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Review Article

Os Acromiale Operative Treatment: A Systematic Review

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Abstract

Importance: An os acromiale occurs when the distal acromion does not properly fuse to the spine of the scapula. There are 4 different types depending on what part of the ossification center does not fuse with the meso-acromial type being the most common. The majority of os acromiale are asymptomatic but when they become symptomatic and non-surgical treatment fails, surgical management is indicated. Surgical options include open excision, Open Reduction Internal Fixation (ORIF), arthroscopic subacromial decompression/acromioplasty, arthroscopic reduction and internal fixation, and arthroscopic excision. **Objective:** The purpose of our systematic review is to investigate and review relevant studies in which different surgical modalities were used to treat os acromiale and provide direction on surgical management. **Evidence Review:** A systematic search of the medical literature was carried out through using the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines and 29 publications were analyzed. Surgical techniques utilized included open reduction internal fixation, open excision, open acromioplasty, arthroscopic reduction internal fixation, arthroscopic acromioplasty and debridement, and arthroscopic excision. Clinical outcome measurements included PENN shoulder score, VAS pain score, Katz Index of Independence in ADL, patient satisfaction, Constant score, ASES, deltoid function/strength, return to sport/activity, physical exam, Simple shoulder score, SANE, QuickDash, UCLA shoulder score, isokinetic testing, and range of motion. **Findings/Results:** In total, 262 subjects (275 shoulders) from 29 studies were included, with an average age of 49 years (range, 16 - 76 years). There were 168 males and 90 females reported and the sex of 4 subjects was not reported. There was a mean follow-up time of 37 months (range, 5-124 months). The meso-acromiale type was most common (214 shoulders) (78%) reported followed by the pre-acromion (7 shoulders) (3%) and a meta-acromion (3 shoulders) (1%). There was no description in 51 shoulders (19%). One hundred fifty-four shoulders (56%) were treated with open reduction internal fixation, 17 (6%) shoulders were treated with arthroscopic reduction internal fixation, 19 (7%) shoulders were treated with open excision, 58 (21%) were treated with arthroscopic excision, 11 (4%) were treated with open acromioplasty, and 16 (6%) were treated with arthroscopic acromioplasty and debridement. **Conclusion:** The most common surgical technique employed was open reduction and internal fixation (56%) with screw fixation used in the majority of the cases (55%). Open reduction with screw fixation had less complications and better results than open reduction and internal fixation using Kirschner (K) wires. However, open reduction and internal fixation in general gave mixed results due to painful hardware, poor patient satisfaction and a high complication rate. Open excision of a large os acromiale (meso-type) has less favorable results and patient outcomes due to residual deltoid and weakness and residual pain. Arthroscopic techniques including arthroscopic reduction internal fixation, arthroscopic acromioplasty and arthroscopic excision appear to have better outcomes secondary to preserved deltoid function and installation of less invasive hardware. However, future comparative studies are needed. Rehabilitation after arthroscopic techniques is faster as patient's gain greater range of motion and have a higher satisfaction rate. Surgeons may prefer arthroscopic acromioplasty over arthroscopic excision due to possible muscle weakness, cosmetic deformity or technical difficulty but the results of both techniques are favorable. **Level of Evidence:** Systematic Review. Level IV Study.

Introduction

What is already known?

- Os acromiale is a frequently encountered pathology, and various forms of surgical treatment have been well-documented, but which treatment provides the most successful outcomes remains controversial
- Few studies have evaluated clinical outcomes in all forms of surgical management of os acromiale, and the recommended treatment is yet to be determined

What are the new findings?

- Open excision of large os acromiale (meso-type) appear to have less favorable patient outcomes due to deltoid weakness
- While ORIF of an os acromiale can lead to bony union, it frequently results in painful hardware necessitating removal and a higher complication rate
- Arthroscopic techniques appear to lead to better patient outcomes due to preserved deltoid function, installation of less invasive hardware, and faster rehabilitation times
- Success of subacromial decompression/acromioplasty may depend more on the quality and management of the rotator cuff and not disrupting the os acromiale fragment rather than the os acromiale fragment itself
- Arthroscopic excision, although technically difficult, may prove to a better option in the future with less complications, faster rehabilitation and a quicker return to normal function

Os acromiale occurs when part of the acromial apophysis does not properly fuse with the spine of the scapula in a skeletally mature individual [22]. Os acromiale subtypes are classified by the particular ossification center that fails to fuse and by the unfused segment that is found immediately anterior to the site of nonunion [1]. The four main ossification centers are the pre-acromion, the meso-acromion, the meta-acromion and the basi- acromion. The majority of os acromiale are meso-acromions which are formed by the failed fusion between the meta-acromial and meso-acromial ossification centers. Maturation of the apophysis typically occurs between the ages of 18 and 25 years although it can occur as early as ages 12 to 14 years of age [22,47,48]. Yammine, et al. in their systematic review reported an incidence of approximately 7% in large sample studies [49]. Despite its prevalence, it is not frequently diagnosed as a cause of shoulder pain [2].

Clinically, the os acromiale is often asymptomatic and is an incidental radiographic finding. It can become symptomatic after trauma disrupts the fibrous union and MRI may show inflammation at the site of nonunion [35]. Presenting symptoms can be secondary to pain and inflammation at the pseudarthrosis site from the mobile fragment impinging on the rotator cuff, deltoid contraction and elevation of the arm causing motion across the interface of the os acromiale [35], or from arthritic changes of the acromioclavicular joint due to hypermobility of the os. In acute cases, the os acromiale fragment may become painful after the patient has minor trauma or from repetitive overhead activities of the shoulder. In chronic cases, the persistent pain may be due to acromioclavicular (AC) joint arthropathy or from localized inflammation at the non-union site. A thorough clinical examination is needed to define the source of the pain.

The clinical diagnosis of a symptomatic os acromiale can often overlap with the diagnosis of subacromial impingement or acromioclavicular (AC) joint arthrosis. Symptoms of both a painful os acromiale and subacromial impingement include difficulty with overhead activities, sleeping on the affected side, rotator cuff weakness, decreased active forward elevation of the arm and positive impingement signs [36].

Non-surgical management of symptomatic os acromiale is usually recommended for a minimum of three to six months and includes rest, non-steroidal anti- inflammatory medications, physical therapy, and a possible corticosteroid injection (into the subacromial space or the os acromiale pseudoarthrosis site). Surgical treatment may be necessary for a symptomatic os acromiale that does not resolve with non-surgical management. A number of surgical techniques have been widely described such as open excision, Open Reduction and Internal Fixation (ORIF), arthroscopic subacromial decompression/acromioplasty, arthroscopic reduction and internal fixation, and arthroscopic excision [2]. The purpose of this systematic review is to review, investigate, and compare relevant studies regarding different surgical modalities for treatment of os acromiale and to give recommendations on surgical management.

Methods

A systematic search of the literature was carried out through June 2021 of three electronic databases (PubMed, MEDLINE, Cochrane Library) to identify relevant published studies. Terms used included “os acromiale”, “os acromial”, “os acromion”, “os” AND “acromiale”, “os” AND “acromial”, “os” AND “acromion”, in conjunction with “surgery”, “treatment”, “management”, “fixation”, “excision”, and “repair” through the Boolean term AND. This yielded 136 studies in Pubmed and MEDLINE and 1 study in Cochrane Library that were reviewed and discussed among the authors for inclusion and exclusion. Inclusion criteria were for full-text English-language publications that assessed outcomes of surgical treatment of symptomatic os acromiale. Exclusion criteria included review articles, basic science studies, articles not in English, studies of non-operative management of os acromiale, studies without description of clinical outcomes or follow-up, and studies of acromial fractures. Twenty-eight publications met all the inclusion criteria, and these articles and bibliographies were analyzed for other relevant studies, resulting in the addition of 1 study to bring the final count to 29 publications (Figure 1). The guidelines for this systematic review followed the PRISMA guidelines [3].

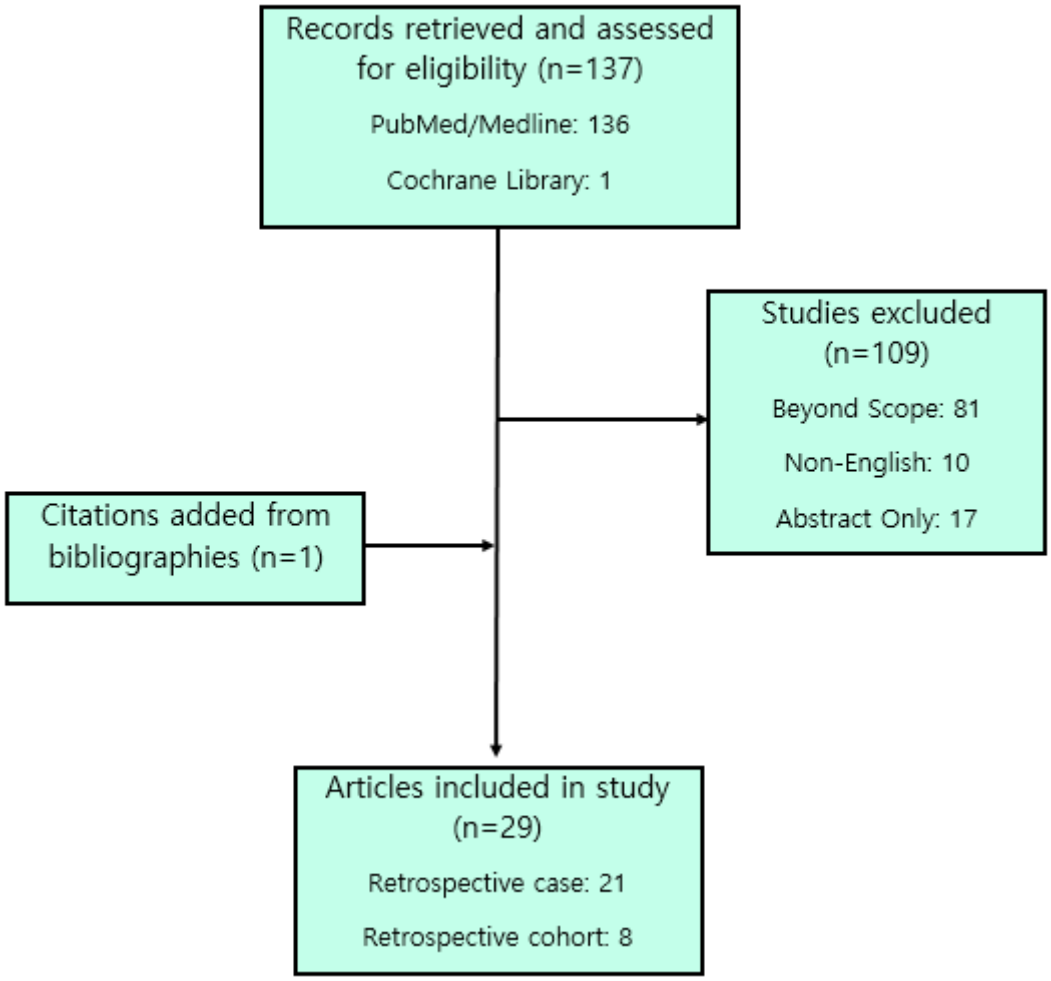

Figure 1: Systematic Review Flow Diagram.

A qualitative analysis of the studies was performed in order to integrate the study results. Information was collected on study design, number of subjects, surgical technique, mean age, mean duration of symptoms prior to surgery, os type, concurrent pathology, mean follow-up, radiological outcomes assessed, clinical outcomes assessed, and number of patients that required hardware removal, if any. All numbers recorded were rounded to the nearest whole number.

Classifications of os acromiale type were defined by the unfused segment immediately anterior to the site of nonunion (Figure 2). Failure of union between the pre- and meso-acromion was classified as pre-os acromiale, failure of union between the meso- and meta-acromion was classified as meso-os acromiale, and failure of union between meta- and basi-acromion was defined as meta-os acromiale [37]. All of the included studies described a surgical technique for addressing a painful os acromiale. Excision was defined as complete removal of the os acromiale fragment by either open anterior approach or an arthroscopic technique [7,18,22,29,31,38]. In comparison, acromioplasty was defined as partial or incomplete removal of the os acromiale fragment by an either open Neer technique or arthroscopic techniques [7,9,32,39,40]. Internal fixation was defined as internal placement of hardware with either Kirschner wires or screws stabilizing the os acromiale fragment to the more proximal acromion with or without the use of a tension band technique [1,7,9,14,16,22,24,25,41,42]. The clinical assessment tools used post-surgically included the American Shoulder and Elbow Surgeons score (ASES), the simple shoulder score, the Constant score, the Penn shoulder score, and the University of California Los Angeles shoulder evaluation form (UCLA) [9, 16, 1, 7, 18, 38, 24, 32, 41, 20, 25, 29]. Additionally, multiple studies used postoperative radiographs to determine union versus nonunion rates [9, 14, 16, 7, 38, 24, 41, 20, 25, 22]. Only a single study reported isokinetic strength testing as its postsurgical clinical assessment [31].

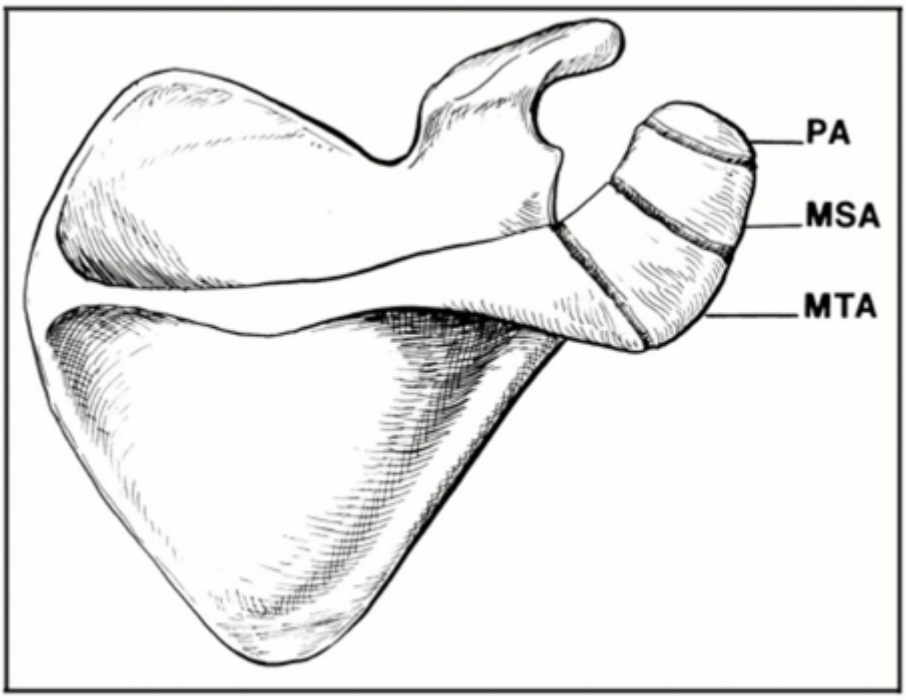

Figure 2: Visual representation of the 3 possible non-union sites of the acromion: pre-acromion (PA), meso-acromion (MSA), meta-acromion (MTA), and basi-acromion [5].

Results

The search strategy identified a total of 29 publications for review after exclusion criteria were employed. An oft-cited study performed by Armengol et al, in which 41 patients underwent one of five distinct surgeries for their os acromiale, was not included in this review because it was published exclusively in abstract form at the ASES Ninth Open Meeting and therefore, lacked the outcome data available in the other studies included in this systematic review [4]. Additionally, two studies by Neyton et al and Petri et al were not included because they were single case studies that examined patients who had undergone 3 prior surgical procedures on the shoulder in question and were deemed incomparable to the rest of the data [5,6].

262 patients (275 shoulders) with an average subject age of 49 years and a mean follow-up time of 37 months were reviewed (Table 1). Specifically, 168 males and 90 females were included, and the sex of four subjects was not formally stated. All studies included were retrospective case or cohort series. There were no randomized clinical trials reporting outcomes following the surgical management of os acromiale. The average cohort size was 9 individuals and ranged from 1 to 33 individuals (Boehm 2003). Only 9 studies had cohort sizes of 10 or more and 8 were case studies with one subject.

Os Acromiale Lit Search	Study Design	N	Surgical Technique	Mean Age	Mean pre-op duration of symptoms (months)	Os type (n)	Concurrent pathology (n)	Mean Follow-up (months)	Radiological Outcome Measures	**Clinical Outcome Measures**	**Number of pts w/ hardware removal**
Abboud 2006 JSES	Retrospective Cohort	8	ORIF	53	N/A	Meso (19)	Full- thickness RCT (8)	40	X-ray	PENN shoulder score, VAS Pain, ADLs, patient satisfaction	7
		6	Open acromioplasty								
		5	Arthroscopic acromioplasty								
Arenas-Miquelez 2020 JSES	Retrospective Case	4	ORIF with resection	19	16	Meso (4)	None	58	X-ray	Physical Exam, Oxford Shoulder Score, Simple Shoulder Test	1
Atinga 2020 JSES	Retrospective Cohort	31 (32 shoulders)	ORIF	50	14	Unspecified	RCT (25), Multiple tendon irreparable tear (1), Distal clavicle nonunion (1), Type III AC joint dislocation (1), Acromion fracture (1)	47	X-ray	N/A	4
Atoun 2012 JSES	Retrospective Case	8	ARIF w/ absorbable screws	54	18	Meso (8)	Full-thickness RCT (3), Partial thickness RCT (2)	22	X-ray	Constant Score, satisfaction score	0
Barbier 2013 Orthop Traumatol Surg Res	Retrospective Case	10	ORIF w/ tension band wiring/ pinning w/ embedded iliac crest graft w/o acromioplasty	43	15	Meso (10)	None	48	X-ray, CT	Constant Score	10
Boehm 2003 JBJS Br (The bone and joint journal)	Retrospective Cohort	6	Open excision	56	N/A	Meso (30), Pre (3)	Full-thickness RCT (32), Partial thickness RCT (1)	41	X-ray	Constant Score	21
		5	Open acromioplasty								
		22	Open fusion								

Campbell 2012 Orthopedics	Retrospective Case	28 (31 shoulders)	Arthroscopic excision	55	9	Meso (28), Pre (3)	Full-thickness RCT (16), Long-head biceps rupture (8)	41	N/A	ASES, Deltoid function/ strength	0
Daylin 2003 J Sports Sci Med	Retrospective Case	1 (2 shoulders)	Arthroscopic acromioplasty, debridement	19	4	Meso (2)	SLAP tear (1)	8	N/A	Return to sport and ADLs	0
Demtracopoulos 2006 Am J Sports Med	Retrospective Case	1	ORIF	16	24	N/A	None	25	X-ray	Return to sport and ADLs	0
Edelson 1993 JBJS Br (The bone and Joint J)	Retrospective Cohort	5	Open excision	N/A	N/A	N/A	RCT (5)	18 - 40	N/A	Physical exam, ROM	2
		2	ORIF								
Guo 2019 Annals of Translational Medicine	Retrospective Cohort	1	ORIF w/ polyester sutures	62	>6	Meso (10)	RCT (4), Frozen shoulder (3), Biceps tendonitis (1)	29	X-ray, CT	Constant score, VAS score	0
		9	ARIF w/ polyester sutures								
Harnett 2008 Int J Shoulder Surg	Retrospective Case	1	ORIF	45	60	Meso (1)	Long head biceps rupture (1)	6	X-ray	Simple Shoulder Score	1
Hertel 1998 JSES	Retrospective Case	12 (15 shoulders)	ORIF	54	N/A	Meso (15)	RCT (15), Long head biceps rupture (4)	44	X-ray	Constant Score	10
Hutchinson 1993 Arthroscopy	Retrospective Case	3	Arthroscopic subacromial decompression	24	13	Meso (3)	None	N/A	N/A	Physical exam	0
Johnston 2013 Orthop Clin North Am	Retrospective Case	6	Arthroscopic acromioplasty	53	N/A	Meso (6)	RCT (4)	25	X-ray	PENN shoulder score, PENN pain score, SANE, QuickDASH	0
Kawaguchi 2016 J Med Invest	Retrospective Case	1	Arthroscopic excision	73	8	Meso (1)	None	27	CT	UCLA shoulder score	0
Mudge 1984 JBJS	Retrospective Case	7	Open excision	56	N/A	N/A	RCT (9)	N/A	N/A	N/A	0

Ozbaydar 2006 AOTT	Retrospective Case	4	ORIF w/ cannulated screw	59	26	Meso (6)	RCT (6)	29	X-ray	UCLA shoulder score	2
		2	ORIF w/ K-wire								
Pagnani 2006 JSES	Retrospective Case	9 (11 shoulders)	Arthroscopic excision	18-25	2-14	Meso (11)	None	4	X-ray	Isokinetic testing, return to full athletic participation	0
Peckett 2004 JSES	Retrospective Cohort	17	ORIF w/ compression lag screws	54	N/A	Meso (26)	RCT (17), Biceps tendonitis (3)	≥12	X-ray	Pain relief, patient satisfaction	8
		5	ORIF w/ K-wire								
		4	ORIF w/ K-wire and compression lag screw								
Sahaipal 2007 Bull NYU Hosp Jt Dis	Retrospective Case	1	ORIF 1 year post arthroscopic rotator cuff repair w/ subacromial decompression	53	N/A	Meso (1)	RCT (1)	6	X-ray	Tenderness, range of motion, impingment signs	0
Sassmannshausen 2003 Orthopedics	Retrospective Case	1	ORIF	15	9	Meso (1)	RCT (1)	N/A	X-ray	Physical exam, Return to activity	0
Satterlee 1999	Retrospective Case	6	ORIF w/ cannulated screw	48	N/A	Meso (6)	Full- thickness RCT (3)	55	X-ray	Physical exam, investigator- designed questionnaire similar to ASES	1
Sterling 1995 Med Sci Sports Exerc	Retrospective Case	1	ORIF	17	12-18	Meso (1)	None	36	X-ray, CT	Physical exam, Return to sport	0
Swain 1996 Med Sci Sports Exercise	Retrospective Case	1	Arthroscopic excision	45	2	N/A	RCT (1)	N/A	N/A	Return to golf	0

Warner 1998 JBJS	Retrospective Cohort	1	Open excision	57	N/A	Pre (1), Meso (11), Meta (3)	RCT (8)	34	X-ray	Physical exam	10 (11 shoulders)
		4 (5 shoulders)	ORIF w/ tension-band pins and wiring								
		7	ORIF w/ cannulated screws								
		2	Failed ORIF, open excision								
Wright 2000 Arthroscopy	Retrospective Case	12 (13 shoulders)	Extended arthroscopic subacromial decompression	36	N/A	Meso (13)	Partial-thickness RCT (5), SLAP tear (2)	29	N/A	Physical exam, UCLA shoulder score, patient satisfaction	0
Belien J Exp Orthop	Retrospective Cohort w/ pre-bent Osteosynth plates	3	ORIF With pre-bent osteosynthesis plates	52	N/A	N/A	RCT(1), Partial Thickness RCT(1)	8	CT, X-rays	Constant murley and Disabilities of the Arm, Shoulder, Hand (DASH) scores	1
Stetson, McIntyre, & Mazza 2017 Arthroscopic Excision	Restrospective Case (Patient was 6 years s/p left shoulder arthroscopic SLAP repair, made full recovery)	1	Arthroscopic excision of meso-acromion	54	N/A	Meso (1)	Not mentioned, but patient did experience pain and weakness of the left shoulder and the inability to perform his regular duties at work	4	X-rays	Return to full activities, range of motion normalizes	N/A
	Retrospective Case	Total N	ORIF (12 without red)	Total (weighted) Mean	Total (weighted) Mean	Meso	RCT	Total (weighted) Mean	X-ray		Total
	21	262	18	49	13	214	168	37	22		78
	Retrospective Cohort	Total Shoulders	Open excision			Pre	SLAP tear		MRI		
	8	275	4			7	3		0		
	AVERAGE N	9	**Open acromioplasty**			Meta	Biceps Tendonitis		CT scan		

	N of 1	10	2			3	4		5		
			ARIF			Unclassified	Long head biceps rupture				
			2			51	13				
			Arthroscopic acromioplasty, debridement								
			1								
			Arthroscopic excision								
			5								

Table 1: Systematic review of research articles used in this paper

The meso type of os acromiale was the most common type reported in the literature (95.3%). Meso-acromion was seen in 214 (78%) of shoulders, pre-acromion was seen in 7 (3%), and a meta-acromion was seen in 3 (1%) of shoulders, while 51 (19%) were unclassified. In studies that recorded data on how long patients experienced symptoms prior to surgery, the average time before surgery was approximately 13 months (range, 4-120 months) and patients were on average 49 years old (range, 16 - 76 years) at the time of surgery. Patients were assessed at an average follow-up of 37 months (range, 5-124 months).

Radiological outcomes were assessed using x-ray in 22 studies and CT scan in 5 studies, while 7 studies did not assess outcomes using any form of radiology. Clinical outcomes were assessed using a variety of methods, including patient satisfaction, physical exam, return to sport/activities of daily living, VAS pain, Simple Shoulder Score, ASES score, UCLA Shoulder Score, Constant Score, PENN Score and isokinetic testing. Surgical techniques utilized included open reduction internal fixation (18 studies), open excision (4 studies), open acromioplasty (2 studies), arthroscopic reduction internal fixation (2 study), arthroscopic acromioplasty and debridement (1 study), and arthroscopic excision (5 studies).

Open Excision

No studies directly compared the surgical outcomes of open excision of an os acromiale/meso-acromion to arthroscopic excision. There were 19 shoulders (7%) that underwent open excision, the vast majority of which were the meso-acromial type. On average, patients from this subgroup were 57 years old and they had a mean follow-up time of 38 months. The ratio of males to females was approximately 9 to 2. Boehm et al reported an average post-operative Constant score of 73 [7] and a significant improvement in Constant pain score from 3.3 to 13.4 (P=0.27) after 6 open excisions (3 pre-os acromiale and 3 meso-os acromiale) and had comparable results compared to their age and gender matched cohorts (82%) undergoing acromioplasty or internal fixation. With regard to range of motion values, Edelson et al. [8] reported on 5 patients that underwent open excision and concomitant rotator cuff repair. Four of the five patients were satisfied with their results and the one failure was a 70-year-old gentleman with an irreparable rotator cuff tear. Warner et al. [22] reported on three patients treated with open excision (1 pre-os acromiale and 2 meo-os acromiale), two of which had a failed open reduction and internal fixation of a meso-acromion with poor results because of residual weakness and pain. Mudge et al. [21] reported on 6 cases treated with open excision, four with good results and two with poor results due to residual deltoid weakness and dysfunction.

Open Reduction and Internal Fixation (ORIF)

One hundred fifty-four (56%) shoulders had open reduction and internal fixation (ORIF) with an average age of 38 years. The mean follow-up time was 34 months. The male to female ratio for these cases was on average about 2 to 1. The technique of open reduction and internal fixation (ORIF) was performed with either Kirschner (K-wires), metal or absorbable screws. Reviewing the data, internal fixation with metal screws had a higher rate of radiographic union (98%) when compared to Kirschner wires (72%). The overall radiographic union rate for both techniques was 86% (125 shoulders) with a non-union rate of 14% (20 shoulders) (Table 2). When comparing the K-wire technique which included the use of a tension band wire or non-absorbable sutures, the radiographic union rate was 72% (47 shoulders) and the non-union rate was 28% (18 shoulders). The screw technique had a higher rate of radiographic union of 98% (78 shoulders) with only a 2% (2 shoulders) non-union rate. Overall, 78 shoulders (51%) required hardware removal with the vast majority of those using the K-wire technique requiring hardware removal (59 patients,

76%) compared to only (19 patients, 24%) with screw fixation.

Overall: Internal Fixation	N (%)
Radiographic Union	125 (86%)
Radiographic Non-Union	20 (14%)
Total	145 (plus 7 unreported)
Screw Technique	
Radiographic Union	78 (98%)
Radiographic Non-Union	2 (2%)
Total	80 (plus 3 unreported)
K-Wire Technique	
Radiographic Union	47 (72%)
Radiographic Non-Union	18 (28%)
Total	65

Table 2: Radiographic Union vs. Non-Union.

Warner et al. [22] performed internal fixation of an os acromiale (meso-type) in 12 patients using a K-wire technique with tension band wiring in 5 patients and 7 patients with screw and tension band wiring technique. Those in the screw with tension band internal fixation group had better rates of radiographic union (86%) when compared to those in the K-wire with tension band group (20%). Overall, patients that achieved radiographic union as a whole had better outcomes (85%) compared to those with radiographic non-union (15%). Two patients who had undergone ORIF of a meso-acromion had failure of fixation and required a secondary salvage procedure of open excision of the fragment.

Aboud et al. [9] reported a 100% union rate in 8 patients who underwent open reduction and internal fixation of a meso-acromiale, five with K-wires with tension band internal fixation and 3 patients with screws without tension band fixation. Despite the 100% union rate, only 3 of 8 patients had satisfactory results defined as minimal or no pain, active forward elevation greater than 120 degrees, functional capacity of at least 50% of the contralateral unaffected shoulder, and outcomes graded as good or excellent [46].

Hertel et al. [24] performed K-wire with tension band wiring in 15 meso-acromiale patients with either a deltoid stripping (devascularized) or a transacromial (vascularized) technique. Patients in the devascularized group had radiographic union in only 43% of cases whereas patients in the vascularized group had a radiographic union of almost 88%. Those patients with radiographic union had significantly higher Constant scores than those who did not (P=0.0.17) [46].

Boehm et al. [7] reported on 22 cases treated with open reduction and K-wire internal tension band fixation with a 68% union rate with no difference in the Constant score between those with radiographic union and those that did not. In that same study there were also no differences in outcomes when comparing internal fixation versus open excision or open acromioplasty [46].

Barbier et al. [1] reported significant improvements in Constant scores from 53 to 82 with a 100% union rate in 10 patients treated with internal fixation with K-wire and tension band wiring and a 100% satisfaction rate.

Ozbaydar et al. [41] reported on 6 cases who underwent internal fixation, four with screw fixation with wire tension band internal fixation and two with K-wire with wire or non-absorbable suture tension band fixation. The two with K-wire fixation failed to heal (0% union rate) while the four patients with screw fixation did heal (100% union rate).

Five other studies reported on open reduction and internal fixation with a screw technique [25,42,16,38,14]. Saterlee [25] reported on 6 patients treated with metal screws and non-absorbable suture tension band technique of a meso-acromiale with improvements in ASES scores and excellent results with all achieving radiographic union. Ryu et al. [42] reported on 4 patients with a meso-acromion treated with metal screws only without tension band wiring. All patients demonstrated full motion and normal strength with maximum UCLA shoulder scores of 35. Atoun et al. [16] treated 8 meso-acromiale patients with absorbable screws without tension band wiring with a marked improvement in Constant scores from 49 to 81 and 88% (6 patients) with complete radiographic unions and one partial union. Garcia et al. [38] reported a 100% union rate following screw fixation without tension band fixation of 12 os acromiale patients with an improvement in UCLA scores from 21.5 to 28.9. Atinga et al. [14] reported similar results following screw fixations with wire tension band fixation with 100% union rate of 32 patients with an os acromiale.

Open Acromioplasty

Two studies retrospectively reviewed the results of 11 (4%) patients who underwent open acromioplasty. The average age for these patients was 54 years, and they had a mean follow-up time of 22 months. Six of the patients included in the review were male, but the remaining five patients' sex was not documented. Boehm, et al [7] retrospectively reviewed patients undergoing open acromioplasty, internal fixation, and open excision. In the 5 cases of open acromioplasty of a meso-acromiale, he noted that patients reported an average Constant score of 72 following surgery and an 80% patient satisfaction rate. All patients in their study had comparable results and overall constant score of 72. Abboud et al. reported on 6 patients who underwent an open (Neer) acromioplasty with 4 of 6 patients reporting a satisfactory result. The authors did not differentiate between arthroscopic and open acromioplasty when they reported on improvements in pain, functional capacity or forward flexion. The authors combined the results of open acromioplasty (6 patients) with arthroscopic subacromial decompression/acromioplasty (5 patients) and reported a subjective patient satisfaction rate of 63.6% with improvements in pain (P=0.0001), functional capacity (P=0.001) and forward flexion (P=0.04) [9]. All patients (3) with worker's compensation claims had unsatisfactory outcomes in this subgroup

of 11 patients.

Arthroscopic Subacromial Decompression/Acromioplasty

27 patients underwent an arthroscopic subacromial decompression/acromioplasty. These patients were on average 37 years old and had a mean follow-up of 20.6 months. The ratio of males to females was 2 to 1. Abboud et al. [9] reported on 5 patients who underwent an arthroscopic subacromial decompression/acromioplasty in their overall study of nineteen consecutive patients treated for a symptomatic meso-acromiale. Three of five patients (60%) reported a satisfactory result. Hutchinson et al. [15] reported on three patients who underwent an asrthroscopic subacromial decompression of either the entire os acromiale or simply of the impinging spur, all three subjects reported initial good results. However, after one year all three subjects reported continued pain with overhead movement following surgery and continued to present with impingement signs upon follow up. Johnston et al. [32] performed arthroscopic acromioplasty with partial resection in 6 meso-acromiales with improvements in PENN shoulder scores from 50.6 to 78.5 and forward flexion from 143 degrees to 163 degrees and a decrease in pain from 5.6 to 1.3. Although all parameters showed improvement, the only statistically significant improvement was the PENN pain score (P=0.027).

Wright et al. [21] reported on 13 patients, all with meso-acromiales treated with an extended arthroscopic subacromial decompression and partial excision of the anterior acromial tip and found no decrease in anterior deltoid strength and no occurrence of deltoid detachment [29]. None of these patients had preoperative symptoms or signs localized to the os acromiale pseudo-arthrosis site. Good or excellent results were reported in eleven of the thirteen cases with an average UCLA shoulder rating scale of 31 and an 85% patient satisfaction rate.

Arthroscopic Reduction and Internal Fixation

A total of 17 (6%) patients underwent arthroscopic reduction and internal fixation, with an average age of 58 years and mean follow-up of 26 months. The ratio of males to females was 1 to 5. Atoun et al. [16] reported on 8 patients treated with arthroscopic assisted internal fixation with 4.5 mm absorbable screws. The Constant score improved from 49 points pre-operatively to 81 post-operatively and the average satisfaction score improved from 4.5/10 pre-operatively to 8.5/10 post-operatively. Full radiographic union was noted in 6 patients with partial union in one patient and a non-union in one patient. Guo et al. [17] reported on 9 patients with an average post-operative Constant score of 75.6 and an average VAS score of 1.6 after surgery with all patients achieving bony union of the os acromiale.

Arthroscopic Excision

Pagnani et al. [31] and Campbell et al. [18] treated a total of 42 patients with arthroscopic excision. Pagnani et al. [31] used arthroscopic excision of 11 meso-acromiales and all patients were able to return to sports by 14 weeks after surgery with no strength deficits in abduction, external rotation, and internal rotation with isokinetic testing compared to the contralateral side. Campbell et al. [18] reported on 31 patients treated with arthroscopic excision, 28 with a meso-acromion and 3 with pre-acromiales. A rotator cuff tear was identified in sixteen (52%) of the thirty-one shoulders. Arthroscopic repair was performed in nine shoulders and a mini-open repair (lateral deltoid splitting) was performed in seven shoulders. Only two patients complained of increased pain post-operatively with an 89% patient satisfaction rate. The two patients who complained of increased pain post-operatively had evidence of glenohumeral arthritis at the time of arthroscopic surgery. These patients also demonstrated a significant improvement ($p<0.05$) in ASES scores from 33.71 to 80.33 post-operatively with no considerable difference in deltoid strength when compared to the contralateral side.

Discussion

An os acromiale is a failure of fusion of the acromial apophysis in a skeletally mature individual [22]. Edelson in an examination of 270 scapular bone specimens found the incidence to be 8.2% [8]. The meso-acromial type is by far the most common type in our systematic review. An os acromiale is often an incidental finding on x-ray and is often asymptomatic. It can become symptomatic after trauma disrupting the fibrous union and MRI may show inflammation at the site of non-union [35]. It can also become symptomatic due to inflammation at the pseudoarthrosis site, the mobile fragment impinging on the rotator cuff, or arthritic changes of the acromioclavicular joint due to hypermobility of the os fragment [16].

The diagnosis of a meso-acromion is often made incidentally on the axial view of the plain radiographs when evaluating for another shoulder condition [33]. Lee et al [43] described the double density sign on a supraspinatus outlet view that was highly suggestive of an os acromiale. MRI in particular may show sclerotic or inflammatory changes at the site that may be indicative of degeneration in a symptomatic meso-acromion. Differentiating a meso-acromion from a normally developing acromial ossification center may be difficult because acromial fusion may not be complete until age 18 to 25 years. On MRI, a meso-acromion can be diagnosed by transverse orientation irregular margins with marrow and interface edema, whereas in a normally developing acromial ossifications center, the developing acromion has an arched interface and lobulated margins with no evidence of marrow or interface edema [44].

In cases of an os acromiale or meso-acromion that becomes symptomatic, patients often present with a mobile fragment that results in pain and tenderness at the non-union site and positive impingement signs. There have also been reports of rotator cuff pathology ranging from tendinitis to full thickness tearing associated with an os acromiale [32]. The diagnosis can be confirmed by a selective injection of 5 ml of 1% lidocaine into the site with re-examination 10 minutes later. This diagnostic tool is useful to determine if the meso-acromiale is the source of pain [1].

The symptomatic os acromiale or meso-acromion can sometimes be overlooked as a source of shoulder pain especially in shoulders with other concomitant pathology such as subacromial impingement, partial or full thickness rotator cuff tears, and acromioclavicular osteoarthritis. Once the diagnosis has been made and patients have failed non-operative management, surgical intervention is the next treatment option for a symptomatic meso-acromion. However, the literature is unclear as to what is the best treatment option for surgical management of the symptomatic os acromiale. The purpose of our systematic review was to summarize the current surgical treatment options and compare both radiographic and clinical outcomes following surgical intervention.

Open Excision

Open fragment excision of the symptomatic os acromiale has exhibited mixed results in the literature due to residual deltoid weakness and dysfunction post-operatively. Mudge et al reported on six patients with an os acromiale who underwent open fragment excision [21]. Of note, all of these patients also had associated rotator cuff tears that were repaired with an open technique. Four patients had excellent results, but two patients had poor results that may have been attributed to the severity of the rotator cuff tear or to the excision of the os acromiale. It is also unclear from the research performed by Mudge et al what type of os acromiale was present.

In 1993 Edelson et al reported on seven different cases of patients with symptomatic os acromiale. Five out of the seven patients also presented with rotator cuff tears, and these patients were treated with open excision of the acromion. All rotator cuff tears were repaired through a deltoid-splitting incision. The superior aspect of the distal clavicle was preserved to leave soft-tissue attachments for secure deltoid reconstruction. Post-operatively, these five patients were immobilized in a cast or a brace for 6 weeks [8]. At a follow-up of 18 to 40 months, all patients were satisfied with their results with 150 degrees of forward flexion in the scapular plane, internal rotation to the belt line, and external rotation averaged 45 degrees. No shoulder rating scores were reported.

Boehm et al reported on a total cohort of thirty-three patients with os acromiale and concurrent rotator cuff tears [7]. They used an anterior approach, releasing the deltoid in all thirty-three patients and reconstructing the rotator cuff before proceeding with treatment of the os acromiale. In six patients, the mobile fragment of the acromion was deemed too small or unsuitable for reattachment; all six patients subsequently underwent an excision of their os acromiale. Post-operatively, three patients rated their outcomes as excellent, and three patients rated their outcomes as good. The post-operative mean Constant score was 73.2.

The outcomes reported for open excision of an os acromiale by other authors are poor. Warner et al reported on three patients who underwent fragment excision [22]. Although one patient with a pre-acromion resulted in excellent improvement, the other two patients with meso-acromions which were openly excised exhibited unsatisfactory poor results defined with persistent weakness and pain. It is possible that the pain and weakness these patients had post-operatively was due to the loss of normal acromial fulcrum for function of the deltoid or from the detachment of the deltoid musculature to access the meso-acromion.

In reviewing the literature, the results of open excision are mixed. Most of the poor results are due to residual weakness and pain secondary to deltoid dysfunction. Open fragment excision has limited indications and is recommended only for a symptomatic pre-acromion with a relatively small fragment or as a salvage procedure after a failed ORIF.

Open Reduction and Internal Fixation (ORIF)

There are various studies regarding open reduction and internal fixation (ORIF) of symptomatic os acromiale that highlight different techniques including the use of tension-band wires, sutures, or cannulated screws with or without bone grafts. Internal fixation in general is technically difficult, can frequently lead to nonunion rates, and often requires hardware removal as a result of postoperative irritation.

In our retrospective review, ORIF had a high complication rate depending on the technique that is used. The use of K-wire fixations had only a 72% union rate with a 28% non-union rate. The use of screw fixation had a much higher rate of union at 98% with a only a 2% non-union rate. However, overall, 51% required hardware removal with 76% of those with K-wire fixation requiring removal compared to 24% with screw fixation requiring hardware removal.

The clinical results of ORIF have also been mixed. Abboud et al reported on nineteen patients with a meso-acromion, eight (42%) of which were treated with ORIF [9]. Even though all eight patients achieved union of the fragment, only three of these eight (38%) patients reported a satisfactory result.

Barbier et al performed a retrospective case study ten patients with extensive shoulder pain with an os acromiale meso type, which failed to diminish despite fifteen months of non-operative management [1]. All patients had pain at the superior aspect of the acromion, and in eight patients, the diagnosis of a symptomatic os acromiale was confirmed by a local injection of the os acromiale. The operative procedure was defined as reduction and fixation of the acromion by tension band wiring and pinning associated with an embedded iliac crest graft without acromioplasty. The hardware was removed at an average of 6.8 months after surgery in all patients. Following the surgery, the mean follow-up time was 48 months, and pain was overall relieved in seven cases. All patients reported that their symptoms had improved, with a mean postoperative Constant score improving from 53.4 to 82.2 (40-100). Postoperative CT scans of all patients revealed union of the os acromiale. However, strength was reduced in 6 patients by 20% compared to the contralateral side

In 2004, Peckett et al reviewed twenty-six patients with

symptomatic meso os acromiale that were treated with either K-wires or screws and a tension band [23]. If the bone stock was adequate, local bone graft was placed in the pseudarthrosis site (there was no documentation of the number of cases that utilized this method). The rate of union was 96% and twenty-four of twenty-six patients (92%) had adequate pain relief and were satisfied with their postoperative results. However, no objective or subjective shoulder scores were reported. Two patients sustained postoperative fractures, while eight patients had postoperative pain that was subsequently relieved by wire or screw removal. Seventeen patients also had a concomitant rotator cuff tear with 11 being repaired and with 6 being irreparable. The lack of objective and subjective measurements make this study difficult to interpret.

In 1998 Warner et al reported on eleven patients (twelve shoulders) who underwent ORIF with iliac crest bone grafting and compared two different fixation techniques [22]. Each technique incorporated debridement of the nonunion site with incorporation of iliac crest autograft spanning the debrided nonunion site. Five shoulders in four patients underwent ORIF with a tension-band procedure with pins and wires. Four of these five shoulders (80%) resulted in persistent nonunion. The other seven patients had an ORIF using cannulated screws and an eighteen-gauge wire passed through the screws in a figure eight fashion. Six of these seven procedures resulted in successful unions. Overall, 7 of 12 patients had union of the os acromiale. Nine of the twelve shoulders treated with ORIF required hardware removal. Two patients who failed ORIF had subsequent open excision of a grossly unstable meso-acromion, and they reported persistent pain and weakness following the procedure.

Hertel et al reported on fifteen shoulders in 1998 in twelve patients that underwent ORIF for unstable os acromiale fragments using tension band wiring and bone grafting [24]. Two surgical approaches were used. An anterior deltoid-off approach was used on seven shoulders, whereas the other eight shoulders were approached trans-acromially to preserve the deltoid origin. Union occurred in three of the seven cases approached anteriorly and in seven of the eight shoulders repaired without detachment of the deltoid. The investigators concluded that fusion was more successful when the vascularity of the acromial epiphysis was maintained, likely through the acromiale branch of the thoracoacromial artery. Clinically, the results were mixed with only two patients stating they had complete relief of their, two patients still complained of severe shoulder pain, five had moderate pain and 6 had minimal pain. The panderated Constant scores ranged from 23 to 105 with an average of 66. Even with fusion, not all patients did well with three patients still complaining of moderate pain with a solid fusion by x-ray.

In 1999 Satterlee et al treated six patients with an unstable meso- acromion type os acromiales with a new technique utilizing a dorsal wedge osteotomy of the non-union site. A 4.5 millimeter cannulated Herbert screw and a local dorsal bone graft obtained from the anterior acromion [25] was used. No complications such as malunion or pain from hardware were noted three to six years following each surgery and all 6 shoulders were rated as excellent according to the ASES shoulder rating scale. The authors emphasized that their success was due to preservation of soft-tissue attachment to the acromion, ultimately increasing the stability and blood supply to the acromion. The dorsal wedge osteotomy also enabled two parallel, bleeding, and compressible sites for union, and helped relieve impingement by allowing the anterior fragment to tilt upward.

Boehm et al reported on a total cohort of thirty-three patients with os acromion and concurrent rotator cuff tears [7]. Twenty-two out of the thirty-three patients underwent open surgery with an anterior deltoid release using a tension band technique with two parallel unthreaded Kirschner wires drilled from the anterior aspect of the acromion across the pseudarthrosis, emerging on the posterior aspect of the acromion and secured with a figure-of- eight cerclage wire. A partial acromioplasty was carried out if acromial osteophytes existed. The deltoid muscle was re-attached to the os acromiale with transosseous sutures. In all but one patient the metal was subsequently removed. Fifteen patients demonstrated radiological fusion of the os acromiale and seven patients had non-unions. One patient had deep infection following surgery, while two had superficial infections. Subjectively, seven patients rated the result as excellent, seven patients rated the result as good, one patient rated the result as moderate, and one patient rated the result as poor. The postoperative mean total Constant score was 73.8.

More recently in 2018 Atinga et al reported on thirty-two shoulders in thirty-one patients that underwent ORIF using two 4-millimeter cannulated screws [14]. Eighteen patients received a figure-8 wire tension band using two 22-gauge stainless steel wires and an iliac crest bone graft while 14 received a 1.3-mm tension cable and a local bone graft. 25 patients were additionally treated for rotator cuff repair, one patient underwent a latissimus dorsi transfer, one patient underwent a distal clavicle nonunion internally fixed, one patient underwent a reconstruction of a type III acromioclavicular joint dislocation, and one patient underwent an acromial fracture fixation. All 32 patients (100%) achieved radiological bone union at an average of 46.9 month follow-up. The authors concluded that the study showed that a local bone graft was as effective as iliac crest bone graft in achieving fusion. However, four patients (13%) did require removal of hardware. No subjective or objective clinical outcome measures were reported in the study but rather only the results of the radiographic findings demonstrating a 100% bone union.

In 2020 Arenas-Miquelez and Hertel reported on four athletes aged 17-21 with symptomatic meso os acromiale [13]. All four had 80% of the interacromial articulation resected with a burr, and the space was filled with autologous cancellous bone graft from the ipsilateral iliac crest. Internal fixation was performed by two 3.5 millimeter fully threaded cannulated screws in three of the patients. The fourth patient was considered stable with the bone graft. All four patients achieved radiologic union of the os acromiale and returned to full sport activities within seven to nine months. They reported an increase of mean Simple Shoulder Test score from 7 to 12 and an Oxford Shoulder Score from 29 to 48.

The techniques and approaches associated with the most successful types of ORIF include those with rigid internal fixation and preservation of the blood supply of the os acromiale or meso acromion fragment. However, even in cases of successful union, patients may still have hardware discomfort requiring hardware removal. Overall, 49% of patients required hardware removal in the ORIF group. The vast majority of those patients (80%) treated with Kirschner (K-wire) fixation required hardware removal. In those patients treated with screw fixation, only 9% required subsequent screw removal.

Open Acromioplasty

In 11 of the 214 patients included in the literature review, an open acromioplasty using the Neer method was used. Boehm et al reported on five patients with an os meso-acromiale who underwent an open acromioplasty [7]. Two of these patients had two tendon tears (supraspinatus and infraspinatus), while the other three had isolated tears of the supraspinatus. Two patients suffered from deep infections post-operatively and required additional surgery at six and ten days respectively. Following surgery, one excellent, two good and two satisfactory objective results were noted.

Abboud et al reported on 19 patients with a meso-acromion, six (32%) of which were treated with an open acromioplasty (9). Two patients reported excellent subjective outcomes, two patients reported good subjective outcomes, one patient reported a fair subjective outcome, and 1 patient reported a poor subjective outcome. Four out of these six patients reported satisfactory results.

Boehm et al reported on a total cohort of thirty-three patients with os acromion and concurrent rotator cuff tears treated with an open repair (7). Five out of the thirty-three patients were diagnosed with stable acromiale and thus underwent an open acromioplasty with transosseous reattachment of the deltoid. One patient rated the result as excellent, two patients rated the result as good, one patient rated the result as satisfactory, and one patient rated the result as fair. The postoperative mean Constant score was 72.

Open acromioplasty of a symptomatic os acromiale may lead to unfavorable results because of a lack of sufficient reduction in the dynamic impingement mechanism (46). Open acromioplasty runs the risk of destabilizing the os acromiale or meso-acromion. If open acromioplasty is performed, an attempt should be made to preserve the deltoid origin or to make sure it is properly repaired.

Arthroscopic Subacromial Decompression/ Acromioplasty

Arthroscopic subacromial decompression/acromioplasty is used primarily when impingement with or without a rotator cuff tear is present and when the nonunion site of the os acromiale is non-tender and considered to be incidental. As with other treatment options, the results are variable. Wright et al reported on thirteen patients following an arthroscopic acromioplasty of a meso-acromion and found no decrease in anterior deltoid strength and no occurrence of deltoid detachment (29). Good or excellent results were noted in 11 of 13 patients. None of these patients had preoperative symptoms or signs localized to the os acromiale pseudo-arthrosis site. Johnston et al (32) reported on 6 patients with an arthroscopic acromioplasty and partial resection of the meso-acromiale with significant improvements in the Penn pain score (5.6 to 1.3) and Penn shoulder scores (50.6 to 78.5)

Hutchinson et al reported on three cases of impingement syndrome with an associated os acromiale treated with arthroscopic subacromial decompression (15). Each patient reported either good or excellent results in the early postoperative period but the pain returned in all cases. Thus, these three cases required additional surgical intervention. Repeat arthroscopic debridement and excision of the fragment resulted in a good result in one patient. The os acromiale was not removed in the other two patients, and they reported residual pain with impingement-like symptoms and pain with overhead activities.

Wright et al. (21) reported on 13 patients, all with meso-acromiales treated with an extended arthroscopic subacromial decompression and partial excision of the anterior acromial tip. The goal was to create a flat acromion with a tip unable to impinge the rotator cuff with shoulder motion. This consisted of more bony resection than a regular acromioplasty. Overall UCLA shoulder score improvement from 17 pre-operatively to 31 post-operatively and an 85% patient satisfaction.

Arthroscopic subacromial decompression/acromioplasty can be used if the os acromiale or meso-acromion is stable. Careful attention should be made during the arthroscopic procedure not to destabilize the pseudo-arthrosis which can lead to instability and poor results requiring repeat surgery.

Arthroscopic Reduction and Internal Fixation

Less invasive forms of internal fixation using arthroscopic techniques can result in higher patient satisfaction due to the preservation of the deltoid and less potentially painful hardware. Atoun et al proposed an alternative arthroscopic technique that utilizes absorbable screws to fixate the os acromiale in symptomatic patients (16). Eight patients with an average age of fifty-four-years old received surgery. These screws were composed of biodegradable polymers that are metabolized by the body into carbon dioxide and water. All eight patients had positive shoulder impingement, three patients had full-thickness rotator cuff tears, and two patients had partial rotator cuff tears before their surgical procedures. The average postoperative follow-up time was twenty-two months, and during this time, the Constant score increased from 49 points to 81 points, and the average satisfaction score increased from 4.5 to 8.5 of 10. Full radiographic union was observed in six patients, partial union in one patient, and persistent radiologic nonunion in one patient.

Guo et al reported a novel arthroscopic technique utilizing polyester sutures to fixate the os acromiale (17). In the cohort of ten patients, nine were done arthroscopically and one was done with an open incision. A 12-month follow-up CT scan showed bony union of the os acromiale in all patients. The average Constant

score increased from 40.5 to 75.6 and the average VAS score decreased from 5.2 to 1.6.

Arthroscopic reduction and internal fixation can be technically demanding but the limited series in this review shows that it can be successful but larger studies are needed.

Arthroscopic Excision

Arthroscopic excision can be a better option with a larger os acromiale such as a meso- acromion. The arthroscopic technique minimizes deltoid disruption with preservation of the periosteum and deltoid fascia (46).

Campbell et al reported on twenty-eight patients with a total of thirty-one os acromiale (18). Three patients had a pre-acromion, and twenty-eight patients had a meso-acromion. All patients underwent surgery where arthroscopic excision of the pre-acromions and meso-acromions was done using a 4.5 millimeter flat acromionizer burr. They reported 89% good or excellent results with little difference in deltoid strength and subjective or objective change in the appearance or contour of the anterior deltoid.

Pagnani et al (31) reported on nine patients (eleven shoulders) treated with arthroscopic excision of the anterior acromial fragment. Using an arthroscopic technique, the acromial fragment was carefully shelled out, and the deltoid fascia insertion on the remaining acromion was preserved to prevent deltoid disruption. All patients were able to return to full athletic participation by fourteen weeks following their surgeries. No deltoid function was compromised by the procedure, and there was no evidence of deltoid weakness or cosmetic deformity post-operatively.

Johnston et al detailed a case study of six patients with symptomatic meso-acromions (32). The diagnoses of a meso-acromion, along with impingement and rotator cuff tears, were confirmed with radiographs and MRI scans. Four out of the six patients presented with rotator cuff tears. All patients underwent a diagnostic arthroscopy with an acromioplasty and partial resection of the os acromiale. None of the patients required additional surgery for treatment of the os acromiale, nor developed painful instability of the anterior os fragment or of the acromioclavicular joint.

Stetson et al detailed the precise technique for excising a symptomatic meso-acromiale (33). This involves arthroscopic excision with minimal or no disruption of the deltoid attachment, preserving the fascial insertion on the remainder of the acromion. Upon examination, patients presented with pain and tenderness at the site of nonunion, and they displayed positive impingement signs. All patients were diagnosed preoperatively on the axial view of radiographs, MRI, or computed tomography scan. MRI or bones scans were helpful in showing inflammatory changes at the symptomatic meso-acromion. Immediately before the surgery, the patients were examined while under anesthesia to note any crepitus related to the symptomatic meso-acromion. A diagnostic arthroscopy was performed in the glenohumeral joint to address any intra-articular pathology, including loose bodies, labral tears, or rotator cuff tears. An arthroscopic subacromial decompression followed in order to establish adequate visualization in conjunction with hypotensive anesthesia. The surgeon inserted a radiofrequency device to remove soft tissues around the acromion, making sure not to cut deltoid fibers. Arthroscopic excision was then performed with a 4.5-mm oval burr in a sweeping motion from posterior to anterior, ensuring complete removal of the meso-acromion. Post-operative radiographs were obtained to ensure fragment removal. All patients were placed in slings and immobilized for 2 weeks, and an aggressive physical therapy program was initiated. Full range of motion was achieved after 6 weeks, and full recovery was reached after 3-4 months postoperatively. No strength deficits were noted compared to the contralateral side.

Cooper et al (45) described a new arthroscopic technique coined the "wallow" procedure in which an arthroscopic shaver is used to resect the os site resulting in complete resection of the os acromiale pseudoarthrosis and avoiding the need for an open approach or the use of implants. Care is taken to preserve all soft tissue attachments around the perimeter of the anterior acromial fragment including the deltoid fascia.

The studies of Pagnani (2006) and Campbell (2012) are the only examples that focus on the arthroscopic excision of symptomatic meso-acromions. The surgical technique requires no special instrumentation and may be reproducibly performed by those familiar with arthroscopic techniques of the shoulder. The advantages include more rapid rehabilitation, better range of motion and shorter surgical times. There is also no need for a second surgery for symptomatic metal removal

In our review of the literature with our systematic review, no study directly compared open excision versus arthroscopic excision of a symptomatic os acromiale. The open technique involves detachment of the deltoid origin not only from the os acromiale or meso-acromiale fragment but also from the remainder of the acromion. The arthroscopic technique minimizes the disruption of the deltoid with preservation of the periosteum and fascia of the deltoid. Both of these arthroscopic techniques described appear to yield excellent results but larger prospective studies are needed.

Limitations

Some limitations to the systematic review remain due to the quality of the selected studies. Selection bias within each study, including the limited number of patients selected for each study, may limit the generalizability of this review. Additionally, all studies were retrospective cohort or case studies with no randomized clinical trials. Differences in technique and concurrent pathologies between studies also serve as potential sources of performance bias. Heterogeneity of clinical outcome measures of surgery success between the studies further limits the comparability of the selected studies. Further studies including control groups and with objective outcome measures should be done to better understand surgical management of os acromiale.

Conclusion

After reviewing the literature, open excision and ORIF of os acromiale appear to have less favorable results, as exhibited through higher incidences of poor patient satisfaction; this is likely attributed to deltoid weakness or painful hardware. The successes with ORIF emphasized the importance of preservation of soft-tissue attachment to the acromion, ultimately increasing the stability and blood supply to os acromiale fragment. Arthroscopic reduction and internal fixation allows for the installation of less invasive and painful hardware and preserves the deltoid attachments.

Arthroscopic techniques with modified or extended acromioplasties or complete resection of the os acromiale or meso acromion fragments appear to have better outcomes and may be superior for deltoid preservation. Quality of the rotator cuff tendons, as well as surgeon technique, likely played a large role in post- operative results.

The studies of Pagnani (2006) and Campbell (2012) are the only examples that focus on the arthroscopic excision of symptomatic meso-acromions. Even though both studies reported excellent results, most orthopaedic surgeons are reluctant to recommend or perform an arthroscopic excision for fear of resultant muscle weakness, cosmetic deformity and/or perhaps the technical difficulty of performing such a procedure (34). Further prospective, randomized, controlled studies are needed to compare arthroscopic excision versus open reduction and internal fixation versus arthroscopic fixation techniques.

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William B. Stetson was responsible for the conception and design of the study. All authors participated in the acquisition, analysis, and interpretation of data. All authors contributed to, edited, and approved the final version of the manuscript.

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