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Management of failed rotator cuff repair: a systematic review

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ABSTRACT

Importance Recurrent tear after rotator cuff repair (RCR) is common. Conservative, and open and arthroscopic revisions, have been advocated to treat these failures.

Aim or objective The purpose of this systematic review was to evaluate the different options for managing recurrent rotator cuff tears.

Evidence review A search was conducted of level I through 4 studies from January 2000 to October 2015, to identify studies reporting on failed RCR. 10 articles were identified. The overall quality of evidence was very low.

Findings Mid-term to long-term follow-up of patients treated conservatively revealed acceptable results; a persistent defect is a well-tolerated condition that only occasionally requires subsequent surgery. Conservative treatment might be indicated in most patients, particularly in case of posterosuperior involvement and poor preoperative range of motion. Revision surgery might be indicated in a young patient with a repairable lesion, a 3 tendon tear, and in those with involvement of the subscapularis.

Conclusions and relevance The current review indicates that arthroscopic revision RCR can lead to improvement in functional outcome despite a high retear rate. Further studies are needed to develop specific rehabilitation in the case of primary rotator cuff failure, to better understand the place of each treatment option, and, in case of repair, to optimise tendon healing.

What is already known

- Recurrent tear after rotator cuff repair (RCR) is common. Structural failure does not always result in clinical failure. The efficacy of various treatment options has still to be determined. Arthroscopic revision RCR can lead to improvement in functional outcome; however, the retear rate may be high.
- Level of evidence: systematic review of level I-IV prognostic studies, level IV.

INTRODUCTION

Failure of tendon healing after rotator cuff repair (RCR) is common, reported in approximately 20% of cases, depending on tear size.[1] Tear recurrence can be related to various factors such as: (1) inadequate strength of the initial repair construct, (2) biological failure to heal despite strong initial fixation and (3) inappropriate postoperative rehabilitation causing structural failure of the repair.[2–9] While functional outcome has been correlated with postoperative rotator cuff integrity,[3] many patients maintain a satisfactory outcome despite structural failure.[10] The ideal treatment for a recurrent tear is thus not completely defined.

Our aim was to perform a systematic review of the literature regarding recurrent rotator cuff. The purpose was to (1) analyse postoperative techniques of evaluation of repaired rotator cuffs, (2) review the natural history of failed RCR, (3) evaluate the different treatment options, (4) determine if revision leads to better clinical and functional outcome compared with non-operative treatment and (5) identify prognostic factors associated with outcome following revision. The hypothesis of the study was that arthroscopic revision RCR can lead to substantial improvement in functional outcome.

METHODS

Literature search

A systematic review was performed on PubMed articles from January 2000 to October 2015. To avoid overlooking appropriate studies, no filters were applied to the search strategies. Two authors (AL and PJD) independently identified published studies addressing treatment of failed RCR. Search terms included "open and arthroscopic rotator cuff repair", "failure", "revision surgery", "physiotherapy", "non-operative", "conservative treatment" and "postoperative imaging". In addition, we reviewed the references of the initially identified articles. Inclusion criteria included (1) functional outcome data on treatment of failed RCR, (2) level I-IV evidence relevant to the search terms, (3) English, French or German language and (4) a minimum of 12-month follow-up. Studies that did not specifically focus on treatment of failed RCR, but that provided useful information about diagnosis and treatment outcome, were also included. Expert opinions were excluded.

Information collected included year of publication, number of shoulders included, age of participants, surgical approach (open or arthroscopic), duration of follow-up, postoperative imaging, functional outcome measures and associated prognostic factors.

Statistical analysis

Continuous data were described by mean or median value, SD, percentage and range.

RESULTS

Literature search

The MEDLINE search identified 33 studies that focused on revision RCR.[11–43] Fifteen studies were

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excluded because they were reviews,[11 14 16 17 20 23 25 27 32 36 41 43] case reports[19] and commentary on studies.[13 42] One study dealt with results of surgery after failed attempt at repair of irreparable rotator cuff tear[35] and six had insufficient data (ie, no distinction in the results between primary and revision cases).[12 21 29 31 37 39] Two studies described the results[24] and the operative technique[26] of the same population. Finally, 10 met our inclusion criteria and were included in this study (table 1). All studies that met the study inclusion criteria were level IV evidence except for one (table 1).[38]

We also identified 9 studies that described the natural history and outcome after structural failure of RCR[3 10 44–50] and 29 studies that presented initial imaging findings. Two studies presented the outcome of the same patients at different points of follow-up.[10 48] Postoperative scores were reported in every study, but tendon healing was only reported in four studies.[12 24 29 38] Patient demographic characteristics and results for all included studies are shown in table 2.

Initial radiological findings

The goal of imaging studies is to confirm the site of the recurrent tear. Trantalis *et al*[51] were the first to report five patients with retearing of the cuff after double-row RCR. All five patients had retearing medial to the medial row as sutures were placed near the musculotendinous junction of the supraspinatus.[51] Hayashida *et al*[52] observed that the prevalence of complete retearing of the tendon after a double-row RCR is similar around the medial anchors, with a well-preserved footprint. Another point of interest is the quality of the tendon.[53] A significant and growing number of RCRs are performed in individuals with poor rotator cuff tissue quality. Djurasovic *et al*[18] reported an incidence of 30% (24 on 80) of poor rotator cuff tissue quality (graded subjectively at the time of surgery). At the same time, the muscle undergoes intrinsic degeneration. After a retear, Deniz *et al*[54] found that fatty infiltration and atrophy continued to worsen significantly. However, fatty infiltration of the supraspinatus does not seem to be a determinant factor in tendon healing. Park *et al*[55] did not find significant relationship between preoperative supraspinatus fatty infiltration and postoperative tendon healing. Contrarily, it seems that fatty infiltration of the infraspinatus and subscapularis is a highly significant factor ($p<0.001$).[55] Another point is the bone quality. Oh and colleagues demonstrated that bone mineral density within the greater tuberosity decreases in patients with rotator cuff tears. In another retrospective study that investigated the relationship between greater tuberosity osteopaenia and chronicity of rotator cuff tears, Cadet *et al*[56] found that there were significantly greater osteopaenic changes in the greater tuberosity in patients with chronic retracted rotator cuff tears. However, this localised osteoporosis may not influence tendon healing. In a recent study, Park *et al*[55] did not, after primary repair, observe that bone mineral density influenced final results. Nevertheless, the greater tuberosity in revision cases can also be deficient due to anchor removal or perianchor cyst formation. Kim *et al*, in a retrospective case series of 209 patients, observed bone cyst formation in 97 instances (46.4%), and these authors questioned the utility of bioabsorbable anchors because of possible interference with revision surgery. Consequent bone lysis can be noticed after trauma. Lädermann *et al*[57] reported massive bone resorption after osteosynthesis of the greater tuberosity, leading to combined tendon and bony insufficiency, and pseudoparalysis.

Postoperative MRI are difficult to interpret.[58] Recent prospective studies have confirmed that ultrasound has a high sensitivity and specificity for detecting a recurrent rotator cuff tear compared with MRI.[59–62] In a study comparing MRI and ultrasound after RCR, Codsi *et al*[59] found 92% agreement with a coefficient of 0.70. Similarly, Collin *et al*[60] reported that ultrasound had 80% sensitivity and 98% specificity compared with MRI.

Conservative treatment of failed RCR

Jost *et al*[10] evaluated 20 patients with a failed RCR at a mean follow-up of 38 months and reported that the adjusted Constant score and Subjective Shoulder Value (SSV) averaged 83% and 75%, respectively. Namdari *et al* demonstrated a successful outcome in 54% of patients (defined by an American Shoulder and Elbow Surgeons (ASES) score of >80 points) and a mean 15 point improvement in the ASES score at a mean of 52 months postoperatively. Finally, the same group compared the 2-year and 10-year results for patients with known structural failures of RCR. The average long-term ASES score was 79 points (range 50–95 points) and the average visual analogue scale (VAS) pain score was 2.2 points (range 1–4 points); both scores were unchanged from those at 2 years. The average Simple Shoulder Test (SST) score was 9.2 points (range 6–12 points), and the average age-adjusted Constant score was 73 points (range 59–90 points).[50]

Clinical and radiological results after revision RCR

The clinical results of the 10 studies are summarised in table 2. Seven studies used an arthroscopic technique and three studies used an open technique for revision. Overall, range of motion improved, except in one series of open RCR.[22] Functional outcome improved in all series and 70% or more of patients were satisfied or very satisfied.

The short-term to intermediate-term incidence of complications—including subsequent revision surgery—after revision RCR, is relatively low, around 10% in this review (table 2). However, the studies in this review primarily considered reoperation a complication and did not examine complications such as haematoma, hardware failure and postoperative stiffness. The prevalence of postoperative complications is therefore probably higher than reported. The prevalence of non-healing or retear was around 40% (range 0–62%) in the four studies with postoperative imaging.[12 24 29 38] Furthermore, these tears may progress with time; Shamsudin *et al* reported a prevalence of defect of 28% at 6 months and of 40% at 2 years.

Risk factors for poorer postoperative results

Several patient-related factors appear to be associated with poorer results. Female sex [15 28 34] and, in one study, if the surgery was performed on the dominant arm, were negatively associated with postoperative outcome.[15] There is still controversy about certain risk factors such as age of patients.[15 24 28]

Disease-related factors included patients with a recurrent tear after the revision repair,[24] preoperative VAS pain score greater than five[28] and poor preoperative range of motion.[15 18 22 28 34 63] The ranges vary from less than 90° in the studies from Piasecki *et al*[34] and Denard *et al*[63] to 140° in the study of Chuang *et al*.[15] The latter factor has been reported in almost all series and is probably the most important preoperative indicator. In addition, acromiohumeral distance (<7 mm) can be associated with a satisfactory outcome.[22] There is controversy about patients with more than one prior surgery, with one study reporting that this negatively impacted results and another study reporting that it did not.[28 34]

Table 1 Summary of key articles used in systematic review

Study	Year of publication	Technique	Shoulders	Age in years, mean (range)	Massive tears (% of total)	Follow-up in month, mean (range)	Design	Level of evidence
Djurasovic *et al*[18]	2001	Open	80	59.0	30%	49 (25–110)	Retrospective case series	IV
Lo and Burkhart[30]	2004	Arthroscopic	14	57.6	79%	23.4 (12 to NA)	Retrospective case series	IV
Keener *et al*[24]	2010	Arthroscopic	21	55.6	NA	36 (24–50)	Retrospective case series	IV
Piasecki *et al*[34]	2010	Arthroscopic	54	54.9	7%	31.1 (12–78)	Retrospective case series	IV
Lädermann *et al*[28]	2011	Arthroscopic	74	60.8	72%	59 (24–120)	Retrospective case series	IV
Hartzler *et al*[22]	2013	Open	37	58 (41–80)	16%	7.0 (1–14.9)	Retrospective case series	IV
Parnes *et al*[33]	2013	Arthroscopic	94	52 (44–72)	54%	NA (NA to 12)	Retrospective case series	IV
Chuang *et al*[15]	2014	Arthroscopic	32	69.3	59%	70.3 (13–165)	Retrospective case series	IV
Shamsudin *et al*[38]	2015	Arthroscopic	50	63 (43–80)	NA	35 (19–45)	Cohort study	III
Skoff[40]	2015	Open	10	58 (47–65)	0%	24 (12–44)	Retrospective case series	IV

NA, not available.

Operative-related factors, such as poor tendon quality,[18 30] are associated with poorer results. One study compared outcomes between massive and non-massive tears and did not find any significant difference in terms of postoperative anterior elevation, pain, or functional outcome.[28]

Postrevision rehabilitation

In all studies, participants took part in standardised rehabilitation protocols. Most studies did not allow immediate overhead passive motion.[28 30 34] In all studies except one,[40] the sling was discontinued after 6 weeks. Strengthening was delayed until 6,[38] 12[15 18 22 30 33 34 40] to 16 weeks[24 28] postoperatively. Full return to activity was not allowed until 4,[24] 6,[38] or even 12 months.[15 28 30]

DISCUSSION

This systematic review summarises the current literature regarding failed RCR and confirms the hypothesis of the study that arthroscopic revision surgery can lead to substantial improvement in functional outcome. However, due to the relative small number of studies, it was not possible to reach any definitive conclusion regarding appropriate management of failed RCR. Moreover, the low methodological quality of the included studies and, subsequently, the low quality of evidence, seriously affected the strength of recommendation of the present review. Any proposed assessment and treatment algorithm therefore also includes personal experience and extrapolated scientific data that are offered for consideration.

One aim of the study was to evaluate postoperative imaging. When milestones of typical postoperative recovery are not met,

Table 2 Clinical results of revision RCR

	Djurasovic *et al*	Lo and Burkhart	Keener *et al*	Piasecki *et al*	Lädermann *et al*	Hartzler *et al*	Parnes *et al*	Chuang *et al*	Shamsudin *et al*	Skoff
Active postoperative forward elevation, mean ±SD (gain)	130°±NA (25)	153°±33° (32)	146°±29° (NA)	136°±11.8° (15)	152°±42° (16)	Median 110° (–20)	NA	156°±17° (9)	NA (2)	NA
Postoperative ASES, mean ±SD (gain)	NA	NA	74±24 (NA)	68±7 (24)	77±25 (26)	NA	NA	87±13 (NA)	NA	75 (57)
Postoperative UCLA, mean ±SD (gain)	NA	28±7 (15)	NA	NA	27±7 (9)	NA	NA	30±5 (14)	NA	28 (24)
SST, mean±SD (gain)	NA	NA	8.9±3.2 (3.5)	7.5±1.1 (4)	NA	NA	NA		NA	NA
Postoperative VAS pain score, mean±SD (gain)	3 (4.4)	NA	2.7±2.6 (NA)	2.7±0.8 (2.4)	2.0±2.3 (3.0)	median 5.0 (3)	NA	0.9 (3.7)	NA	NA
Patient satisfaction (%)	70	93	NA	NA	78	NA	NA	NA	NA	NA
SANE score, mean±SD	NA	NA	NA	68.1±8.3	74.7±20.9	NA	NA	NA	NA	NA
Non-healing or retear (%)	NA	NA	52	NA	NA	NA	10.6	NA	40	0
Complications/revision (%)	NA	0	0	11.1	8.1	2.7	9.6	NA	12	0

ASES, American Shoulder and Elbow Surgeons; NA, not available; RCR, rotator cuff repair; SANE, Single Assessment Numeric Evaluation; SST, Simple Shoulder Test; UCLA, University of California Los Angeles; VAS, visual analogue scale.

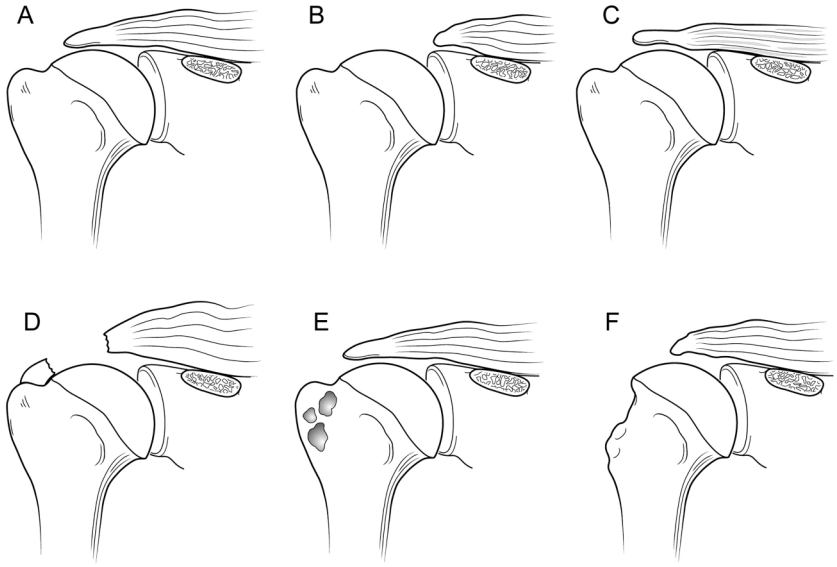

Figure 1 Six patterns of anatomic deficiency associated with failed rotator cuff repair. (A) Failure of tendon healing; (B) poor tendon quality; (C) fatty infiltration/atrophy; (D) retear medial to the medial row of fixation; (E) bone defects in the greater tuberosity after anchor removal, or perianchor cyst formation and (F) bony and tendinous insufficiency.

analysis of RCR should be considered, and a multimodal evaluation is required. The goal of imaging studies is to confirm the site of the recurrent tear (figure 1),[52 64] the type of failure (eg, in continuity)[65] and, if possible, its cause. Other points of interest are the quality of the bone (tuberosity deficiency),[57] tendon and muscle,[54] and whether further surgery is feasible. Standard shoulder radiographs, including anteroposterior, axillary lateral and scapular Y (outlet) views, may demonstrate decreased acromiohumeral distance, glenohumeral arthritis, subacromial spurs, acetabularisation of the acromion, femoralisation of the humeral head and implant or anchor migration.[22 66] It can also be used to rule out chondrolysis, anchor migration or prominence, and acromial fracture. Among evaluation techniques, the most widely accepted reference standard is MRI, which allows visualisation of the tendons and does not involve radiation exposure. Intra-articular contrast may be used in association with MRI to increase the sensitivity for detecting a recurrent tear.[61] Postoperative MRI are difficult to interpret[58 67]; inadequate coverage of the greater or lesser tuberosity may indicate partial healing and not a recurrent full-thickness tear.[68 69] Furthermore, only 10% of reattached tendons generate a normal MRI signal. Thus, a common finding is the presence of an intermediate signal within the tendon, indicating granulation tissue, or of a low-intensity signal produced by fibrous tissue.[58 69–73] These signal changes may persist for longer than 6 months, due to tissue remodelling, and seem to have no clinical implications.[74 75] Finally, the evaluation of MRI scans is made difficult by the normal leakage of fluid into the subacromial space after the opening of the rotator interval and passage of instruments through the tendon, which may contain artefacts generated, for instance, by metal anchors or high-strength sutures. These factors, together with the high cost of MRI, lend considerable appeal to ultrasound as a method for evaluating RCR, even if its effectiveness is operator dependent.[76 77] CT arthrogram can also be used to aid in the identification of recurrent rotator cuff tears when neither ultrasound nor MRI are options.[78] Failure after RCR was previously believed to occur during the first 3 months.[79 80] While the majority of retears do occur within the first 3 months, it has now been demonstrated that retears can occur up to 6 months after repair.[81 82]

Another goal of the present article was to analyse the natural history of failed RCR. Structural failure does not always result in clinical failure. Many patients with partial healing of the cuff and a residual defect will be much improved after surgery. Characteristics associated with successful and unsuccessful results after structural failure of RCR are poorly understood. Retear or non-healing of tendons is rather frequent and surgery is rarely proposed because this condition is often well tolerated with marked clinical improvement in comparison with the preoperative state.[3 10 44–50] One reason for clinical failure is probably the non-restoration of balanced force couples and the suspension bridge system of force transmission in the shoulder.[83] The location (involvement of the subscapularis on which the rotator cable is attached) along with the size (more than 2 tendons) is the primary determinant of rotator cuff function.[84]

It has long been recognised that revision RCR is challenging, as there are frequently multiple components to the pathoanatomy and multiple reasons for the failure of the initial repair. We consequently aimed to evaluate the different surgical treatment options and the prognostic factors associated with the outcomes of the procedure. The most important factor related to poor results seems to be poor preoperative range of motion. If revision is planned, patients have to be aware of the high prevalence of persistent structural defect. Moreover, retear rate after reoperation continues to deteriorate with time.[38 85] The alarming retear rate revealed by this review indicates that several surgical options can be considered that must be individualised to the patient. For example, in the setting of an acute traumatic retear in a physiologically young, healthy, active and non-pseudoparalytic patient, arthroscopic revision surgery is generally recommended. Techniques to enhance mechanical fixation, such as linked load-sharing rip-stop constructs, should be considered.[86] Augmented repairs using scaffold devices derived from autografts,[40 57 87] allograft,[12] xenograft extracellular matrix[37] or synthetic matrices such as poly-L-lactide grafts,[29] have been used to offer a structural support to the repair during the crucial healing period and to improve healing rates. The scientific literature does not contain enough data to justify any systematic-associated augmentation techniques. Tendon transfers may be used in patients without advanced glenohumeral arthritis who have significant loss of external rotation strength and maintain anterior active elevation.[88 89] If the patient is young, pseudoparalytic, and suffers from a combined bony and tendinous rotator cuff insufficiency, a calcaneum and Achilles tendon allograft could be considered.[90] Finally, whereas primary pseudoparalysis responds well to arthroscopic RCR, persistent

pseudoparalysis after a previous attempt at RCR may be more predictably managed with reverse shoulder arthroplasty (RSA). We reported in a previous study that pseudoparalysis was reversed in the revision setting in only 43% of patients, with a low rate (54%) of satisfaction.[63] In contrast, Boileau *et al*[91] found that anterior elevation was reliably restored with RSA after failed RCR and 73% of patients were satisfied.

Limitations

This study has several limitations. First, we were inherently limited to a review of primarily level III and IV studies, and the low quality of evidence seriously affected the strength of recommendation. We also excluded studies from journals that had insufficient data available; this lowered our sample sizes and could have introduced a selection bias. Second, no attempt was made to contact the authors of each study, to obtain individual patient data for the purposes of a meta-analysis. Third and lastly, many outcomes such as Constant score[92] were not considered due to the paucity of studies. This lack of data or heterogeneity of the studies did not allow statistical analysis.

CONCLUSION

The current review indicates that arthroscopic revision RCR can lead to improvement in functional outcome despite a high retear rate. A clear deficiency exists in the literature concerning this topic; more research should be performed in the future to develop specific rehabilitation in cases of failure, to better understand the place of each treatment option with comparative studies and, in cases of repair, to optimise tendon healing.

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Appendix 1

MEDLINE	EMBASE	CINHAL	PUBMED	WEB OF SCIENCE
1. Exp Cartilage, Aritcular.mp 2. Exp Chrondrocytes.mp 3. Exp Microfracture.mp 4. Exp Cartilage Diseases.mp 5. 1 or 2 or 3 or 4 6. Exp Rehabilitation.mp 7. 5 and 7	1. Exp microfracture.mp 2. Exp. Cartilage graft.mp 3. Exp cartilage transplantation.mp 4. Exp cartilage injury.mp 5. Exp cartilage 6. Exp articular cartilage.mp 7. Exp hyaline cartilage.mp 8. Exp cartilage fracture.mp 9. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 10. Exp rehabilitation.mp 11. 9 and 11	1. Exp microfracture.mp	1. Exp microfracture.mp	1. Exp microfracture.mp

Appendix 2A

Study	Year	Lesion Location	Number of Lesions	Average Size of Lesion (SD/Range)
Karthikeyan *et al.*[20]	2012	Ac (Sup and Ant-Sup zones)	1	154mm^2 (50-300mm^2)
McDonald *et al.*[21]	2014	Ac or FH (Outerbridge grade IV)	NR	119mm^2 (20-250mm^2)
McDonald *et al.*[22]	2013	30 Ac, 5 FH, 4 Ac+FH	NR	162mm^2 (20-378mm^2)
Philippon *et al.*[23]	2008	Ac (Sup quadrant 9-3 o'clock) + FH in 1 Pt	1-2	163mm^2 (40-240mm^2)
Singh *et al.*[24]	2010	22 cam, 3 pincer, 2 pincer+cam, 93% rim	1	"Lesions up to 300mm^2", mean NR

Appendix 2B

Study	Year	Complications	Reoperations
Karthikeyan *et al.*[20]	2012	1 failure: avascular necrosis	All cases were re-operation after an initial arthroscopy.
McDonald *et al.*[21]	2014	NR	NR
McDonald *et al.*[22]	2013	NR	NR
Philippon *et al.*[23]	2008	12 failures: 6. capsulolabral adhesions; 3. myositis ossificans; 2. femoral head defect	All cases were re-operation after an initial arthroscopy. One patient underwent a total hip arthroplasty 3 years following secondary evaluation
Singh *et al.*[24]	2010	NR	NR

Appendix 3A

Study	Year	Lesion Location	Number of Lesions	Mean Size of Lesion (SD/Range)
Asik *et al.*[43]	2008	MFC	1	<200 (76%) - >200 (24%)mm^2
Basad *et al.*[44]	2010	MFC/LFC, P	1	400-1000mm^2 (mean NR)
Chung *et al.*[25]	2014	MFC or LFC or PF	1 to multiple	150mm^2 (100mm^2)
Crawford *et al.*[26]	2012	MFC or LFC	1 to multiple	252mm^2 (135mm^2)
Gobbi *et al.*[27]	2013	MFC or LFC or trochlea	1 to multiple	401mm^2 (27mm^2)
Gudas *et al.*[28]	2012	MFC or LFC	NR	277mm^2 (68mm^2)
Knutsen *et al.*[45]	2004	MFC or LFC or trochlea	1	200-1000mm^2 (mean NR)
Kon *et al.*[29]	2011	MFC or LFC or trochlea	1 to 2	190mm^2 (60mm^2)
Kon *et al.*[30]	2009	MFC or LFC or trochlea	1	240mm^2 (140-440mm^2)
Krych *et al.*[31]	2012	MFC or LFC or trochlea	1	255mm^2 (100-625mm^2)
Lim *et al.*[32]	2012	MFC or LFC	1	277mm^2 (120-360mm^2)
Marder *et al.*[46]	2005	MFC or LFC	1	<200mm^2 (no specifics reported)
Mithoefer *et al.*[33]	2006	MFC or LFC	1	492mm^2 (24-2000mm^2)
Mithoefer *et al.*[34]	2005	MFC or LFC	1	482mm^2 (24-2000mm^2)
Petri *et al.*[35]	2012	PF	1	300mm^2 (120mm^2)
Saris *et al.*[36]	2014	MFC or LFC or trochlea	1	470mm^2 (180mm^2)
Saris *et al.* [37]	2008	MFC or LFC	1	240mm^2 (120mm^2)
Stanish *et al.*[38]	2013	MFC or LFC	1	195mm^2 (135mm^2)
Steadman *et al.*[39]	2003	Trochlea, MFC, LFC, lateral tibial plateau, medial tibial plateau, patella	1 to multiple	38mm^2 (15-100mm^2)
Ulstein *et al.*[40]	2012	MFC or LFC or trochlea	1	260mm^2 (200-520mm^2)
Van Assche *et al.*[41]	2010	NR	NR	240mm^2 (100mm^2)
Vanlauwe *et al.*[42]	2011	MFC or LFC	1	246.7mm^2 (200-500mm^2)

Appendix 3B

Outcome Measure	Number of Patients Contributing EWB Data OR # of studies contributing EWB	EWB Score	Number of Patients Contributing DWB Data OR # of studies contributing DWB	DWB Score

	data		data	
Lysholm	20	44 (36.86 to 51.13)	288	31.0 (26.84 to 33.35)
Tegner	20	3.35 (2.29 to 4.41)	307	1.48 (1.13 to 1.88)
KOOS pain	0	N/A	96	21.5 (17.23 to 25.8)
KOOS ADL	0	N/A	199	20.23 (16.02 to 24.44)
KOOS QoL	0	N/A	199	24.75 (20.35 to 29.20)
KOOS Overall	0	N/A	138	11.33 (5.11 to 17.55)
IKDC Subjective	0	N/A	159	26.25 (22.80 to 29.84)
Complications	0	N/A	420	7.92% (95% CI = 3.62% to 13.69%); heterogeneity 75.7% (95%CI = 55.9% to 84.3%)
Reoperations	0	N/A	388	11.41% (95% CI = 5.26% to 19.52%); heterogeneity 74.8% (95%CI = 48.5% to 84.7%)

Appendix 3C

Study	Year	Complications	Reoperations
Asik *et al.*[43]	2008	9 recurrent painless articular effusions	0
Basad *et al.*[44]	2010	1 post-operative pain	1 arthroscopic debridement and retrograde bone grafting
Chung *et al.*[25]	2014	0	0
Crawford *et al.*[26]	2012	0	NR
Gobbi *et al.*[27]	2014	7 meniscal issues/pain	7 repeat arthroscopic debridement
Gudas *et al.*[28]	2012	13 failures (not further specified)	0
Knutsen *et al.*[45]	2004	1 post-operative pain	1 repeat arthroscopic debridement and microfracture
Kon *et al.*[29]	2011	0	0
Kon *et al.*[30]	2009	0	1 repeat arthroscopic debridement and microfracture
Krych *et al.*[31]	2012	NR	NR
Lim *et al.*[32]	2012	0	3: 2. repeat arthroscopic debridement and microfracture; 1.

			Arthroscopic adhesiolysis and debridement
Marder *et al.*[46]	2005	2: 1 deep vein thrombosis; 1 superficial infection	5 repeat arthroscopic debridement and microfracture
Mithoefer *et al.*[33]	2006	NR	NR
Mithoefer *et al.*[34]	2005	NR	NR
Petri *et al.*[35]	2012	NR	NR
Saris *et al.*[36]	2014	54: 46 arthralgia; 8 joint effusions	NR
Saris *et al.* [37]	2008	39: 35 arthralgia; 3 joint effusions; 1 Post-operative joint crepitations	NR
Stanish *et al.*[38]	2013	1 serious adverse event (not further specified)	NR
Steadman *et al.*[39]	2003	NR	NR
Ulstein *et al.*[40]	2012	NR	6: 2. OAT mosaicplasty; 1. autologous chondrocyte implantation; 1 open wedge osteotomy; 1 removal of loose body; 1 arthroscopic debridement
Van Assche *et al.*[41]	2010	NR	NR
Vanlauwe *et al.*[42]	2011	5 serious adverse events, not considered related to intervention	10 repeat arthroscopic debridement and microfracture

APPENDIX 4A

Study	Year	Lesion Location (talus)	Number of Lesions	Average Size of Lesion (SD/Range)
Backus *et al.*[47]	2012	Medial, Lateral, Central, Unknown	34(M), 27(L), 1 (C), 1 (unknown)	70.7 mm^2 (6 – 314mm^2)
Becher *et al.*[48]	2010	Medial, Lateral, Bilateral	21(M), 6(L), 3(M+L)	Mean NR (50 - 200 mm^2)
Becher *et al.*[49]	2005	Medial, Lateral, Bilateral	30 (M), 11 (L), 4 (M+L)	Mean NR (50 - 200 mm^2)
Chuckpaiwong *et al.*[50]	2008	Medial, Lateral, Bilateral, Tibial involvement (global).	30 (M), 24 (L), 32 (M+L), 19 (T)	3.5mm^2 (2.6, n=74); 21.6mm^2 (3, n=31)
Cuttica *et al.*[51]	2012	Anterior lateral, Anterior central, Medial central, Posterior central, Central, Posterior medial.	4 (AL), 3 (AC), 2 (MC), 2 (PC), 1 (C), 1 (PM)	<100mm^2 (n=7); <100 mm^2 (n=6)
Doral *et a.l.*[52]	2012	Lateral, Medial	41 (M), 16 patients (L)	<20 mm diameter (not further specified)
Gobbi *et al.*[53]	2006	Lateral, Medial	7 (L), 3 (M)	450mm^2 (150-800mm^2)
Guney *et al.*[54]	2013	Medial	7, 11 (R); 13,12 (M)	NR
Guo *et al.*[55]	2010	Medial, Lateral, Bilateral	39 (M), 7 (L), 2 (M+L), Total: 50	10.9mm (2.7; n=35); 14.2 (4.7; n=8), note these are diameters
Jung *et al.*[56]	2011	Medial 91%, Lateral 9%. Centromedial, Posteromedial	12 (CM), 7 (PM)	median 76 mm^2 (12-212mm^2)
Kuni *et al.*[57]	2012	Lateral, Medial	6 (L), 16 (M)	377 mm^3 (median interquartile distance: 417mm^3)
Lee, DH *et al.*[58]	2012	Lateral, Medial	35(85%)/33(82.5%) (M); 6(15%)/7(17.5%) (L) [DWB/EWB]	DWB (10 mm^2 (60-180mm^2); EWB 10 mm^2 (60-190mm^2)
Lee, KB *et al.*[59]	2010	Lateral, Medial	29 (M), 6 (L)	90 mm^2 (60-140mm^2)
Lee, KB *et al.*[60]	2009	Posteromedial, Anterolateral	16 (PM), 4(AL)	90 mm^2 (60-130mm^2)
Li *et al.*[61]	2014	Lateral, Medial	46 (M), 12 (L)	<200mm^2
Park *et al.*[62]	2015	Lateral, Medial	53^{Ch} (M), 5^{Ch} (L); 39^{OC} (M), 7^{OC} (L)	Ch 93.5 mm^2 (83-104mm^2); OC: 110.3 mm^2 (98.9-121.7mm^2)
Sallakh *et al.*[63]	2012	Lateral, Medial	20 (M), 5 (L)	11 mm^2 (7-15mm^2)
Saxena *et al.*[64]	2007	Anterolateral, Anteromedial, Centromedial, Posterolateral, Central	12 (AL), 9 (AM), 3 (CM), 1 (PL), 1 (C)	NR
van Bergen *et al.*[65]	2013	Centromedial talus, Centrolateral talus	25 (CM), 25 (CL)	

				641.2mm^3 (38.8mm^3)

APPENDIX 4B

Outcome Measure	Number of Patients Contributing EWB Data OR # of studies contributing EWB data	EWB Score	Number of Patients Contributing DWB Data OR # of studies contributing DWB data	DWB Score
AAS	145	3.61 (3.30 to 3.96)	75	3.00 (2.65 to 3.35)
AOFAS	401	21.72 (20.00 to 23.01)	270	22.22 (19.94 to 24.50)
VAS pain	337	-4.39 (-4.70 to -3.14)	253	-4.49 (-5.03 to -3.94)

APPENDIX 4C

Study	Year	Complications	Reoperations Required
Backus *et al.*[47]	2012	NR	NR
Becher *et al.*[48]	2010	0	4 revision surgeries for cartilage abnormalities
Becher *et al.*[49]	2005	5: 3. Anteroimpingement symptoms; 2. temporary hyposensitivity in deep peroneal nerve distribution	3 osteophyte removal surgeries
Chuckpaiwong *et al.*[50]	2008	11: 4. Post-operative stiffness; 3. superficial deep venous thrombosis; 2. Complex Regional Pain Syndrome; 1. chronic superficial peroneal neuritis; 1. deep infection	19: 17. Repeat debridement and microfracture; 2 manipulation under anesthetic.
Cuttica *et al.*[51]	2012	0	3 required repeat surgery: Repeat microfracture, synthetic ostheochondral plug removal with repeat microfracture, OATS procedure for cystic defect.
Doral *et a.l.*[52]	2012	0	0
Gobbi *et al.*[53]	2006	4: 2. post-operative stiffness; 2. Post-operative pain	3: 2. revision arthroscopic debridement; 1. revision arthroscopic chondroplasty and synovectomy
Guney *et al.*[54]	2013	NR	NR
Guo *et al.*[55]	2010	0	0

Jung *et al*.[56]	2011	1 superficial peroneal nerve neuralgia	NR
Kuni *et al*.[57]	2012	NR	NR
Lee, DH *et al*.[58]	2012	0	0
Lee, KB *et al*.[59]	2010	0	0
Lee, KB *et al*.[60]	2009	0	0
Li *et al*.[61]	2014	NR	NR
Park *et al*.[62]	2015	None	None
Sallakh *et al*.[63]	2012	1 Superficial wound infection	0
Saxena *et al*.[64]	2007	0	1 arthroscopic revision
van Bergen *et al*.[65]	2013	4 hypoesthesias	6: 5. arthroscopic debridement; 1. open debridement