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Long-term clinical and radiological outcomes following arthroscopic microfracture of the glenohumeral joint for chondral defects

Sam Hookway, BBioMed, MBBS, MPhil[a,*], Angela Alder-Price, MBBS[a,b], Stephen D. Gill, PhD, B Physio (Hons)[a,c,d], Andrew Mattin, BSc, MChiro, BMBS, FRACS(Ortho), FAOrthA[e], Richard S. Page, BMedSci, MBBS, FRACS(Ortho), FAOrthA[a,c,d]

[a]Department of Orthopaedics, University Hospital Geelong, VIC, Australia
[b]The University of Adelaide, School of Medicine, SA, Australia
[c]School of Medicine, Deakin University, Geelong, VIC, Australia
[d]Department of Surgery, Barwon Centre for Orthopaedic Research & Education, St John of God Hospital Geelong, VIC, Australia
[e]Department of Surgery, Fiona Stanley Hospital, Perth, WA, Australia

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Background: The primary aim of this study was to evaluate mid- and long-term outcomes following microfracture in patients with glenohumeral chondral lesions.
Methods: This prospective cohort study assessed patients with shoulder pain who were treated with arthroscopic microfracture for full-thickness chondral lesions of the glenohumeral joint. Outcomes included the Simple Shoulder Test at baseline, mid-term (approximately 1 year) and long-term (approximately 10 years), and the Oxford Shoulder Score, shoulder pain (0-10 numerical scale) and radiological assessment using a modified Samilson & Prieto score at long-term follow-up. Data were analyzed with paired *t*-tests and Wilcoxon's signed rank tests, which were considered significant if $P < .05$.
Results: Twenty-five patients with a mean age of 52.7 ± 12.1 were enrolled. The mean Simple Shoulder Test score improved from baseline to 1 year (6.7 ± 2.5 to 11.0 ± 1.4, $P < .001$), which was maintained at long-term follow-up (10.3 ± 2.1, $P < .001$). Additionally, at long-term follow-up, Oxford Shoulder Score and Verbal Pain Score scores were 43 ± 4.8 and 1.1 ± 1.5, respectively while median modified Samilson & Prieto scores increased from 1 preoperatively to 2 at 10 years ($P < .001$).
Conclusion: Patients undergoing microfracture for full-thickness chondral lesions of the glenohumeral joint reported substantial improvements in shoulder pain and function at 1 and 10 years, despite progressive radiological degeneration.

The optimal management of symptomatic chondral lesions of the glenohumeral joint remains challenging, particularly in younger patients with high functional demands.[17,18] Challenges include difficulty diagnosing isolated chondral lesions, the presence of concomitant pathology, and a scarcity of evidence regarding long-term results.[1,6,21] When nonoperative strategies have been exhausted, operative treatment options may be considered, which are broadly stratified into reparative, restorative, and salvage procedures. The mainstay reparative procedure is microfracture surgery. Restorative options include autologous chondrocyte implantation, matrix-induced autologous chondrocyte implantation, and autologous osteochondral transfers. Salvage options include capsular release, biological resurfacing, joint arthroplasty, and chondroplasty.[3,5]

Microfracture, first popularized by Steadman et al[25] in the 1980's, is an established management strategy for full thickness chondral lesions in the knee.[15] Surgically created subchondral bone perforations allow marrow clot formation and migration of mesenchymal stem cells with associated growth factors to the joint surface. Subsequent cell differentiation produces histologically determined 'hyaline-like' fibrocartilage, with improvement in clinical outcomes.[12,25] Most evidence regarding microfracture relates to knees,[12,25] and the role of microfracture for glenohumeral chondral defects is less clear. Clinical improvements have been

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*Corresponding author: Sam Hookway, BBioMed, MBBS, MPhil, 61 Moubray Street, Albert Park, VIC 3206, Australia.
E-mail address: srhookway@gmail.com (S. Hookway).

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demonstrated in several small cohort studies,[7,8,10,14,20,22,23,28] but long-term data assessing pain, function, osteoarthritis (OA) progression and subsequent arthroplasty is limited.

Frank et al[7] recently published a retrospective cohort study of 16 patients who underwent microfracture for glenohumeral chondral defects with a mean follow-up of 10 years. They concluded that microfracture 'seems to be a feasible treatment option for contained cartilage lesions in active patients, reproducibly yielding good mid- to long-term outcomes.' This was based on a statistically significant improvement in the Oxford Shoulder Score (OSS), Constant Score, and Subjective Shoulder Value postoperatively. Three patients (19.8%) in their cohort showed radiological progression of OA and two patients (12.5%) underwent revision surgery to hemiarthroplasty during the study period.

Given the limited evidence regarding microfracture in glenohumeral OA, we report our experience with microfracture for full thickness chondral lesions of the glenohumeral joint to a mean follow-up of 10 years assessing both clinical and radiological outcomes.

Materials and methods

A prospective cohort from a single surgeon's practice was recruited during a four-year period from 2008 to 2012.[13] Included patients had shoulder pain and preoperative imaging (x-ray, computed tomography or magnetic resonance imaging [MRI]) suggesting glenohumeral OA. Subsequently, during arthroscopy, these patients were identified as having full-thickness chondral lesion of the humeral head and/or glenoid, which was treated with microfracture. Patients were excluded if they had a concomitant irreparable full-thickness rotator cuff tear due to the inability to control for the altered mechanics of the glenohumeral joint. Concomitant shoulder pathology was assessed and treated at the time of microfracture as per the surgeon's usual practice, such as bursectomy and acromioplasty (see Results for details).

Patients completed the Simple Shoulder Test (SST),[11] a self-reported shoulder function questionnaire with range 0-12, (12 = asymptomatic) preoperatively, at mid-term (approximately 1 year, mean 14.2 ± 9.2 months) and long-term (approximately 10 years, mean 123.7 ± 15.1 months). The OSS (range 0-48, 48 = asymptomatic), numerical pain scale (0-10 scale, 0 = asymptomatic), and subsequent ipsilateral shoulder procedures were assessed at 10 years.

Surgical methods

For all patients, a diagnostic shoulder arthroscopy was performed in beach chair position using standard posterior and anterior portals. Chondral defects were assessed visually using a calibrated probe and concomitant pathology documented. The area for microfracture was débrided using an arthroscopic shaver to remove loose cartilage and microfracture performed using a chondral pick to produce 3-4 mm perforations in the subchondral bone 3-4 mm apart (Fig. 1). The size of the chondral defect was determined by measuring the two broadest dimensions with a calibrated probe, graded in 2 mm increments. On completing the microfractures, the fluid pump was paused to verify bleeding at the microfracture sites to ensure adequate depth of perforation. Other shoulder pathology was addressed according to the surgeon's standard practice (see Results for details). Prior to closure, the joint was gently lavaged to remove debris and retain the chondral hematoma. Intra-articular local anesthetic was not utilized.

Postoperative care consisted of a broad arm sling for six weeks with removal for wrist and elbow range of motion exercises. For the first four weeks, patients were instructed to perform dependent elbow and hand pendular exercises. Assisted active elevation was introduced at four weeks. At six weeks, active shoulder range of motion exercises were initiated, increasing to overhead exercises at ten weeks prior to the introduction of resistance exercises.

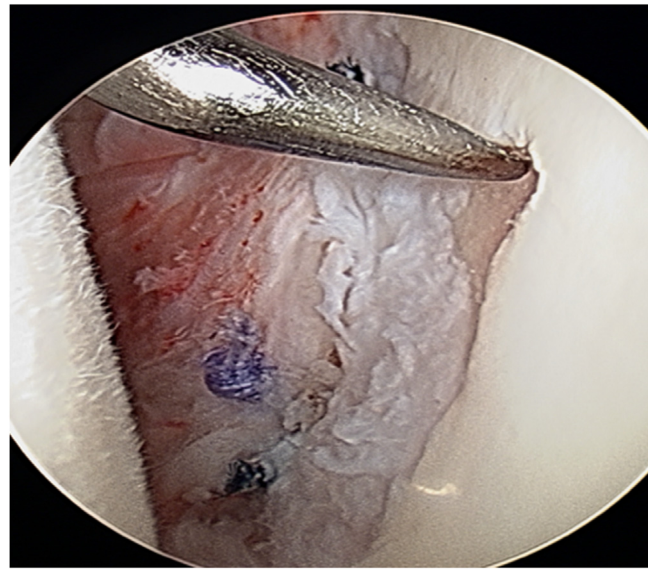

Figure 1 Microfracture in the presence of a labral repair and partial coverage of a chondral defect.

Radiological methods

Preoperative and long-term postoperative imaging of the shoulder was undertaken with MRI and plain radiographs. Two fellowship trained orthopedic surgeons independently reviewed preoperative and postoperative images, blinded to patient outcomes. Radiological assessment of OA employed a modified Samilson & Prieto (mSP) score.[4] This modified score assessed joint degeneration in four stages: stage 1, humeral osteophyte measuring less than 3 mm; stage 2, humeral osteophyte measuring at least 3 mm but less than 8 mm; stage 3, humeral osteophyte measuring at least 8 mm; stage 4, complete obliteration of the glenohumeral joint space. When surgeon mSP scores differed, they were subsequently rescored until consensus was achieved (n = 5).

Statistical methods

SST score data normality testing was performed using an Anderson-Darling test. Preoperative and postoperative SST scores were assessed with a paired student *t*-test. Preoperative and postoperative mSP scores was assessed with a Wilcoxon matched-pairs signed rank test. Normally distributed data are presented as mean ± standard deviation, otherwise median and interquartile ranges are stated. Statistical analysis was performed utilizing GraphPad Prism version 9 [San Diego, CA, USA], with a P value < .05 considered statistically significant.

Ethical approval was provided by the relevant Human Research Ethics Committee (ref. 12/32).

Results

Twenty-five patients were enrolled in the study consisting of 18 (72%) males and 7 (28%) females, with a mean age at time of surgery of 52.7 ± 12.1 years (range 28-71 years). All patients were right hand dominant, with 11 (44%) having microfracture performed on

Table I
Patient reported outcomes, chondral lesion size, and intraoperative copathology.

Patient number	Preoperative SST	Mid-term SST	Long-term SST	Oxford shoulder score	Pain score	Chondral lesion size (mm)	Intraoperative copathology
1	9	11	11	48	0	10 × 30	SLAP tear, Hill-Sach's lesion, biceps tendinopathy
2	7	8	5	37	5	10 × 15	Nil
3	7	12	12	39	2	8 × 10	Biceps tendinopathy, labral tear, SA bursitis
4	3	12	12	48	0	20 × 15	Bursitis, SA spur
5	6	11	10	43	0	10 × 10	SS tendinopathy, bursitis, SA spur
6	0	12	7	45	0	15 × 10	Unstable biceps, SA bursitis, SA spur
7	7	11	9	36	0	30 × 40	Biceps tendinopathy, SLAP tear, SA bursitis
8	7	10	12	44	2	12 × 18	SS tendinopathy, SA bursitis, SA spur, ACJ OA
9	6	12	11	44	1	12 × 8	SA bursitis, SA spur
10	7	10	10	33	3	20 × 25	Loose bodies, SS tendinopathy, SA bursitis, SA spur
11	4	12	12	45	0	20 × 20	SA bursitis, biceps tendinopathy
12	10	12	12	41	4	20 × 15	SS tendinopathy, bursitis, SA spur
13	8	12	12	48	0	12 × 15	SA bursitis, SA spur, ACJ OA
14	11	12	10	42	1	20 × 20	Labral tear, SLAP tear
15	4	9	8	34	1	20 × 8	SS tendinopathy, SA bursitis, SA spur
16	8	11	12	48	0	15 × 8	SA bursitis, ACJ OA
17	7	7	7	42	3	5 × 12	SLAP lesion, SA bursitis, SA spur
18	8	12	12	48	0	12 × 17	SA spur, SA bursitis
19	5	12	10	46	0	15 × 15	SA bursitis
20	10	12	12	48	0	10 × 15	SS tendinopathy, SA bursitis, SA spur
Mean (sd)	***6.7 (2.5)***	***11.0 (1.4)***	***10.3 (2.1)***	***43.0 (4.8)***	***1.1 (1.5)***		

Preoperative, mid-term postoperative and long-term postoperative Simple Shoulder Test (SST) scores (range 0-12, 12 asymptomatic). Long-term post-operative Oxford Shoulder Scores (range 0-48, 48 asymptomatic) and Pain Scores (range 0-10, 0 asymptomatic). Intraoperative chondral lesion size and diagnosed copathology.
SST, Simple Shoulder Test; *SLAP*, superior labral anterior to posterior tear; *SA*, subacromial; *SS*, supraspinatus; *OA*, osteoarthritis; *ACJ*, acromioclavicular joint; *SD*, standard deviation.
$P < .05$ = statistically significant.

the right shoulder. The median chondral defect size was 1.9 cm^2 (interquartile range 1.3-3.0, n = 20 patients), consisting of 4 humeral, 17 glenoid, and 4 bipolar lesions. Mid-term follow-up occurred at a mean of 14.2 ± 9.2 months (range, 3-47 months) postoperatively, and long-term follow-up a mean of 123.7 ± 15.1 months (range, 99-144 months). Five patients were lost to follow-up. Only patients with both mid- and long-term data were included in the statistical analysis (20 of 25 patients, 80%).

Twenty-four (96%) patients had concomitant, intraoperatively confirmed shoulder pathology (Table I) including subacromial bursitis (n = 19), subacromial spurs (n = 13), labral tears (n = 10), supraspinatus tendinopathy (n = 6), and biceps tendinopathy (n = 5). This highlights the additional pathology likely to be encountered when performing glenohumeral microfracture. Concomitant pathology was treated at the time of surgery as required with bursectomy (n = 18), acromioplasty (n = 16), labral repair (n = 5), biceps tenodesis/tenotomy (n = 7), lateral clavicle excision (n = 4), or Latarjet procedure (n = 1). Of the 20 patients followed up at long-term, none had undergone a subsequent operative procedure on the affected shoulder.

The SST score improved from 6.7 ± 2.5 preoperatively, to 11.0 ± 1.4 ($P < .001$, n = 20) at mid-term follow-up. At mean long-term follow-up of 123.7 months, the SST score was maintained at 10.3 ± 2.1 ($P < .001$, n = 20). An evaluation of chondral lesion size and location (bipolar vs. unipolar) did not show any statistically significant difference in outcome. At long-term follow-up, mean OSS was 43 ± 4.8 and mean Verbal Pain Score was 1.1 ± 1.5.

Preoperative radiological assessment involved a combination of MRI (n = 4) and plain radiographs (n = 19). Long-term postoperative assessment utilized plain films only (n = 20). Radiological review demonstrated progression of OA, with an increase in median mSP from 1 preoperatively to 2 at long-term follow-up (n = 19, $P < .001$) (Fig. 2).

Discussion

This prospective cohort study found that patients reported reduced pain and higher function following microfracture of full-thickness chondral lesions of the glenohumeral joint. This improvement was maintained at 10+ years, despite radiological progression of OA. The mean improvement in SST score (4.3) exceeds the minimal clinically important difference of 2-3 points.[19,26] The high OSS (43 ± 4.8) and low numerical pain score (1.1 ± 1.5) provided further evidence that the cohort achieved satisfactory long-term joint function.

Studies with comparable long-term follow-up and cohort size (16-27 patients) have similarly described improved patient reported outcome measures following microfracture of the glenohumeral joint.[7,10,28] Frank et al[7] investigated 16 patients following microfracture and demonstrated statistically significant improvement in Constant Score, OSS, and Subjective Shoulder Value (mean follow-up 10 years), with 88% of their cohort returning to preoperative levels of activity. The cartilage defects were less than 25 mm in diameter in all patients, though the

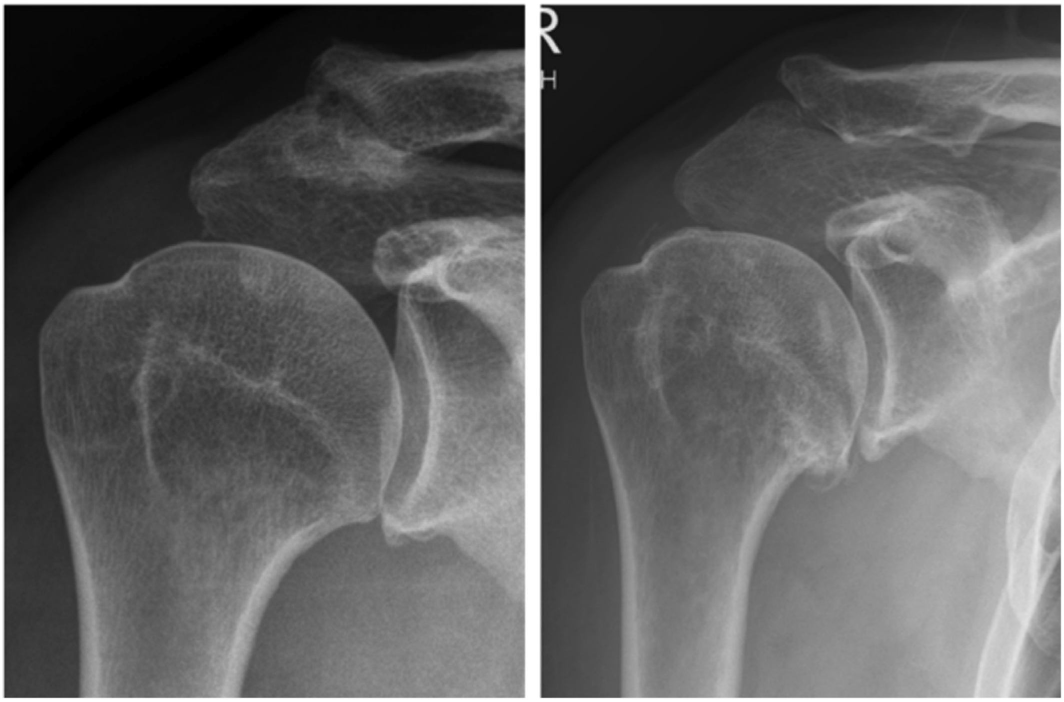

Figure 2 Example preoperative plain radiograph (*Left*) and 10-year long-term follow-up (*Right*). Modified Samilson & Prieto (mSP) joint degeneration score of 1 (*Left*) and 3 (*Right*).

measurement technique was not stated. Seven patients had concomitant procedures including subacromial decompression, rotator cuff repair, and bicep tenotomy/tenodesis. Wang et al[28] investigated 16 patients (17 shoulders) and reported statistically significant improvement in visual analog score, American Shoulder and Elbow Surgeons, and SST scores at similar long-term follow-up. Patient sex, chondral lesion location, and size (average humeral lesion 5.2 cm^2, average glenoid lesion 1.5 cm^2) had no significant correlation with patient reported outcome measures assessed. Furthermore, no significant difference was found in long-term outcomes between patients who did and did not undergo concomitant procedures (biceps tenodesis, distal clavicle resection, rotator cuff repair, subacromial decompression) at the time of microfracture (11 of 17 had concomitant procedures). With regard to physical performance, Hünnebeck et al[10] investigated 27 patients and demonstrated improved internal rotation post glenohumeral microfracture, but no statistically significant improvements in other shoulder movements. Hünnebeck et al[10] reported significantly lower Subjective Shoulder Value scores at long-term follow-up in those patients with bipolar lesions compared to unipolar lesions, which supplements the trend seen in other studies.[7,28] Hünnebeck et al[10] did not report lesion size but indicated that lesions were big enough to locate at least 2-3 microfracture punctures. Similar to our study and others, Hünnebeck et al[10] included concomitant treatments in more than one-half of the patients, which obscured the specific effects of microfracture. Overall, our results align with other case series and provide evidence that patients improve following microfracture, though often in the context of concomitant treatments.

Microfracture has a number of advantages. It is relatively low risk, has utility in combination with concurrent procedures, and preserves joint integrity for subsequent operations. Its use in managing knee chondral defects is well established, with evidence supporting clinical improvement in the mid- and long-term,[15,29] however a significant proportion of patients eventually undergo knee arthroplasty.[24] In the shoulder, less data exists, with lower patient numbers and shorter follow-up intervals. The 'failure rate' as measured by subsequent reoperation and/or arthroplasty following glenohumeral microfracture is between 5% and 30%[7,9,10,14,28] with previous studies reporting the mean time to 'failure' being within 5 years of surgery.[7,14,28] Our study reports a 0% failure rate at mean follow-up of 10.3 years with the described surgery and rehabilitation protocol. This is despite overall radiological evidence of OA progression. This is especially important for younger patients, where microfracture may allow higher levels of activity to be resumed and delay the need for joint-sacrificing procedures. Hünnebeck et al[10] and Frank et al[7] similarly reported radiological progression of OA within their patient cohorts, however, they also reported a higher subsequent arthroplasty rate of 18.5% and 12.5% respectively.

This study had several limitations. Despite being 1 of the largest studies looking at long-term outcomes of microfracture of the glenohumeral joint, patient numbers were still relatively small and the loss of five patients at long-term follow-up introduces the potential for nonresponse bias. Although the utility of the OSS and numerical pain score is limited in the absence of a preoperative comparator, they were added as a protocol amendment to the long-term follow-up to allow broader outcome comparisons. The size of chondral defects varied considerably which increases the generalizability of the study. Outcomes did not vary significantly according to the size of the lesion, suggesting that microfracture could still be useful for smaller chondral lesions. The size of each chondral lesion was estimated using a calibration probe and might include measurement error. The high proportion of patients that had a concurrent procedure (24 of 25 patients) and the absence of a comparison group makes it difficult to distinguish the benefit of microfracture from concurrent procedures. The British Medical Journal Rapid Recommendation[2,16,27] suggested there is no clinical benefit of subacromial decompression alone when compared to placebo. Given that 72% of patients in this study had either acromioplasty or bursectomy performed as the concurrent procedure, it supports a conclusion that the improvement in SST scores were a result of the microfracture, rather than the decompression. Despite the lack of control group, our results demonstrate that patients receiving microfracture reported sustained benefits for more than ten years.

The strengths of this study include the homogeneity in operative methods (single surgeon, single center), standardized rehabilitation, relatively large cohort size compared to previous studies, and the extended duration of follow-up. This study adds to scarce literature regarding the role of microfracture of the glenohumeral joint. Further research is needed to aid in accurate preoperative identification of isolated chondral lesions of the glenohumeral joint, and to assess how early microfracture may influence consequent joint degeneration in the long-term. This research would ideally include larger patient numbers, isolated lesions to avoid concomitant procedures and a control group.

Conclusion

This study demonstrated symptomatic improvement post-microfracture of glenohumeral osteochondral defects when combined with concomitant procedures, maintained 10 years postoperatively. Although radiological progression of OA was seen, no patients required subsequent procedures including joint arthroplasty. In conclusion, relatively young patients with contained small chondral defects who undergo microfracture along with other concomitant procedures may experience good long-term outcomes with respect to pain and function.

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References

1. American Academy of Orthopaedic Surgeons. Management of glenohumeral joint osteoarthritis evidence-based clinical practice Guideline. 2020. Available at: www.aaos.org/gjocpg. Accessed January 21, 2023.
2. Beard DJ, Rees JL, Cook JA, Rombach I, Cooper C, Merritt N, et al. Arthroscopic subacromial decompression for subacromial shoulder pain (CSAW): a multi-centre, pragmatic, parallel group, placebo-controlled, three-group, randomised surgical trial. Lancet 2018;391:329-38. https://doi.org/10.1016/S0140-6736(17)32457-1.
3. Bhatia S, Hsu A, Lin EC, Chalmers P, Ellman M, Cole BJ, et al. Surgical treatment options for the young and active middle-aged patient with glenohumeral arthritis. Adv Orthop 2012;2012:1-8. https://doi.org/10.1155/2012/846843.
4. Buscayret F, Edwards TB, Szabo I, Adeleine P, Coudane H, Walch G. Glenohumeral arthrosis in anterior instability before and after surgical treatment: incidence and contributing factors. Am J Sports Med 2004;32:1165-72. https://doi.org/10.1177/0363546503262686.
5. Elser F, Braun S, Dewing CB, Millett PJ. Glenohumeral joint preservation: current options for managing articular cartilage lesions in young, active patients. Arthroscopy 2010;26:685-96. https://doi.org/10.1016/j.arthro.2009.10.017.
6. Fiegen A, Leland DP, Bernard CD, Krych AJ, Barlow JD, Dahm DL, et al. Articular cartilage defects of the glenohumeral joint: a systematic review of treatment options and outcomes. Cartilage 2019;13:1-13. https://doi.org/10.1177/1947603519870858.
7. Frank JK, Heuberer PR, Laky B, Anderl W, Pauzenberger L. Glenohumeral microfracturing of contained glenohumeral defects: mid- to long-term outcome. Arthrosc Sports Med Rehabil 2020;2:341-6. https://doi.org/10.1016/j.asmr.2020.04.016.
8. Frank RM, Van Thiel GS, Slabaugh MA, Romeo AA, Cole BJ, Verma NN. Clinical outcomes after microfracture of the glenohumeral joint. Am J Sports Med 2010;38:772-81. https://doi.org/10.1177/0363546509350304.
9. Gross CE, Chalmers PN, Chahal J, Van Thiel G, Bach BR, Cole BJ, et al. Operative treatment of chondral defects in the glenohumeral joint. Arthroscopy 2012;28:1889-901. https://doi.org/10.1016/j.arthro.2012.03.026.
10. Hünnebeck SM, Magosch P, Habermeyer P, Loew M, Lichtenberg S. Chondral defects of the glenohumeral joint: long-term outcome after microfracturing of the shoulder. Obere Extrem 2017;12:165-70. https://doi.org/10.1007/s11678-017-0415-3.
11. van Kampen DA, van Beers LWAH, Scholtes VAB, Terwee CB, Willems WJ. Validation of the dutch version of the simple shoulder test. J Shoulder Elbow Surg 2012;21:808-14. https://doi.org/10.1016/j.jse.2011.09.026.
12. Kraeutler MJ, Aliberti GM, Scillia AJ, McCarty EC, Mulcahey MK. Microfracture versus drilling of articular cartilage defects: a systematic review of the basic science evidence. Orthop J Sports Med 2020;8:1-7. https://doi.org/10.1177/2325967120945313.
13. Mattin A, Page R, Thomas W, Thai D, Whan A, Shaw K. Clinical and MRI outcomes following microfracture of the glenohumeral joint during shoulder arthroscopy. Jeju, Korea. In: Paper presented at: 13th international congress on shoulder and elbow surgery; 2016. p. 18-20.
14. Millett PJ, Huffard BH, Horan MP, Hawkins RJ, Steadman JR. Outcomes of full-thickness articular cartilage injuries of the shoulder treated with microfracture. Arthroscopy 2009;25:856-63. https://doi.org/10.1016/j.arthro.2009.02.009.
15. Orth P, Gao L, Madry H. Microfracture for cartilage repair in the knee: a systematic review of the contemporary literature. Knee Surg Sports Traumatol Arthrosc 2020;28:670-706. https://doi.org/10.1007/s00167-019-05359-9.
16. Paavola M, Malmivaara A, Taimela S, Kanto K, Inkinen J, Kalske J, et al. Subacromial decompression versus diagnostic arthroscopy for shoulder impingement: randomised, placebo surgery controlled clinical trial. BMJ 2018;362:k2860. https://doi.org/10.1136/bmj.k2860.
17. Page RS. Managing chondral lesions of the glenohumeral joint. Int J Shoulder Surg 2008;2:77. https://doi.org/10.4103/0973-6042.44143.
18. Page RS, Bhatia DN. Arthroscopic repair of a chondrolabral lesion associated with anterior glenohumeral dislocation. Knee Surg Sports Traumatol Arthrosc 2010;18:1748-51. https://doi.org/10.1007/s00167-010-1095-3.
19. Roy J-S, Macdermid JC, Faber KJ, Drosdowech DS, Athwal GS. The simple shoulder test is responsive in assessing change following shoulder arthroplasty. J Orthop Sports Phys Ther 2010;40:413-21. https://doi.org/10.2519/jospt.2010.3209.
20. Salata MJ, Kercher JS, Bajaj S, Verma NN, Cole BJ. Glenohumeral microfracture. Cartilage 2010;1:121-6. https://doi.org/10.1177/1947603510366577.
21. Seidl AJ, Kraeutler MJ. Management of articular cartilage defects in the glenohumeral joint. J Am Acad Orthop Surg 2018;26:230-7. https://doi.org/10.5435/JAAOS-D-17-00057.
22. Siebold R, Lichtenberg S, Habermeyer P. Combination of microfracture and periostal-flap for the treatment of focal full thickness articular cartilage lesions of the shoulder: a prospective study. Knee Surg Sports Traumatol Arthrosc 2003;11:183-9. https://doi.org/10.1007/s00167-003-0363-x.
23. Snow M, Funk L. Microfracture of chondral lesions of the glenohumeral joint. Int J Shoulder Surg 2008;2:72. https://doi.org/10.4103/0973-6042.44142.
24. Solheim E, Hegna J, Inderhaug E. Long-term Survival after microfracture and Mosaicplasty for knee articular cartilage repair: a comparative study between two treatments cohorts. Cartilage 2020;11:71-6. https://doi.org/10.1177/1947603518783482.
25. Steadman JR, Rodkey WG, Briggs KK. Microfracture: its history and experience of the developing surgeon. Cartilage 2010;1:78-86. https://doi.org/10.1177/1947603510365533.
26. Tashjian RZ, Deloach J, Green A, Porucznik CA, Powell AP. Minimal clinically important differences in ASES and simple shoulder test scores after nonoperative treatment of rotator cuff disease. J Bone Joint Surg Am 2010;92:296-303. https://doi.org/10.2106/JBJS.H.01296.
27. Vandvik PO, Lähdeoja T, Ardern C, Buchbinder R, Moro J, Brox JI, et al. Subacromial decompression surgery for adults with shoulder pain: a clinical practice guideline. BMJ 2019;364:l294. https://doi.org/10.1136/bmj.l294.
28. Wang KC, Frank RM, Cotter EJ, Davey A, Meyer MA, Hannon CP, et al. Long-term clinical outcomes after microfracture of the glenohumeral joint: average 10-year follow-up. Am J Sports Med 2018;46:786-94. https://doi.org/10.1177/0363546517750627.
29. Weber AE, Locker PH, Mayer EN, Cvetanovich GL, Tilton AK, Erickson BJ, et al. Clinical outcomes after microfracture of the knee: midterm follow-up. Orthop J Sports Med 2018;6:2325967117753572. https://doi.org/10.1177/2325967117753572.