain level measured with the NRS decreased significantly from 4 (0–9) preoperatively to 1 (0–7) 1 year postoperatively ($p < 0.0001$).

The comparison of FAAM (Table 5) and FAOS (Table 6) between patients who undergoing OCLT treatment with or without CAI-treatment showed similar improvements during the first year postoperatively. The FAAM subscales and the FAOS subscales improved in both treatment groups significantly from preoperatively to 1-year postoperatively. All subscales of the FAAM and the FAOS did not differ significantly between both groups 1 year postoperatively.

Preoperatively, the majority of patients with M-BMS and ankle stabilization ($n = 26$ (67%)) had an abnormal or severely abnormal function in the FAAM functional overall subscale. 12 months postoperatively, the majority of patients ($n = 15$ (78.9%)) who underwent M-BMS combined with ankle stabilization had a "nearly normal" subjective ankle function. The majority of patients with M-BMS alone ($n = 29$ (73.5%)) had a FAAM overall function of abnormal or severely abnormal, preoperatively. In the 12-month follow-up, three patients (15.0%) had normal subjective ankle function, and 13 patients (65.0%) had nearly normal subjective ankle function. Pain levels decreased from 4 (0–9) to 2 (0–7) and from 3 (0–9) to 1 (0–5) in patients without or with CAI stabilization. Groups did not differ significantly.

Discussion

The most important finding of our study was that complaints and joint function of patients with a solitary OCLT were improved by M-BMS therapy. All subscales of the FAAM and FAOS, as well as the pain levels, were improved significantly within the first year following the surgery. This improvement was found in patients with M-BMS alone as

Table 1 Overview of demographic, lesion-related and therapeutic factors of the total cohort and the subgroups osteochondral lesion of the talus with chronic ankle instability (OCLT + CAI) and treatment of the osteochondral lesion of the talus (OCLT) alone

	Total cohort (*n* = 78)	OCLT + CAI (*n* = 38)	OCLT alone (*n* = 40)
Age [years] (mean ± SD (minimum–maximum))	35.5 ± 13.4 (18–65)	34.4 ± 12.1 (18–64)	36.5 ± 14.7 (18–64)
Gender (*n* (%))			
Female	41 (52.6)	24 (63.2)	17 (42.5)
Male	37 (47.4)	14 (36.8)	23 (57.5)
BMI [kg/m^2] (mean ± SD (minimum–maximum))	25.9 ± 4.9 (18.6–49.6)	25.8 ± 3.9 (18.6–34.6)	25.9 ± 5.8 (19.3–49.6)
Aetiology of OCLT (*n* (%))			
Missing data *n* = 2			
Traumatic	20 (25.6)	16 (42.1)	4 (10.0)
Posttraumatic	31 (39.7)	16 (42.1)	15 (37.5)
Degenerative	25 (32.1)	6 (15.8)	19 (47.5)
Duration of symptoms [months] (median, range)	12 (1–144)	11.0 (1–120)	12.5 (1–144)
Location frontal plane (*n* (%))			
Missing data *n* = 2			
Medial	57 (75.0)	26 (68.4)	31 (81.6)
Lateral	19 (25.0)	12 (31.6)	7 (18.4)
Location sagittal plane (*n* (%))			
Missing data *n* = 6			
Anterior	3 (4.2)	0	3 (8.8)
Central	53 (74.6)	28 (73.7)	25 (73.5)
Posterior	16 (22.2)	10 (26.3)	6 (17.6)
Lesion size [mm^2] (median, range)	147 (15–600)	120 (15–600)	150 (32–550)
Stage BHL (*n* (%)			
1	3 (3.8)	2 (5.3)	1 (2.5)
2	10 (12.8)	6 (15.8)	4 (10.0)
3	23 (29.5)	11 (28.9)	12 (30.0)
4	20 (25.6)	10 (26.3)	10 (25.0)
5	22 (28.2)	9 (23.7)	13 (32.5)
Stage ICRS (*n* (%))			
1	0	0	0
2	5 (6.4)	3 (7.9)	2 (5.0)
3	25 (32.1)	14 (36.8)	11 (27.5)
4	48 (61.5)	21 (55.3)	27 (67.5)
Approach (*n*)			
Arthroscopy alone	12	4	8
Arthroscopy + osteotomy	6	2	4
Arthroscopy + arthrotomy	22	13	9
Arthrotomy alone	35	19	16
Arthrotomy + osteotomy	1	0	1
Osteotomy alone	2	0	2
Combined bone grafting (*n* (%))	42 (53.8)	22 (57.9)	20 (50.0)

BMI, body mass index, ICRS, International Cartilage Repair Society, BHL, Berndt–Harty–Loomer

well as in patients with OCLT and CAI receiving M-BMS combined with a stabilization of the ankle joint. One year postoperatively, no significant difference of patient reported outcomes were found between patients with OCLT and CAI treated with M-BMS and ankle stabilization and patients with OCLT without CAI treated with M-BMS alone.

PROMs gain increasing popularity and importance in clinical practice and research [18]. Most of the previous studies about M-BMS used the AOFAS, which is a clinical outcome score. In the present study, surgical outcomes were measured using established and frequently used PROMs evaluating foot and ankle function (FAAM, FAOS) [18].

Table 2 Comparison between baseline, 6-month follow-up and 12-month follow-up of the FAAM subscales (median (minimum–maximum) as well as the *Functional overall* subscale of the FAAM score (*n* (%))

FAAM subscales	Total cohort	Differences between preoperative to 12-month FU
Activities of daily living (%)		
Preoperative	$n=78$; 66.7 (4.8–100)	
6-month FU	$n=74$; 83.9 (29.8–98.8)	$p<0.0001$
12-month FU	$n=41$; 89.3 (39.3–100)	
Sports (%)		
Preoperative	$n=70$; 34.4 (0–100)	
6-month FU	$n=66$; 51.6 (0–100)	$p=0.0002$
12-month FU	$n=36$; 65.6 (0–93.8)	
Functional activities of daily living (%)		
Preoperative	$n=59$; 60 (0–100)	
6-month FU	$n=55$; 75 (20–100)	$p<0.0001$
12-month FU	$n=33$; 80 (30–100)	
Functional sports (%)		
Preoperative	$n=73$; 30 (0–100)	
6-month FU	$n=67$; 60 (0–96)	$p<0.0001$
12-month FU	$n=39$; 70 (0–100)	

FAAM functional overall subscale (*n* (%))			
	Preoperative ($n=77$)	Normal:	0 (0%)
		Nearly normal:	22 (28.6%)
		Abnormal:	45 (58.4%)
		Severly abnormal:	10 (13.0%)
	6-month FU ($n=72$)	Normal:	6 (8.3%)
		Nearly normal:	53 (73.6%)
		Abnormal:	12 (16.7%)
		Severly abnormal:	1 (1.4%)
	12-month FU ($n=39$)	Normal:	4 (10.3%)
		Nearly normal:	28 (71.8%)
		Abnormal:	7 (17.9%)
		Severly abnormal:	0 (0%)

Improvements of the FAAM subscales between preoperative and 12 months postoperative were statistically significant using the paired Wilcoxon signed-rank test. FAAM, Foot and Ankle Ability Measure

Our study reported only short-term outcomes within the first year following the M-BMS. Besides differences in the follow-up period and outcome measures, differences in lesion size, sample size, concomitant injuries, and therapy must be taken into account when comparing studies. Kubosch et al. [11] analysed 17 patients following M-BMS in medial OCLT. They found for a lesion size ≥ 3 cm^3 a higher postoperative pain level as well as lower AOFAS values after a mean follow-up of 39.5 ± 18.4 months. The mean preoperative VAS pain score significantly improved from 7.8 ± 2.1 to 3.2 ± 2.4 postoperatively. The AOFAS score was on average, 82.6 ± 13.4 postoperatively. In contrast, Weigelt et al. [24] could not find a correlation between OCLT size and clinical outcome. They included in their retrospective study only patients who received isolated M-BMS for OCLT without any further surgical interventions. The preoperative osteochondral lesion was 0.9 cm^2 (range: 0.4-2.3 cm^2). The 33 patients included showed a significant improvement in NRS from 6.4 ± 1.9 preoperatively to 1.4 ± 2.0 at the mean follow-up of 4.7 years postoperatively.

In this study, the median lesion size was 1.47 cm^2 and ranged from 0.2 to 6.0 cm^2. Seven out of 36 patients reported 1 year postoperatively an abnormal ankle joint function. Due to the relatively small sample size, we did not find significant risks for an inferior subjective outcome. Interestingly, five out of seven patients suffering from a degenerative OCLT, 5 patients received bone grafting, and all 7 patients had a lesions graded ICRS stage 4. These findings indicate that more severe lesions may end up with inferior subjective results. Subgroup analysis of Weigelt et al. [24] did not find any significant difference between patients who received subchondral bone grafting and those who did not.

Table 3 Detailed analysis of patients who assessed their ankle joint as "abnormal" according to FAAM one year postoperatively ($n = 7$ out of 36)

	Patients with "abnormal" function according to FAAM ($n = 7$)	OR (95% CI); p value
Age [years]	43 ± 12.0 (26–62)	1.03 (0.97–1.10); 0.3213
Female (n (%))	3 (42.9%)	0.61 (0.12–3.23) 0.5581
BMI [kg/m^2]	29.1 ± 9.9 (20.8–49.6)	1.12 (0.96–1.31); 0.1259
Degenerative aetiology of OCLT (n (%))	5 (71.4)	5.28 (0.85–32.62); 0.0588
Duration of symptoms [months]	12 (1–144)	1.00 (0.97–1.02); 0.8763
Stabilization (n (%))	3 (42.9%)	0.61 (0.12–3.23); 0.5581
Lesion size [mm^2]	147 (15–600)	1.00 (0.99–1.01); 0.8422
Stage BHL (n (%))		
1	0	1.79 (0.68–4.67); 0.2029
2	0	
3	1 (14.3)	
4	3 (42.9)	
5	3 (42.9)	
Stage ICRS (n (%)): 4	7 (100)	*
Combined bone grafting (n (%))	5 (71.4)	2.03 (0.34–12.24); 0.4257

*As all 7 patients had ICRS stage 4, no odds ratio could be calculated

Table 4 Comparison of all FAOS subscales at the baseline, 6-month and 12-month follow-up

FAOS subscale	Total cohort	Difference preoperative vs. 12-month FU
Pain (%)		
Preoperative	$n = 68$; 62.5 (8.3–94.4)	$p < 0.0001$
6-month FU	$n = 65$; 83.3 (41.7–100)	
12-month FU	$n = 37$; 86.1 (47.2–100)	
Symptoms (%)		
Preoperative	$n = 74$; 57.1 (17.9–96.4)	$p = 0.0002$
6-month FU	$n = 70$; 75.0 (17.9–100)	
12-month FU	$n = 39$; 78.6 (28.6–100)	
Activities of daily living (%)		
Preoperative	$n = 58$; 75.7 (23.5–100)	$p < 0.0001$
6-month FU	$n = 56$; 89.7 (55.9–100)	
12-month FU	$n = 28$; 96.3 (58.8–100)	
Sport/recreational activities (%)		
Preoperative	$n = 69$; 30.0 (0–100)	$p < 0.0001$
6-month FU	$n = 65$; 60 (5–100)	
12-month FU	$n = 33$; 65 (0–100)	
Quality of life (%)		
Preoperative	$n = 73$; 31.3 (0–75)	$p < 0.0001$
6-month FU	$n = 71$; 43.8 (0–93.8)	
12-month FU	$n = 40$; 46.9 (18.8–100)	

Improvements between preoperative and 12 months postoperative were statistically significant using the paired Wilcoxon signed-rank test. FAOS, Foot and Ankle Outcome Score

In our study, lesion size and duration of symptoms had no increased risk of abnormal function following M-BMS. Moreover, patients' demographic (age, BMI) did not relate to inferior subjective results. This finding is in accordance with the majority of other studies [3, 24]. However, Kubosch et al. [11] reported lower AOFAS values and higher postoperative pain level (VAS) in patients with increased BMI (> 30 kg/m^2).

Table 5 Descriptive comparison of all FAAM subscales at the baseline, 6-month and 12-month follow-up between group M-BMS and ankle stabilization (AS) and group M-BMS alone

FAAM subscales	M-BMS + AS (*n* = 38)	M-BMS alone (*n* = 40)	Differences between groups
Activities of daily living (%)			
Preoperative	*n* = 38; 68.8 (4.8–98.8)	*n* = 40; 64.3 (10–100)	
6-month FU	*n* = 36; 83.9 (29.8–97.6)	*n* = 38; 84.5 (35.7–98.8)	
12-month FU	*n* = 21; 90.5 (45.2–100)	*n* = 20; 88.1 (39.3–100)	n.s.
Sports (%)			
Preoperative	*n* = 32; 32.8 (0–87.5)	*n* = 38; 34.4 (0–100)	
6-month FU	*n* = 31; 59.4 (9.4–84.4)	*n* = 35; 40.6 (0–100)	
12-month FU	*n* = 18; 64.1 (0–93.8)	*n* = 18; 65.6 (12.5–93.8)	n.s.
Functional activities of daily living (%)			
Preoperative	*n* = 28; 62.5 (25–100)	*n* = 31; 50 (0–90)	
6-month FU	*n* = 26; 75 (40–100)	*n* = 29; 80 (20–95)	
12-month FU	*n* = 14; 80 (60–90)	*n* = 19; 80 (30–100)	n.s.
Functional sports (%)			
Preoperative	*n* = 37; 30 (0–100)	*n* = 36; 30 (0–100)	
6-month FU	*n* = 34; 60 (0–80)	*n* = 33; 60 (5–96)	
12-month FU	*n* = 20; 67.5 (0–95)	*n* = 19; 70 (5–100)	n.s.
FAAM functional overall subscale (*n* (%))			
Preoperative	Normal: 0 (0%)	Normal: 0 (0%)	
	Nearly normal: 11 (29.7%)	Nearly normal: 11 (27.5%)	
	Abnormal: 20 (54.1%)	Abnormal: 25 (62.5%)	
	Severely abnormal: 6 (13.0%)	Severely abnormal: 4 (10.0%)	
6-month FU	Normal: 0 (0%)	Normal: 6 (16.2%)	
	Nearly normal: 28 (80%)	Nearly normal: 25 (67.6%)	
	Abnormal: 6 (17.1%)	Abnormal: 6 (16.2%)	
	Severely abnormal: 1 (2.9%)	Severely abnormal: 0 (0%)	
12–month FU	Normal: 1 (5.3%)	Normal: 3 (15.0%)	
	Nearly normal: 15 (78.9%)	Nearly normal: 13 (65.0%)	
	Abnormal: 3 (15.8%)	Abnormal: 4 (20.0%)	
	Severely abnormal: 0 (0%)	Severely abnormal: 0 (0%)	

FAAM, Foot and Ankle Ability Measure

Additional surgical interventions can bias reported surgical outcomes for M-BMS. There are only view studies available analysing combined surgical therapy of OCLT and CAI [5, 27]. Valderrabano et al. [23] prospectively followed up 26 patients with OCLT treated with M-BMS (debridement, autologous grafting, and sealing of the defect with a collagen scaffold). Ligament repair was performed in 17 out of these 26 cases, and corrective calcaneal osteotomy was performed in 16 out of these 26 cases. The AOFAS improved significantly from 60 to 89 points after a mean follow-up of 31 months. In a retrospective study by Ayyaswamy et al. [1], 25 patients with a mean OCLT lesion size of 1.75 mm treated with M-BMS were evaluated using the AOFAS and VAS score. 20 patients had a modified Broström–Gould procedure and one had an internal brace for lateral ligament augmentation. The mean follow-up was 24 months (ranging from 8 to 42 months). The AOFAS increased from 34.7 to 84 points. The mean preoperative pain level was 8.4 and decreased to 3.08. No correlation between either age or lesion size with the functional outcome was found. Gregush et al. [5] demonstrated that simultaneous arthroscopic treatment of an OCLT and open lateral ankle stabilisation is a safe and effective procedure in the long term. In their cohort of 31 patients, OCLT treatment was heterogeneous. Patients received excision of the OCLT alone (6%) or combined with drilling (61%) or microfracture (23%). 2 patients (6%) were treated with chondroplasty and one patient (3%) was treated with excision, microfracture, and bone grafting. Jiang et al. [8] evaluated the effect of concurrent arthroscopic osteochondral lesion treatment and lateral ankle ligament repair on the outcome of chronic lateral ankle instability. They performed anatomic lateral ankle ligament repair using a modified Broström–Gould technique with suture anchors in 70 patients. Half of the patients received arthroscopic

Table 6 Descriptive comparison of all FAOS subscales at the baseline, 6-month and 12-month follow-up between M-BMS and ankle stabilization (AS) and group M-BMS alone

FAOS subscale	M-BMS + AS (*n* = 38)	M-BMS alone (*n* = 40)	Differences between groups
Pain (%) *n* = 49			
Preoperative	*n* = 33; 66.7 (27.8–91.7)	*n* = 35; 61.1 (8.3–94.4)	
6–month FU	*n* = 31; 83.3 (41.7–100)	*n* = 34; 83.3 (41.7–100)	
12-month FU	*n* = 20; 87.5 (47.2–100)	*n* = 17; 86.1 (50–100)	n.s.
Symptoms (%) *n* = 50			
Preoperative	*n* = 35; 57.1 (28.6–96.4)	*n* = 39; 60.7 (17.9–96.4)	
6-month FU	*n* = 33; 75.0 (28.6–100)	*n* = 37; 75.0 (17.9–96.4)	
12-month FU	*n* = 19; 78.6 (50–100)	*n* = 20; 76.8 (28.6–100)	n.s.
Activities of daily living (%) *n* = 41			
Preoperative	*n* = 28; 80.1 (25–100)	*n* = 30; 72.1 (23.5–100)	
6-month FU	*n* = 27; 89.7 (67.6–100)	*n* = 29; 91.2 (55.9–100)	
12-month FU	*n* = 16; 98.5 (58.8–100)	*n* = 12; 91.9 (67.6–100)	n.s.
Sport/recreational activities (%) *n* = 47			
Preoperative	*n* = 34; 35.0 (0–100)	*n* = 35; 30.0 (0–70)	
6-month FU	*n* = 32; 60.0 (5–95)	*n* = 33; 65.0 (10–100)	
12-month FU	*n* = 19; 70.0 (0–100)	*n* = 14; 62.5 (0–95)	n.s.
Quality of life (%) *n* = 51			
Preoperative	*n* = 34; 25.0 (0–75)	*n* = 39; 31.3 (6.25–50)	
6-month FU	*n* = 33; 43.8 (0–87.5)	*n* = 38; 46.9 (12.5–93.8)	
12-month FU	*n* = 20; 50 (18.8–93.8)	*n* = 20; 46.9 (18.8–100)	n.s.

FAOS, Foot and Ankle Outcome Score

abrasion, curettage, drilling, or microfracture for OCLTs. The follow-up was 46.5 months on average. The VAS improved from 4 (0–7) to 0 (0–7), and the AOFAS score from 74.0 (30–92) to 95.0 (52–100). 90% of patients reached good-to-excellent results. Scores did not differ significantly, but patients with OCLT treatment have a potential risk of a limited range of motion. Wiewiorski et al. [26] followed 60 patients after M-BMS for a mean of 46.9 ± 17.8 months (range 24.5–87.0 months) postoperatively. A medial malleolar osteotomy was performed in 44 out of 46 medial OCLTs. In 2 cases of 14 lateral OCLTs, lateral malleolar osteotomy was performed. 38 out of 60 patients underwent a corrective calcaneal osteotomy. A ligament repair was performed in 41 of 60 patients (8 lateral, 5 medial, 28 combined medial and lateral). The mean VAS score improved significantly from 6.9 ± 1.6 points (range: 5–10 points) preoperatively to 2.3 ± 1.9 points (range 0–6 points). No significant differences in the pain level, functional score, and sports activity score were found regarding the abovementioned concomitant surgical procedures. In our study, data stratification was calculated between patients with M-BMS alone and M-BMS combined with stabilization of an additional CAI. It was demonstrated that the subjective function and pain levels can be improved significantly by the combined procedure.

Usually, M-BMS for the treatment of OCLT is performed with an arthrotomy. Approaches differ regarding the visibility of the talus dome and an individually selected approach is necessary for appropriate treatment of the OCLTs preoperatively [19]. M-BMS can also be performed only arthroscopically [22]. Potential advantages include less soft tissue dissection, better visualization of the joint, and quicker patient recovery compared to the open technique. However, precise fitting and stable fixation of the matrix on the defect can be challenging [24]. Usuelli et al. [21] showed that arthroscopic M-BMS with autologous bone grafting provides a safe and effective minimally invasive technique. Pain and function can be improved. The AOFAS was increased from 57.1 ± 14.9 before surgery to 86.6 ± 10.9 after 24 months and the VAS from 8.1 ± 1.4 to 2.5 ± 2.2. In our cohort, different approaches were used (arthroscopic treatment alone, arthroscopic approach combined with arthrotomy or arthrotomy alone). In some cases, the approach included a medial or lateral osteotomy.

This study has several limitations. Patients were followed up at least 6 months. 52.6% of patients had a recorded follow-up of 12 months. We found significant improvements in all subscales of used scores within the first year. As described above, a direct comparison to other studies with longer follow-up periods is not valid. Because M-BMS, in combination with ankle stabilisation procedures is less frequently reported, the presented study adds valuable knowledge regarding self-reported outcomes for surgical decision-making.

Moreover, it is a cross-sectional cohort study with data collection from a national multicentre registry. The final data set includes 78 patients from 12 different study centres, which may lead to heterogeneity as known for other registry studies. Information regarding the osteochondral lesion, such as size and grade, can be evaluated differently from each surgeon [15].

Based on the registry data set, a large number of patients receiving M-BMS were included. In accordance with a previous publication, only patients with a solitary talus lesion and without prior surgery on the affected ankle joint were included to enhance homogeneity [10]. However, heterogeneity existed because of differences between the included patients. There was no standardized treatment concept for CAI. The diagnosis of CAI and treatment decision was based on the responsible surgeon. Moreover, some patients received additional debridement of a bony or soft tissue impingement as well as autologous bone grafting in combination with M-BMS.

Ankle instability is a relevant concomitant pathology in patients with OCLT. In our study, similar improvements of pain levels and subjective functions were found in patients with only OCLT receiving M-BMS as well as in patients with OCLT and CAI receiving M-BMS combined with a stabilization of the ankle joint. If CAI exists and is treated, patient-reported outcomes of M-BMS of solitary OCLT are not compromised in the first postoperative year. All patients with OCLT should be evaluated for concomitant ankle instability and existing concomitant ankle instability has to be integrated into the surgical treatment concept.

Conclusions

Within the first year following M-BMS, subjective ankle function, daily life activities and sports activities improved, and pain level reduced in patients with a solitary OCLT. Patients with OCLT and concomitant CAI showed comparable results, when ankle stabilization was performed with M-BMS. Pre-existing but treated ankle instability did not compromise patient-reported outcomes in patients treated with M-BMS in the first postoperative year.

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Compliance with ethical standards

Conflict of interest OG received reimbursement of speaker fees and travel expenses from Geistlich Pharma AG. CP is a consultant of Medartis. CP or his institution received personal or scientific support from the following companies: Implantcast, Medartis, Stryker, DePuySynthes, Arthrex, OPED, Albrecht and Synthelix. There is no relevant conflict of interest regarding this paper. All other authors declare no potential conflict of interest.

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Ethical approval The data used in this study were obtained from the *German Cartilage Registry (KnorpelRegister DGOU)*. Approval was given by the institutional review board (IRB) at every participating clinical centre. The identification number of the IRB of the study coordination centre at the University Hospital of Freiburg, Germany is B-F-2013-075#A1.

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