Received: 18 January 2024 | Accepted: 5 July 2024

DOI: 10.1002/ksa.12375

Save the subchondral bone plate: Debridement versus bone marrow stimulation in acetabular cartilage defects over 60 months of follow-up

Moritz Riedl[1] | **Julia E. Lenz**[1] | **Jens Goronzy**[2] | **Christian Sobau**[3] | **Oliver Steimer**[4] | **Steffen Thier**[5] | **Wolfgang Zinser**[6] | **Stefan Landgraeber**[7] | **Volker Alt**[1] | **Stefan Fickert**[7,8]

[1]Department of Trauma Surgery, University Regensburg Medical Center, Regensburg, Germany

[2]Orthopaedics, Trauma and Plastic Surgery, University Hospital Carl Gustav Carus, Dresden, Germany

[3]ARCUS Sportklinik, Pforzheim, Germany

[4]Orthopädische Anästhesiologische Gemeinschaftspraxis, Saarbrücken, Germany

[5]Orthopädische Chirurgie Heidelberg, ATOS Clinic Heidelberg, Heidelberg, Germany

[6]OrthoExpert, Knittelfeld/Graz, Austria

[7]Department of Orthopaedics and Orthopaedic Surgery, Saarland University Medical Center, Homburg, Germany

[8]Sporthopaedicum Straubing, Straubing, Germany

Correspondence

Moritz Riedl, Klinik und Poliklinik für Unfallchirurgie, Universitätsklinikum Regensburg, Franz-Josef-Strauss-Allee 11, 93053 Regensburg, Germany.
Email: moritz.riedl@ukr.de

Funding information

German Orthopaedic and Trauma Society (DKOU); Arthrosehilfe e.V. and the Oscar-Helene-Stiftung e.V.

Abstract

Purpose: Bone marrow stimulation is a common treatment for full-thickness cartilage defects in the hip joint. However, common procedures may result in poor fibrous repair tissue and changes to the subchondral anatomy. This study investigated the clinical outcome of a cohort of International Cartilage Repair Society (ICRS) grades 3 and 4 cartilage defects treated with bone marrow stimulation compared to those who received simple debridement/chondroplasty.

Methods: In this retrospective registry study, 236 patients with uni-focal acetabular chondral lesions of the hip up to 400 mm² (mean 177.4 ± 113.4 mm²) and of ICRS grade ≥3 with follow-up of at least 12 months (mean 33.2 ± 15.3 months) were included. Eighty-one patients underwent bone marrow stimulation (microfracture: $n = 44$, abrasion: $n = 37$) besides treatment of the underlying pathology, 155 patients underwent defect debridement/chondroplasty. The patient-reported outcome was measured using the International Hip Outcome Tool 33 (iHOT33) score and the Visual Analogue Scale (VAS) for pain.

Results: iHOT33 and VAS both improved highly statistically significantly ($p < 0.001$) in the debridement group after 6, 12, 24, 36 and 60 months compared to the preoperative scores, whereas iHOT33 and VAS after microfracture or abrasion did not show statistically significant changes over time. Twenty-four and sixty months postsurgery the debridement group revealed significant higher scores in the iHOT33 compared to the bone marrow stimulation groups.

Conclusion: Patients with chondral lesions of the hip ≤400 mm^2 sustainably benefit from arthroscopic debridement under preservation of the subchondral bone plate in terms of functional outcome and pain in contrast to patients

Abbreviations: ACL, anterior crucial ligament; AMIC, autologous matrix-induces chondrogenesis; AUC, area under the curve; CI, confidence interval; CIOV, clinically important outcome value; CPM, continuous passive motion; DGOU, Deutsche Gesellschaft für Orthopädie und Unfallchirurgie, eng. German Society for Orthopaedic and Trauma Surgery; DVT, deep vein thrombosis; FAI(S), femoroacetabular impingement (syndrome); ICRS, International Cartilage Repair Society; iHOT33, International Hip Outcome Tool 33; (M)ACT, (matrix-associated) autologous chondrocyte transplantation; MCID, minimum clinical important difference; MPC, mesenchymal progenitor/stromal cells; MRI, magnetic resonance imaging; NSAID, nonsteroidal anti-inflammatory drugs; PASS, patient acceptable symptom state; ROC, receiver operator characteristic; SCB, substantial clinical benefit; SD, standard deviation; VAS, Visual Analogue Scale.

treated with bone marrow stimulation. These findings discourage the currently recommended use of microfracture in the hip joint.

Level of Evidence: Level III.

KEYWORDS
bone marrow stimulation, chondroplasty, hip arthroscopy, hip preserving surgery, microfracture

INTRODUCTION

Cartilage therapy is a rapidly developing field in orthopaedics. Articular cartilage defects in the hip joint are primarily caused by prearthritic deformities such as femoroacetabular impingement (FAI) [7, 8]. These defects can lead to pain, discomfort, and impaired mobilit, and may progress to osteoarthritis if left untreated. Due to the limited intrinsic self-regenerative capacity of the bradytrophic cartilage tissue in adults, there is an increasing need for efficient and consistent therapeutic options for treating articular cartilage defects.

Among established treatment modalities, bone marrow stimulating techniques such as microfracture and abrasion are recommended for smaller full-thickness lesions in the hip joint [4, 19]. However, their indication remains a matter of debate as current recommendations primarily rely on data from the knee joint [6]. Specific guidelines tailored for cartilage treatment in the hip joint are still awaiting formulation and validation through hip-specific studies. The extent of the defect plays a central role in defining joint- and technique-specific criteria for addressing chondral lesions in the hip. According to current recommendations, bone marrow stimulation techniques (e.g., microfracture, abrasion) are considered the preferred therapy for focal full-thickness lesions measuring less than 200–400 mm^2, that is, procedures that expose cancellous bone by penetrating the subchondral bone plate [11, 12].

Nevertheless, recent studies cast doubt on the actual benefits of bone marrow stimulation for individuals with chondral defects in the hip [14]. Studies on the knee joint have shown a regression in clinical outcomes coupled with signs of osteoarthritis 2–3 years postmicrofracture, following an initial improvement in clinical results [13, 17]. The worsening of outcomes after microfracture is frequently attributed to the hyperossification of the subchondral lamina, potentially leading to intralesional osteophytes and elevating the failure rate of subsequent therapies like autologous chondrocyte transplantation (ACT) [2, 16]. This highlights the therapeutic importance of an intact subchondral bone in articular cartilage therapy.

Given the relatively brief history of arthroscopy in the hip, the evidence on this subject still remains rather limited [9, 10, 12, 18].

In this study, the question of whether the integrity of the subchondral bone lamella predicts clinical outcomes after arthroscopic cartilage therapy in the hip was addressed. The clinical outcomes of a cohort of patients with full-thickness cartilage defects of the hip joint (<400 mm^2) treated with microfracture or abrasion was examined and compared to patients with focal cartilage lesions who received only chondroplasty/debridement during arthroscopy.

MATERIALS AND METHODS

This trial is a retrospective registry study within the Cartilage Registry of the German Society for Orthopaedics and Trauma Surgery (KnorpelRegister DGOU), validated by the institutional review board of the University of Freiburg (No. 520/14) and the involved centres themselves. Two hundred and thirty-six patients were included in five centres treated by five surgeons between 12/2014 and 12/2019.

Protocol design and patient cohort

The clinical outcome of individuals with solitary acetabular chondral defects in the hip, attributed to FAIS, who were treated arthroscopically either by bone marrow stimulation or simple debridement of the cartilage lesion, were systematically examined (see Figure 1 for an illustration of the treatment options).

Inclusion criteria encompassed an age of 18 years or older, a unifocal acetabular chondral defect in the hip joint of International Cartilage Repair Society (ICRS) grade 3 or higher, with the surrounding cartilage and subchondral bone remaining intact. Additionally, inclusion criteria comprised a defect size of ≤400 mm^2 and a follow-up period of at least 12 months. Exclusion criteria involved patients with femoral cartilage defects, radiographic evidence of osteoarthritis beyond grade 1 according to Kellgren and Lawrence, bone oedema or cysts detected in magnetic resonance imaging (MRI), or a history of prior surgery on the affected joint. For preoperative diagnostics, a comprehensive clinical examination of the hip joints was conducted, along with X-ray imaging using standardised supine anterior–posterior and cross-table radiographs. Additionally, MRI with radial reconstructions was

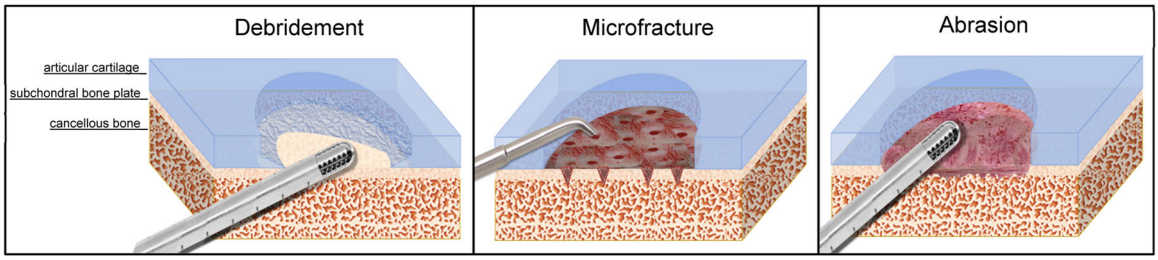

FIGURE 1 Illustration of the cartilage therapy options debridement, microfracture and abrasion.

TABLE 1 Questions regarding patient satisfaction and pain for calculation of the CIOVs.

Question	Value
Are you satisfied with the outcome of the surgery?	1–5/not satisfied–very satisfied
How much did you benefit from the treatment?	1–5/impairing–very beneficial
How would you feel if you had to live with your current hip symptoms for the rest of your life?	1–5/not satisfied–very satisfied
Do you currently have pain in the operated hip?	1–4/no pain–strong pain
How often do you currently take pain medication?	1–5/never–daily

Abbreviation: CIOVs, clinically important outcome values.

performed [1, 15]. The clinical outcome was assessed using the Visual Analogue Scale (VAS) for pain and the International Hip Outcome Tool (iHOT33), which evaluates pain and functional parameters related to daily activities and sports. To further evaluate specific symptoms, patient satisfaction, and pain levels and to calculate the clinically important outcome values (CIOVs) supplementary questions detailed in Table 1 were incorporated into the questionnaire. Patients completed these questionnaires before the index arthroscopy (preoperative) and at subsequent intervals of 6, 12, 24, 36 and 60 months postarthroscopy.

Surgical procedure

Hip arthroscopy was performed in supine position on a traction table with approximately 6–8 mm joint distraction, controlled fluoroscopically. Following arthroscopic inspection through anterolateral and anterior portals, the unstable margins of the cartilage defect were debrided using a shaver and curettage to assess the actual lesion size and establish stable margins. Subsequently, the chondral lesion was categorised according to the ICRS score, and the defect size was quantified in square millimetres by measuring the two main orthogonal diameters (length and width) with a calibrated arthroscopic probe. Treatment for chondral lesions involved either bone marrow stimulation techniques (microfracture, abrasion) or debridement/chondroplasty.

Microfracture entailed drilling holes spaced 3–4 mm apart and approximately 4 mm deep into the subchondral bone using an arthroscopic awl, reaching the bone marrow level to induce adequate bleeding [3].

The abrasion procedure instead was performed with a spherical motorised reamer. The subchondral plate was lightly and evenly abraded down to a depth of approximately 2 mm, which allowed for capillary bleeding.

For debridement/chondroplasty, loose cartilage parts and flaps were resected and the defect bed was debrided with a full radius shaver to smooth the articular surface and ensure a stable structure of the remaining cartilage.

Concomitant corrective procedures like correction of the head–neck offset, labral repair or acetabular trimming (if required) were conducted during the same intervention (refer to Table 2).

Rehabilitation protocol

Postoperative rehabilitation protocols were largely dependent on the specific concomitant surgeries performed. Patients undergoing debridement were prescribed partial weight-bearing (15 kg) for 2–4 weeks on crutches, while patients undergoing bone marrow stimulation were prescribed crutches and partial weight-bearing (15 kg) for 6–8 weeks. Thereafter, full weight-bearing was permitted in a pain-adapted manner. Patients with labral repair were restricted to a maximum flexion of 90° for 6 weeks. Continuous passive motion (CPM) therapy was performed for 4 weeks starting from the first postoperative day with an application of at least 6 h a day. Return to competitive sports was permitted 9–12 months after surgery. Aftercare also included prophylaxis of heterotopic ossification with oral non-steroidal anti-inflammatory drugs (NSAID; 3 × 400 mg ibuprofen daily for a period of 2 weeks) and deep vein thrombosis (DVT) prophylaxis by subcutaneous administration of a low-molecular-weight heparin analogue until full weight-bearing.

TABLE 2 Demographic data and baseline characteristics of the study population ($N = 236$).

		Debridement ($N = 155$)	Microfracture ($N = 44$)	Abrasion ($N = 37$)	p-Value
Sex					
Female	*n* (%)	72 (46.5)	12 (27.3)	8 (21.6)	
Male	*n* (%)	83 (53.5)	32 (72.7)	29 (78.4)	
Age (years)	Mean ± SD	36.1 ± 10.7	36.7 ± 10.2	40.4 ± 10.5	n.s.
BMI (kg/m^2)	Mean ± SD	22.5 ± 6.2	22.1 ± 3.6	23.3 ± 3.8	n.s.
Smoking status					
Yes	*n* (%)	36 (23.2)	8 (18.2)	10 (27.0)	
No	*n* (%)	119 (76.8)	36 (81.8)	27 (73.0)	
Symptoms duration (months)	Mean ± SD	24.1 ± 27.7	17.0 ± 14.1	29.0 ± 39.7	n.s.
Follow-up (months)	Mean ± SD	33.0 ± 14.7	34.0 ± 16.0	34.0 ± 16.2	n.s.
Defect size (mm^2)	Mean ± SD	177.5 ± 117.3	146.8 ± 106.3	212.0 ± 97.8	$p = 0.035$
ICRS grading					
Grade III	*n* (%)	138 (89)	17 (38.6)	18 (48.6)	
Grade IV	*n* (%)	17 (11)	27 (61.4)	19 (51.4)	
Underlying pathology					
CAM deformity	*n* (%)	99 (63.9)	30 (68.2)	28 (75.7)	
PINCER deformity	*n* (%)	7 (4.5)	3 (6.8)		
Combined FAI	*n* (%)	49 (31.6)	11 (25.0)	9 (24.3)	
Labrum lesion					
Yes	*n* (%)	145 (93.6)	38 (86.4)	35 (94.6)	
No	*n* (%)	10 (6.4)	6 (13.6)	2 (5.4)	
Concomitant surgeries					
Labrum resection	*n* (%)	70 (45.2)	10 (22.8)	19 (51.3)	
Labrum refixation	*n* (%)	60 (38.8)	13 (29.5)	15 (40.5)	
Acetabular trimming	*n* (%)	49 (31.6)	5 (11.3)	10 (27.0)	
Femoral neck contouring	*n* (%)	148 (95.5)	31 (93.2)	37 (100)	

Abbreviations: BMI, body mass index; FAI, femoroacetabular impingement (syndrome); ICRS, International Cartilage Repair Society.

Psychometric analysis

CIOVs including minimum clinical important difference (MCID), patient acceptable symptom state (PASS), and substantial clinical benefit (SCB) at 24-month follow-up were computed using distribution-based and anchor-based methods, respectively. The MCID was calculated as one-half the standard deviation (SD) of the change in 24-month iHOT-33 scores. PASS and SCB values were determined through an anchor-based method using receiver operator characteristic (ROC) analysis based on the questions in Table 1. The area under the curve (AUC) was calculated with a 95% confidence interval (CI). An AUC value greater than 0.8 and a 95% CI not including 0.5 are considered excellent characteristics for responsiveness. The Youden index was utilised to optimise sensitivity and specificity values and to determine the best cutoff values for SCB values and PASS.

Statistical analysis

Continuous data are presented as mean ± SD. SPSS software (IBM) was applied for the statistical analyses. Differences in base line data and score values between the different observation time points and treatment groups were assessed using two-tailed paired *t*-tests and one-way analysis of variance (ANOVA) with Bonferroni post hoc test on quantified data in case of normal distribution. If this condition did not apply, Mann–Whitney-*U*-Test and Kruskal–Wallis-Test were used. A multivariate linear regression model was used

to identify elements affecting the change in iHOT33 and VAS. A p-value of <0.05 was considered statistically significant.

RESULTS

At the time of data acquisition (02/2022), the German cartilage registry included 2996 patients in the hip section with 1869 patients having cartilage defects ≤400 mm^2. After exclusion of patients not meeting the inclusion criteria, 296 patients remained of whom 155 underwent simple defect debridement, 81 bone marrow stimulation, 25 matrix-associated ACT (MACT), and 35 other therapy options (e.g., autologous matrix-induces chondrogenesis [AMIC], fibrin glue refixation, treatment combinations. Figure 2 shows the described selection process of the current cohort in a flow chart.

Finally, a population of 236 patients (144 men/92 women) aged 18–60 years (mean age 36.9 ± 10.6 years) with unifocal chondral defects of the hip joint under 400 mm^2 were enrolled in this study. The mean duration of follow-up was 33.2 ± 15.2 months. The mean defect size was 177.4 ± 113.4 mm^2 (range: 10–375 mm^2). Eighty-one patients were treated with bone marrow stimulation techniques, in detail 44 patients were treated with microfracture and 37 patients with abrasion. Cartilage defects in 155 patients underwent debridement, while the subchondral bone was left intact (see Figure 3 for intraoperative imaging of the compared treatment options). While defect grade was relatively equally distributed in the two bone marrow stimulation groups the debridement group included mainly ICRS grade 3 defects. The defect size was significantly higher in the abrasion group compared to the microfracture group (p = 0.03). Apart from this, the demographic data did not show statistically significant differences between the test groups. Concurrently, interventions addressing underlying pathologies were conducted during the same procedure. CAM deformities underwent recontouring of the femoral head-neck region, while acetabular impingement was addressed through acetabular trimming, with subsequent labrum refixation if deemed necessary. Among 79 PINCER deformities, 15 were not treated due to their minor appearance during the intraoperative assessment. Labrum lesions were managed by resection, refixation, or

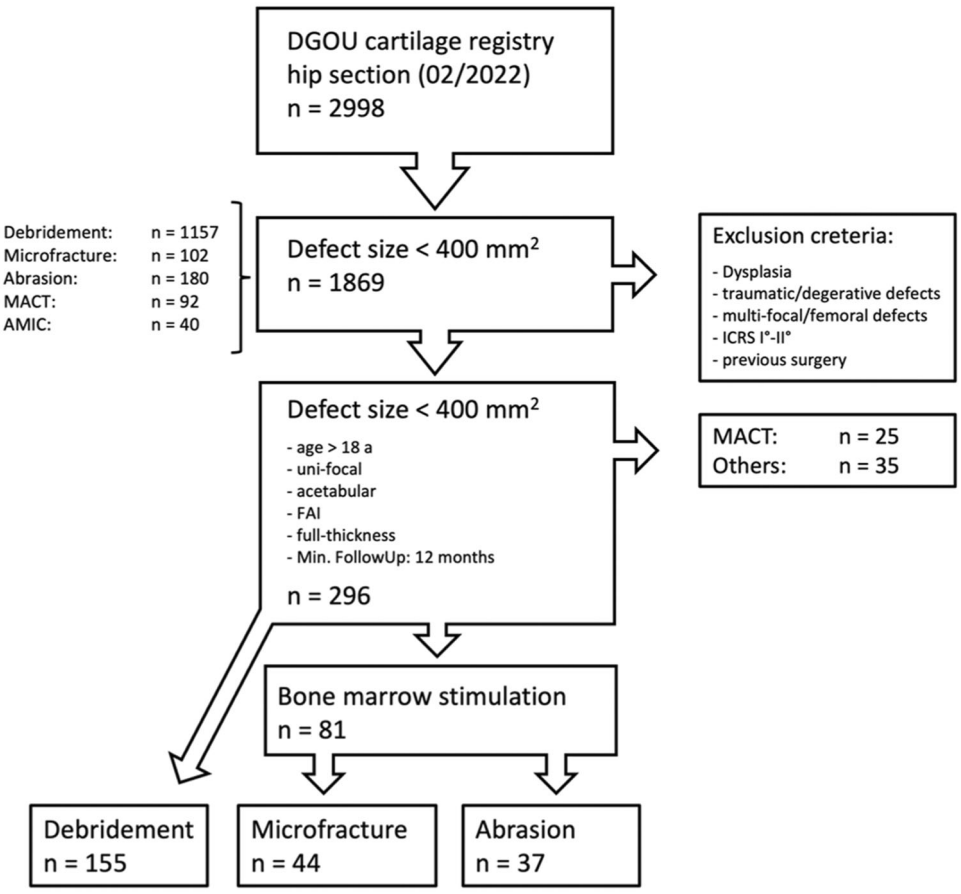

FIGURE 2 Flow chart of the inclusion process for the investigated patient cohort based on the data of the German cartilage registry (DGOU). AMIC, autologous matrix-induces chondrogenesis; DGOU, Deutsche Gesellschaft für Orthopädie und Unfallchirurgie; MACT, matrix-associated autologous chondrocyte transplantation.

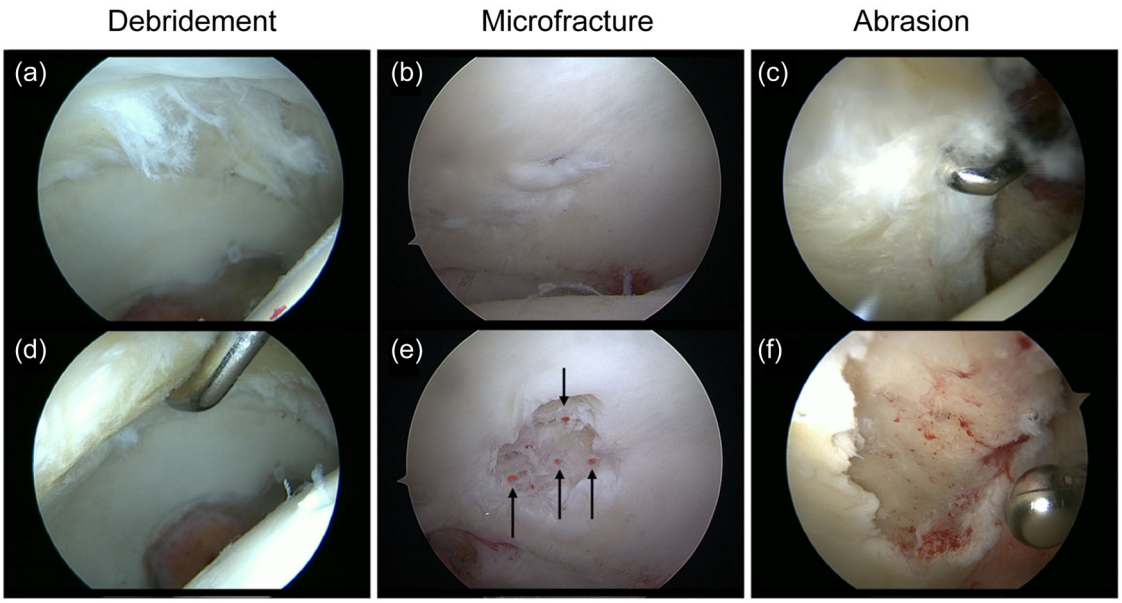

FIGURE 3 Intraoperative imaging of acetabular cartilage defects addressed either by debridement (a, b), microfracture (b, e), or abrasion (c, f) before (a, b, c) and after (d, e, f) treatment. Arrows indicate the perforations in the subchondral bone created during microfracture procedure.

left untreated based on their location and extent. Detailed demographic data and baseline characteristics of the treatment groups are presented in Table 2.

The preoperative investigation revealed a baseline total iHOT33 score of 45.8 ± 19.9 (mean ± SD) in the whole cohort, respectively 47.9 ± 20.6 (mean ± SD) in the microfracture group, 44.3 ± 21.4 (mean ± SD) in the abrasion group and 45.5 ± 19.3 (mean ± SD) in the debridement group. There was no significant difference in the preoperative iHOT33 score between the three test groups.

The overall iHOT33 score in the debridement group exhibited significant improvement at 6 months (66.0 ± 23.0 [mean ± SD]; <0.001), 12 months (66.4 ± 24.4 [mean ± SD], $p < 0.001$), 24 months (70.7 ± 22.0 [mean ± SD], $p < 0.001$), 36 months (69.4 ± 23.5 [mean ± SD], $p < 0.001$), and 60 months (82.1 ± 13.7 [mean ± SD], $p < 0.001$), relative to the preoperative iHOT33 score (Figure 2). Regarding the iHOT33 subcategories, highly significant improvements ($p < 0.001$) over time were observed in each subdomain in the debridement group as well.

Conversely, there were no significant changes in the total iHOT33 over time in the two bone marrow stimulation groups. Notably, the iHOT33 subcategory 'sport' exhibited a temporary significant increase during the follow-up duration in the microfracture and abrasion group; however, this effect was not sustained (Figure 4). However, these results have to be interpreted in consideration of the higher proportion of ICRS grade 4 defects in the bone marrow stimulation groups.

The direct comparison of total iHOT33 in the three groups showed statistically significant higher scores for chondral debridement at the 24-months-follow-up compared to both bone marrow stimulation techniques ($p \leq 0.047$) and at the 60-months-follow-up compared to microfracture alone ($p = 0.01$).

The calculation of the CIOV for the iHOT33 at the 24-month follow-up revealed a MCID of 11.9, a PASS of 62.2 and SCB change, and absolute values of 20.7 and 74.3, respectively. These values align with existing literature on CIOVs after hip arthroscopy [23]. The iHOT33 total score of the debridement group after 24 months (70.7 ± 22.0) fell between the MICD and the SCB absolute score, significantly surpassing the PASS ($p < 0.001$) In contrast, the bone marrow stimulation groups did not reach the PASS level at the 24-months-follow-up and were significantly lower than the SCB absolute score ($p = 0.001$) and the debridement group (Figure 5). The VAS for pain after debridement significantly decreased 6 months postoperatively ($p < 0.001$) and remained low throughout the entire follow-up period, while patients after bone marrow stimulation did not show significant improvements in pain over time (Figure 6). The comparison of the three therapy groups revealed no significant differences of VAS for pain at any time period.

Regression analysis identified a higher ICRS grade as a factor associated with lower total iHOT33 score 6 months after arthroscopy. However, there was no significant influence of the defect grade on later follow-up time points. Additionally, the change in iHOT33 and VAS was not significantly influenced by the analysed parameters, including age, BMI, sex or symptoms duration.

To further investigate the potential impact of the varying distribution of ICRS grades within the test groups, which we consider as an important limitation of

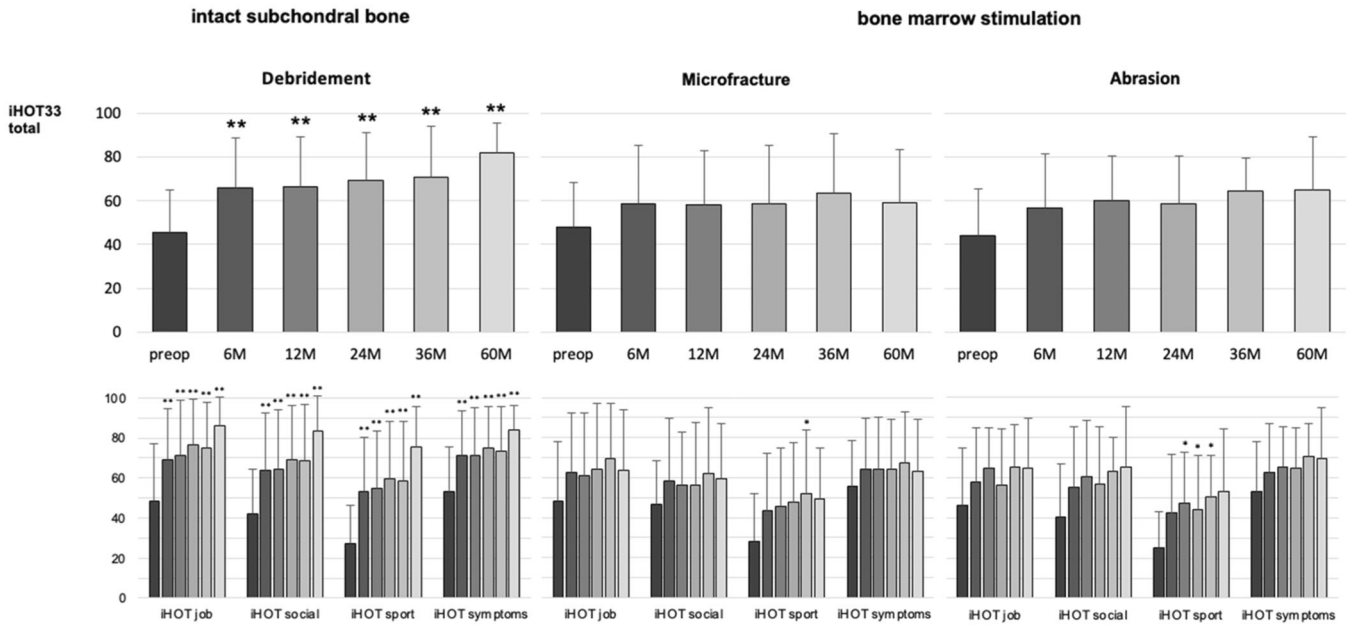

FIGURE 4 Outcome evaluation of the iHOT33 score and its subcategories in patients undergoing debridement, microfracture, or abrasion of acetabular cartilage defects during hip arthroscopy from baseline to 60 months follow-up. Whiskers indicate standard deviation. Asterisks mark statistically significant differences (**$p < 0.001$). iHOT33, International Hip Outcome Tool 33.

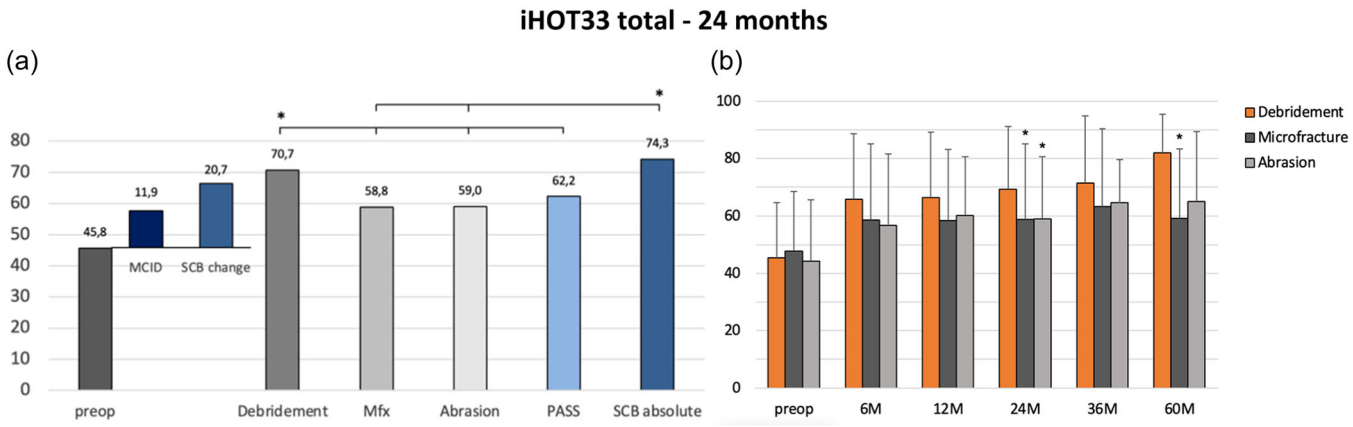

FIGURE 5 CIOVs (a) and direct group comparison (b) of the iHOT33 24 months after hip arthroscopy with or without bone marrow stimulation of the acetabular chondral lesion. Asterisks mark statistically significant differences (*$p < 0.05$). CIOV, clinically important outcome value; iHOT33, International Hip Outcome Tool 33; MCID, minimum clinically important difference; PASS, patient acceptable symptom state; SCB, substantial clinical benefit (absolute/change).

this study, we directly compared ICRS grade 3 and 4 defects regarding iHOT33 outcome (Figure 7). In the debridement group, ICRS grade 3 defects exhibited statistically significant higher scores than grade 4 defects both at baseline and 12 months post-operatively. However, in the bone marrow stimulation cohort, no significant differences between defect grades were observed at any point of time.

The adjusted response rates of iHOT33 at months 6, 12, 24, 36, and 60 were 79.2%, 80.1%, 70.3%, 49.2% and 17,4%, respectively. Figures 4–8 give a detailed overview of the iHOT33 and VAS results.

DISCUSSION

The aim of this study was to compare arthroscopic therapy options for small cartilage defects in the hip that are defined by perforation of the subchondral bone plate (bone marrow stimulation, e.g. microfracture, abrasion) to techniques that leave the subchondral bone intact (e.g., debridement, chondroplasty) and to determine whether the integrity of the subchondral bone lamella was predictive of outcomes and patient satisfaction. The most important finding was a significant improvement in symptoms and functions among

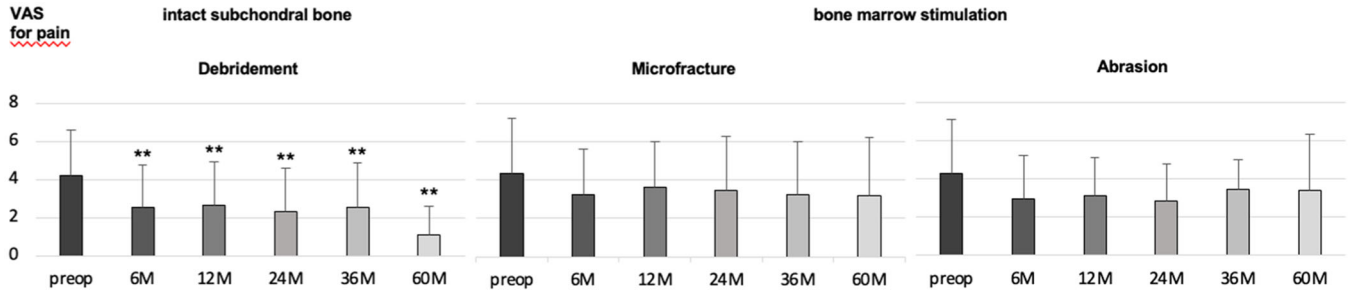

FIGURE 6 Results of the VAS for pain in patients undergoing debridement, microfracture, or abrasion of acetabular cartilage defects during hip arthroscopy from baseline to 60 months follow-up. Whiskers indicate standard deviation. Asterisks mark statistically significant differences (**$p < 0.001$). VAS, Visual Analogue Scale.

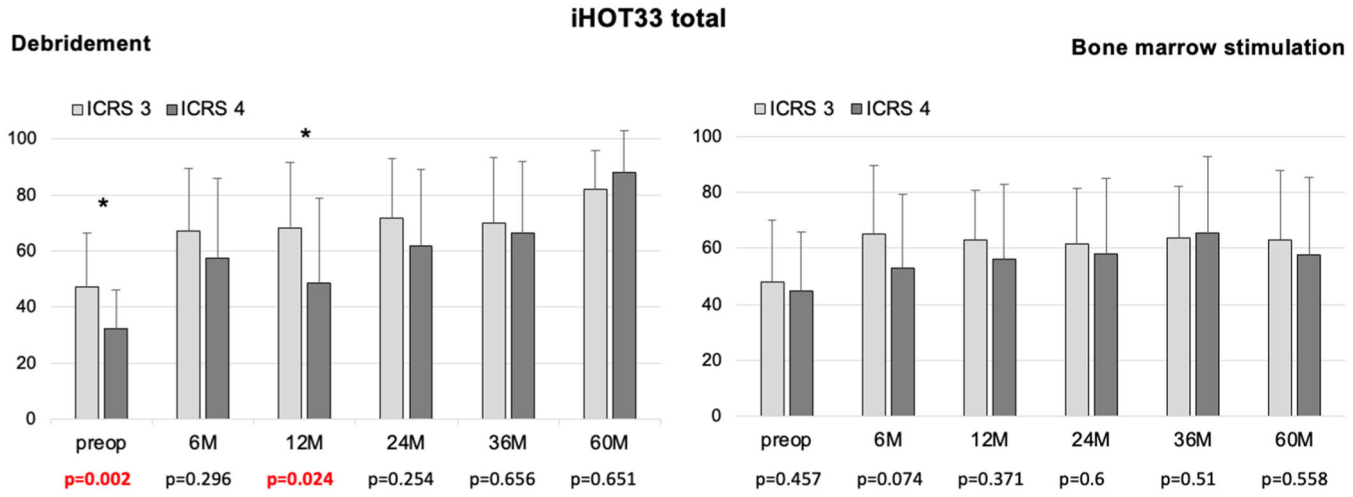

FIGURE 7 Comparison of ICRS grade 3 and 4 defects within the debridement group and the bone marrow stimulation cohort regarding the iHOT33 results. Whiskers indicate standard deviation. Asterisks mark statistically significant differences (*$p < 0.05$). ICRS, International Cartilage Repair Society; iHOT33, International Hip Outcome Tool 33.

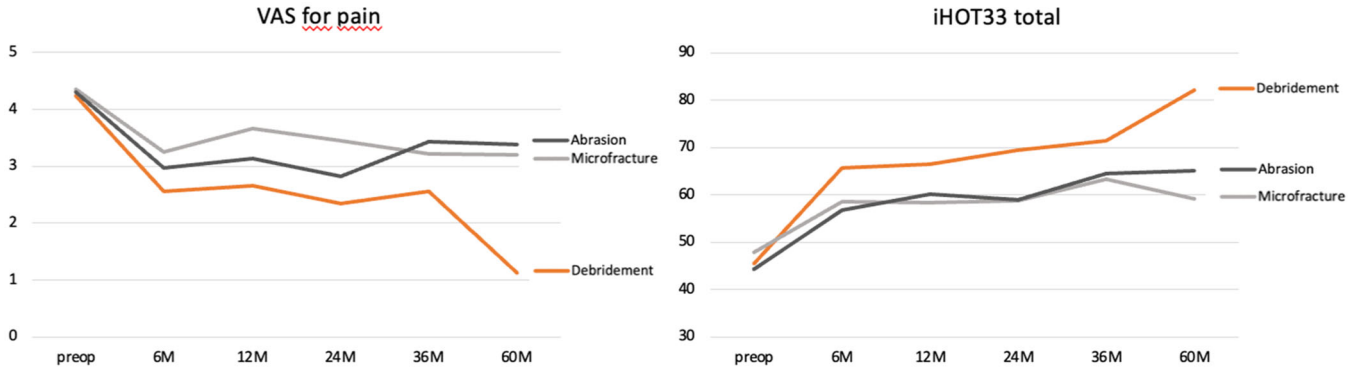

FIGURE 8 Development of pain and patient-reported outcome over time in the three test groups. iHOT33, International Hip Outcome Tool 33; VAS, Visual Analogue Scale.

patients after debridement of their cartilage defects at the time of FAIS surgery and/or labrum repair, whereas a comparable population undergoing bone marrow stimulation did not experience significant benefits from hip arthroscopy.

By 6 months post hip arthroscopy, both the iHOT33 and the VAS pain scores in the debridement group improved significantly compared to preoperative values and clinically relevant improvements maintained or even slightly continued to improve through month 60.

In contrast, patients undergoing bone marrow stimulation did not record significant improvements in any measured score (Figure 8). Regarding the CIOVs, 24 months after arthroscopy, the debridement group reached an iHOT33 score between PASS and SCB levels, while patients after bone marrow stimulation did not reach the PASS and fell significantly under the SCB level.

While current guidelines recommend the use of bone marrow stimulation for small chondral defects of the hip, these results indicate that patients with cartilage lesions in the hip smaller than 400 mm^2 do not benefit from such treatment. At this juncture, additional consideration should be given to other treatment-related factors. Microfracture and similar techniques, being more invasive, entail certain drawbacks, including an extended period of partial weight-bearing with potential complications such as muscle atrophy and thrombosis. Perforation of the subchondral lamina of the acetabulum further disrupts subchondral bone homoeostasis, elevating the risk of hyperossification, intralesional osteophyte formation, and diminishing the prognosis of secondary cartilage therapies.

The principle underlying bone marrow stimulation, particularly microfracture as described by Steadman et al. [22] for the knee joint involves perforating the underlying bone beneath the damaged cartilage by multiple holes (microfracture) or laminar burring (abrasion) to induce bleeding from exposed bone marrow. The blood contains growth factors and mesenchymal progenitor/stromal cells (MPC) capable of developing into new cartilage tissue. In the case of degenerative cartilage defects, Steadman additionally opened the infrapatellar fat pad, which is holding MPCs as well, to reduce scarring and enhance joint movement [21]. This additional procedure ensures the presence of MPCs in the joint, raising doubts about whether Steadman's results can be solely attributed to microfracture in a defined defect. This effect is intentionally used in primary anterior cruciate ligament (ACL) repair, known as healing response procedure [20].

Applied to the hip joint, the healing response is represented by the correction of impingement deformities producing adequate bleeding and intraarticular MPC emission. This theory posits that the key aspect behind bone marrow stimulation may be the surgical opening of MPC-rich tissue, independent of the intraarticular location and that bone marrow stimulation of the defect itself located in the weight baring area of the joint may even have negative effects such as intralesional osteophytes and fractures.

The findings of this study align with the existing literature. In a matched-cohort study including 127 patients, Domb et al. compared the outcome of patients with high-grade cartilage defects (ICRS grade IV) in the hip undergoing microfracture to those with lower-grade lesions (ICRS grade < IV) not treated with microfracture [5]. Both groups demonstrated a significant improvement of the patient-reported outcomes after a 24-month follow-up period with the only difference being a significantly better VAS score in the group without microfracture treatment. Moreover, Hevesi et al. conducted a study comparing microfracture to simple debridement of high-grade acetabular cartilage lesions in 110 patients, finding similar outcome scores and revision rates between the two groups. Based on their findings, they recommended avoiding microfracture for small chondral lesions of the hip [10].

Several limitations existed in the present study design. Most importantly, there was an unequal distribution of defect grades within the test groups with a notably higher proportion of ICRS grade 4 defects in the microfracture and abrasion group (61.4% and 51.4%, respectively) compared to the debridement group (11%). According to the multivariate regression analysis, the preoperative ICRS grade only had a significant influence on the early clinical results 6 months after hip arthroscopy. However, this remains a major limitation regarding the comparability of the test groups and represents a potential selection bias.

Additionally, this study is performed as a retrospective registry study. Results should be confirmed by prospective trials.

The authors' interpretations are based on clinical patient-reported outcome scores. Follow-up arthroscopy or MRI would provide insights into the regenerative potential of the examined cartilage defects; however, they are intricate follow-up devices.

Furthermore, the choice of cartilage treatment was unrandomised and unblinded.

Finally, in all our patients, we conducted additional corrective surgeries to treat the underlying pathology (e.g., labral refixation, femoroplasty, acetabuloplasty), making it challenging to distinguish the extent to which clinical improvement is attributed to cartilage repair or to the concomitant corrective surgery. However, the majority of the patients had a CAM-type FAI and an additional labrum lesion, resulting in a consistent therapy regime.

The strengths of this study include a follow-up of at least 12 months and a long total follow-up period of 60 months. Furthermore, the cohort is restricted to patients with unifocal cartilage defects that are not surgically pretreated to eliminate potential bias.

Based on our findings, a revision of the existing guidelines for articular cartilage therapy is recommended to accommodate the unique conditions in the hip joint. The choice of the appropriate treatment option cannot solely be broken down to lesion size, but also needs to consider factors such as defect morphology and concomitant interventions.

CONCLUSION

In this retrospective registry study, arthroscopical debridement in contrast to bone marrow stimulation (i.e., microfracture, abrasion) significantly and sustainably

improved clinical outcomes among patients with acetabular cartilage lesions due to FAI measuring less than 400 mm^2. Although these findings require confirmation through prospective trials, our results discourage the use of bone marrow stimulation in the hip joint. Instead, they suggest that less invasive methods such as debridement should be preferred for the treatment of acetabular cartilage defects.

AUTHOR CONTRIBUTIONS

Moritz Riedl: Conceptualisation; data curation; formal analysis; investigation; visualisation; writing—original draft. **Julia E. Lenz**: Data curation; investigation; visualisation. **Jens Goronzy**: Conceptualisation; data curation; project administration. **Christian Sobau**: Investigation; writing—review and editing. **Oliver Steimer**: Conceptualisation; methodology; writing—review & editing. **Steffen Their**: Supervision; writing—review and editing. **Wolfgang Zinser**: Data curation; methodology; writing—review and editing. **Stefan Landgraeber**: Supervision; writing—review and editing. **Volker Alt**: Supervision; writing—review and editing. **Stefan Fickert**: Conceptualisation; methodology; project administration; supervision; writing—original draft. All authors have read and agreed to the published version of the manuscript.

ACKNOWLEDGEMENTS

The German Cartilage Registry is funded by the German Orthopaedic and Trauma Society (DKOU), the Arthrosehilfe e.V. and the Oscar-Helene-Stiftung e.V. Open Access funding enabled and organized by Projekt DEAL.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data underlying this article will be shared on reasonable request to the corresponding author.

ETHICS STATEMENT

The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of the University of Freiburg (No. 520/14). Informed consent was obtained from all subjects involved in the study.

ORCID

Moritz Riedl http://orcid.org/0000-0003-3414-6596

REFERENCES

1. Anderson, L.A., Peters, C.L., Park, B.B., Stoddard, G.J., Erickson, J.A. & Crim, J.R. (2009) Acetabular cartilage delamination in femoroacetabular impingement. Risk factors and magnetic resonance imaging diagnosis. *The Journal of Bone and Joint Surgery-American Volume*, 91, 305–313. Available from: https://doi.org/10.2106/JBJS.G.01198
2. Biant, L.C., Bentley, G., Vijayan, S., Skinner, J.A. & Carrington, R.W.J. (2014) Long-term results of autologous chondrocyte implantation in the knee for chronic chondral and osteochondral defects. *The American Journal of Sports Medicine*, 42(9), 2178–2183. Available from: https://doi.org/10.1177/0363546514539345
3. Crawford, K., Philippon, M.J., Sekiya, J.K., Rodkey, W.G. & Steadman, J.R. (2006) Microfracture of the hip in athletes. *Clinics in Sports Medicine*, 25(2), 327–335. Available from: https://doi.org/10.1016/j.csm.2005.12.004
4. Dallich, A.A., Rath, E., Atzmon, R., Radparvar, J.R., Fontana, A., Sharfman, Z. et al. (2019) Chondral lesions in the hip: a review of relevant anatomy, imaging and treatment modalities. *Journal of Hip Preservation Surgery*, 6, 3–15. Available from: https://doi.org/10.1093/jhps/hnz002
5. Domb, B.G., Gupta, A., Dunne, K.F., Gui, C., Chandrasekaran, S. & Lodhia, P. (2015) Microfracture in the hip: results of a matched-cohort controlled study with 2-year follow-up. *The American Journal of Sports Medicine*, 43, 1865–1874. Available from: https://doi.org/10.1177/0363546515588174
6. Fickert, S., Aurich, M., Albrecht, D., Angele, P., Büchler, L., Dienst, M. et al. (2017) Biologische Rekonstruktion lokalisiert vollschichtiger Knorpelschäden des Hüftgelenks: Empfehlungen der Arbeitsgemeinschaft "Klinische Geweberegeneration" der DGOU und des Hüftkomitees der AGA. *Zeitschrift für Orthopädie und Unfallchirurgie*, 155, 670–682. Available from: https://doi.org/10.1055/s-0043-116218
7. Ganz, R., Leunig, M., Leunig-Ganz, K. & Harris, W.H. (2008) The etiology of osteoarthritis of the hip: an integrated mechanical concept. *Clinical Orthopaedics & Related Research*, 466, 264–272. Available from: https://doi.org/10.1007/s11999-007-0060-z
8. Ganz, R., Parvizi, J., Beck, M., Leunig, M., Nötzli, H. & Siebenrock, K.A. (2003) Femoroacetabular impingement: a cause for osteoarthritis of the hip. *Clinical Orthopaedics & Related Research*, 417, 112–120. Available from: https://doi.org/10.1097/01.blo.0000096804.78689.c2
9. Green, C.J., Beck, A., Wood, D. & Zheng, M.H. (2016) The biology and clinical evidence of microfracture in hip preservation surgery. *Journal of Hip Preservation Surgery*, 3, 108–123. Available from: https://doi.org/10.1093/jhps/hnw007
10. Hevesi, M., Bernard, C., Hartigan, D.E., Levy, B.A., Domb, B.G. & Krych, A.J. (2019) Is microfracture necessary? acetabular chondrolabral debridement/abrasion demonstrates similar outcomes and survival to microfracture in hip arthroscopy: a multicenter analysis. *The American Journal of Sports Medicine*, 47, 1670–1678. Available from: https://doi.org/10.1177/0363546519845346
11. Jannelli, E. & Fontana, A. (2017) Arthroscopic treatment of chondral defects in the hip: AMIC, MACI, microfragmented adipose tissue transplantation (MATT) and other options. *SICOT-J*, 3, 43. Available from: https://doi.org/10.1051/sicotj/2017029
12. Karthikeyan, S., Roberts, S. & Griffin, D. (2012) Microfracture for acetabular chondral defects in patients with femoroacetabular impingement: results at second-look arthroscopic surgery. *The American Journal of Sports Medicine*, 40, 2725–2730. Available from: https://doi.org/10.1177/0363546512465400
13. Von Keudell, A., Atzwanger, J., Forstner, R., Resch, H., Hoffelner, T. & Mayer, M. (2012) Radiological evaluation of cartilage after microfracture treatment: a long-term follow-up study. *European Journal of Radiology*, 81, 1618–1624. Available from: https://doi.org/10.1016/j.ejrad.2011.04.071
14. Marquez-Lara, A., Mannava, S., Howse, E.A., Stone, A.V. & Stubbs, A.J. (2016) Arthroscopic management of hip chondral defects: a systematic review of the literature. *Arthroscopy: The*

Journal of Arthroscopic & Related Surgery, 32, 1435–1443. Available from: https://doi.org/10.1016/j.arthro.2016.01.058
15. Meyer, D.C., Beck, M., Ellis, T., Ganz, R. & Leunig, M. (2006) Comparison of six radiographic projections to assess femoral head/neck asphericity. *Clinical Orthopaedics and Related Research*, 445, 181–185. Available from: https://doi.org/10.1097/01.blo.0000201168.72388.24
16. Minas, T., Von Keudell, A., Bryant, T. & Gomoll, A.H. (2014) The John Insall Award: a minimum 10-year outcome study of autologous chondrocyte implantation. *Clinical Orthopaedics & Related Research*, 472, 41–51. Available from: https://doi.org/10.1007/s11999-013-3146-9
17. Mithoefer, K., McAdams, T., Williams, R.J., Kreuz, P.C. & Mandelbaum, B.R. (2009) Clinical efficacy of the microfracture technique for articular cartilage repair in the knee: an evidence-based systematic analysis. *The American Journal of Sports Medicine*, 37, 2053–2063. Available from: https://doi.org/10.1177/0363546508328414
18. Philippon, M.J., Schenker, M.L., Briggs, K.K. & Maxwell, R.B. (2008) Can microfracture produce repair tissue in acetabular chondral defects? *Arthroscopy: The Journal of Arthroscopic & Related Surgery*, 24, 46–50. Available from: https://doi.org/10.1016/j.arthro.2007.07.027
19. Ross, J.R., Larson, C.M. & Bedi, A. (2017) Indications for hip arthroscopy. *Sports Health: A Multidisciplinary Approach*, 9, 402–413. Available from: https://doi.org/10.1177/1941738117712675
20. Steadman, J., Cameron-Donaldson, M., Briggs, K. & Rodkey, W. (2006) A minimally invasive technique ("healing response") to treat proximal ACL injuries in skeletally immature athletes. *The journal of knee Surgery*, 19, 8–13. Available from: https://doi.org/10.1055/s-0030-1248070
21. Steadman, J.R., Rodkey, W.G. & Briggs, K.K. (2010) Microfracture: its History and Experience of the Developing Surgeon. *Cartilage*, 1, 78–86. Available from: https://doi.org/10.1177/1947603510365533
22. Steadman, J.R., Rodkey, W.G., Singleton, S.B. & Briggs, K.K. (1997) Microfracture technique for full-thickness chondral defects: technique and clinical results. *Operative Techniques in Orthopaedics*, 7, 300–304. Available from: https://doi.org/10.1016/S1048-6666(97)80033-X
23. Ueland, T.E., Disantis, A., Carreira, D.S. & Martin, R.L. (2021) Patient-reported outcome measures and clinically important outcome values in hip arthroscopy: a systematic review. *JBJS Reviews*, 9:e20.00084. Available from: https://doi.org/10.2106/JBJS.RVW.20.00084

How to cite this article: Riedl, M., Lenz, J. E., Goronzy, J., Sobau, C., Steimer, O., Thier, S. et al. (2024) Save the subchondral bone plate: Debridement versus bone marrow stimulation in acetabular cartilage defects over 60 months of follow-up. *Knee Surgery, Sports Traumatology, Arthroscopy*, 32, 2395–2405. https://doi.org/10.1002/ksa.12375