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General

Glenoid bone augmentation: a contemporary and comprehensive systematic review of open procedures

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Introduction

There is a trend towards arthroscopically treating shoulder instability with glenoid deficiency. Despite this, there remains the option for treatment through an open technique. Multiple bone augmentation options are available for recurrent anterior shoulder instability.

Objective

To provide a systematic review of recent studies for recurrent anterior shoulder instability necessitating glenoid bone augmentation specifically through open procedures using coracoid bone or free bone blocks [iliac crest bone autograft/allograft or distal tibia allograft (DTA)].

Methods

PubMed, Cochrane, EMBASE, and Google Scholar were searched for studies reporting open glenoid bone augmentation procedures with iliac crest, tibia, or coracoid bones within 10 years. Extracted data included study/patient characteristics, techniques, prior surgeries, prior dislocations, radiographic findings, range of motion (ROM), recurrent instability, patient-reported outcomes, and complications.

Results

92 met inclusion criteria (5693 total patients). Six were studies of iliac crest bone, four of DTA, and 84 using the coracoid bone. 29 studies measured postoperative arthritis showing no development or mild arthritis. 26 studies reported postoperative graft position. 62 studies reported ROM noting decline in internal/external rotation. 87 studies measured postoperative instability with low rates. Rowe Scores with noted improvement across 31/59 (52.5%) studies were seen. Common post operative complications included infection, hematoma, graft fracture, nerve injury, pain, and screw-related irritation.

Conclusion

Despite a trend towards arthroscopic management of recurrent anterior shoulder instability with glenoid deficiency, open procedures continue to provide satisfactory outcomes. Additionally, studies have demonstrated safe and efficacious use of free bone block graft options in the primary and revision setting.

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INTRODUCTION

Shoulder dislocation is the most common major joint dislocation.[1] Following an initial traumatic dislocation, anterior shoulder instability often persists, recurring in up to 60% of patients.[2] An associated glenoid rim fracture or attritional bone injury can increase instability, causing further bone loss.[3] Reconstruction or augmentation of the glenoid rim using bone grafting can be used to correct this loss and provide a static restraint for the shoulder.[4] This procedure can be done either arthroscopically or from an open surgical management prospective.

There are several options to augment the glenoid rim. The most common of these utilizes the coracoid as in the Latarjet procedure.[4] There are also free bone graft options which include iliac crest bone autograft and allograft as well as distal tibia allograft. These procedures are usually reserved for patients with significant glenoid bone loss (greater than 25-30% of the original bone mass).[4] Free graft options are also utilized in the revision setting.

Coracoid based procedures can be technically challenging, particularly when done arthroscopically,[5] and have had high complication rates including graft osteolysis and resorption.[6–9] Glenoid rim augmentation using DTA or iliac crest bone autograft/allograft may provide good alternatives if these procedures result in similar outcomes without additional complications.[10]

This systematic review summarizes studies reporting bone augmentation procedures for recurrent anterior shoulder instability specifically through open surgical management. The aim of the study was to critically evaluate the bone augment options performed solely through an open technique and to demonstrate efficacy of free bone graft options in both the primary and revision setting. This was ultimately achieved by evaluating radiographic outcomes, range of motion (ROM), recurrent instability, patient-reported outcome measures (PROMs), and complications among patients treated with open surgical management and bone augmentation using iliac crest autograft or allograft, DTA, or coracoid bone graft.

METHODS

SEARCH STRATEGY

A systematic review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[11] Given recent modifications in surgical approach and graft positioning, fixation, and origin,[12–15] this review was limited to more contemporary studies. An initial database search of articles published between January 1, 2010, and October 30, 2020, was conducted using PubMed, Cochrane, Google Scholar, and EMBASE on October 30, 2020. Search terms included: shoulder, glenoid augment, shoulder instability, glenoid deficiency, glenoid, glenohumeral, instability, joint instability/surgery, shoulder joint/surgery, surgery, reoperation, recur, re-dislocation, range of motion, Western Ontario Shoulder Instability Index, and WOSI. On March 21, 2021, a second PubMed search was conducted using the original search terms to identify studies published since the original search date. On the same day, an additional PubMed search using different search terms was performed to capture studies published since January 1, 2020; terms included were Latarjet, Bristow, bone graft, allograft, coracoid, dislocation, and Eden-Hybinette. A full list of search strings and term explanations can be found in **Supplementary Table 1.**

STUDY SCREENING AND SELECTION CRITERIA

First, titles and abstracts of the search results were reviewed for inclusion/exclusion. Full texts of identified articles were then reviewed and screened for inclusion/exclusion criteria. Reference lists of original and review articles were also screened for studies not identified by the original search.

The inclusion criteria were: 1) studies of patients who underwent an open primary bone augmentation procedure for anterior shoulder instability; 2) studies available in English published since January 1, 2010; 3) studies including ⩾10 cases; 4) studies with a minimum follow-up period of 24 months after surgery; 5) studies reporting at least one of the outcomes of interest (radiographic outcomes, ROM, recurrent instability, PROMs, complications). The exclusion criteria were: 1) cadaver studies; 2) review articles; 3) case studies with <10 patients; 4) editorials or letters to the editor; 5) technical notes; 6) non-English language articles; 7) studies with follow-up <24 months; 8) studies published before 2010; 9) studies of arthroscopic bone augmentation techniques; 10) studies of arthroplasty.

DATA EXTRACTION

In addition to basic article information (title, authors, year published), the following information was collected from each study: level of evidence, mean age, percent male, sample size, prior surgeries, prior dislocations, treatment type (Latarjet, Bristow, Bristow-Latarjet, modified Latarjet, ICBG, J-bone graft, etc.), bone used for augmentation, treatment notes (e.g., how the procedure was modified), follow-up time, radiographic outcomes (graft positioning, arthritis, etc.), ROM (external rotation [ER], internal rotation [IR], forward flexion/forward elevation, abduction), recurrent instability (e.g., redislocations, subluxations), PROMs (Rowe score [RS],[16] Western Ontario Shoulder Index,[17] Walch-Duplay score,[18] visual analog scale [VAS], Subjective Shoulder Value,[19] American Shoulder and Elbow Surgeons score,[20] Constant score,[21] satisfaction), complications (e.g., infection, hematoma), and study conclusions.

RESULTS

STUDY CHARACTERISTICS

A total of 5,896 studies were retrieved from database searches, with 41 studies identified by reviewing references. After removing 2,461 duplicates, 3,476 abstracts and titles were screened for exclusion criteria. Of these, 3,228 were excluded, yielding 248 articles for full text review. Based on

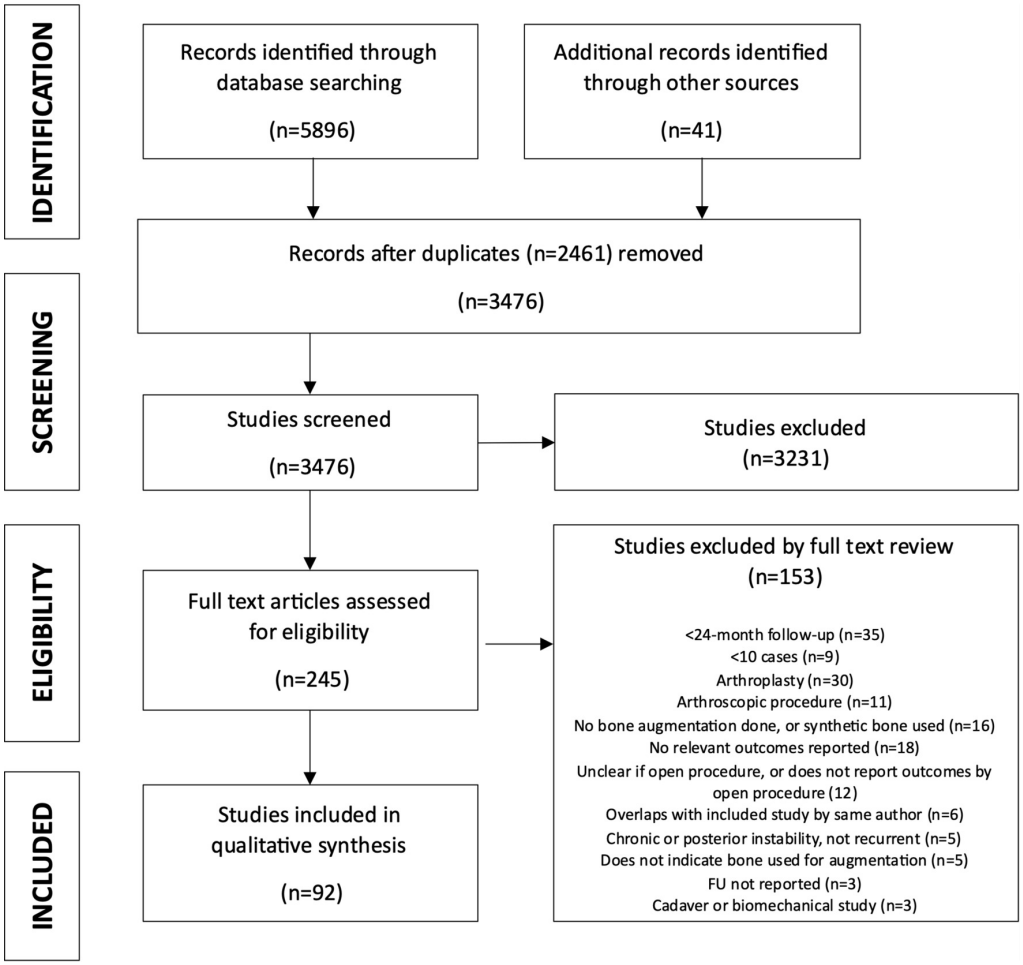

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram.

full text screening, 156 studies were excluded, yielding 92 studies for inclusion in the systematic review. A PRISMA flow diagram is shown in **Figure 1**.

The 92 included studies were of limited quality: 57 (62.0%) were case series with level IV evidence; 33 (35.9%) were cohort studies with level III evidence; one (1.1%) was a level II prospective cohort study[22]; and one (1.1%) was a level I prospective randomized study (**Supplementary Table 2**).[23]

The mean sample size of all included studies was 61.9 patients, with a pooled total of 5,899 cases of glenoid augmentation in 5,693 patients. Six studies (or arms of individual studies) reported the results of bone augmentation using an iliac crest bone (n=197); five were of iliac crest bone autograft[10,23–26] and one of cryopreserved allograft.[27] Four studies or study arms reported results of DTA (n=120),[28–31] including one study comparing DTA to the Latarjet procedure.[28] The remaining 84 studies or study arms used the coracoid bone for augmentation (n=5,376) (**Supplementary Table 2**).

Twenty-four studies focused on distinct patient populations, including patients with epilepsy (n= 83),[32–34] soldiers (n=20),[35] athletes (n=989), patients less than 17 years old (n=45),[36] and patients over the age of 40 (n=68).[37,38] Twenty-seven studies reported using the extent of glenoid bone loss as an inclusion or exclusion criteria for their patient population (**Supplementary Table 3**). An overview of all 92 studies is shown in **Table 1**.

DEMOGRAPHICS AND BASELINE CHARACTERISTICS

Excluding studies that specifically investigated age-related patient populations (e.g., pediatric or geriatric patients), mean age ranged from 19[49] to 35.8[72] years of age. Patient populations were majority male (range 52.0-100.0%) in all studies except two.[46,69] All studies had a mean follow-up of at least two years and ranged up to 35 years.[87] Forty-four studies reported the number of prior dislocations, which ranged from 2.2[51] to 40[93] dislocations. Three studies compared primary and revision surgery[86,100,101]; 30 studies or study arms included only patients having primary surgery; and seven only included those having revision surgery (**Supplementary Table 2**).[30,58,64,75,78,102,103]

RADIOGRAPHIC FINDINGS

Roughly a third of included studies (29/92, 32.5%) measured postoperative arthritis, and an additional eight studies measured postoperative arthropathy. A majority of these studies reported using the Samilson and Prieto classification system for glenohumeral arthritis.[104] In general, studies found that patients did not develop arthritis or de-

Table 1. Characteristics of included studies.

Primary Author (Year)	Treatment	N (shoulders)	Study Population	Primary Author (Year)	Treatment	N (shoulders)	Study Population
Moroder (2019)[39]	Iliac Crest Autograft	30	N/A	**Yang (2018)**[4]	Modified Latarjet	91	N/A
Ortmaier (2019)[40]	Iliac Crest J-bone Autograft	34	N/A			39	Revision patients
Abdelshahed (2018)[27]	Cryopreserved Tri-cortical Iliac Crest Allograft	10	N/A			33	>15% glenoid bone loss
Moroder (2018 AJSM)[17]	Iliac Crest J-bone Autograft	35	N/A			24	Collision/contact athletes
Steffen (2013)[41]	Iliac Crest Autograft	43	Age <35	**Cautiero (2017)**[42]	Modified Latarjet-Patte	26	Competitive contact sport
Auffarth (2011)[43]	Iliac Crest J-bone Autograft	47	N/A	**Elganainy (2017)**[6]	Latarjet	23	N/A
Robinson (2021)[20]	Distal Tibia Allograft	12	N/A	**Erşen (2017 OTSR)**[36]	Latarjet	11	Epilepsy
Provencher (2019)[30]	Distal Tibia Allograft	31	Prior failed Latarjet			54	No epilepsy
Frank (2018)[44]	Distal Tibia Allograft	50	Bone loss >25% or failed Latarjet	**Gough (2017)**[45]	Latarjet	50	N/A
Provencher (2017)[46]	Distal Tibia Allograft	27	N/A	**Kee (2017)**[7]	Latarjet	110	N/A
Belangero (2021)[47]	Latarjet	41	High-demand sports participation	**Kordasiewicz (2017)**[48]	Latarjet	48	N/A
Chillemi (2021)[49]	Latarjet	40	N/A	**Marion (2017)**[50]	Mini-open Latarjet	20	N/A
Marjanovic (2021)[51]	Latarjet	140	N/A	**Vadala (2017)**[52]	Latarjet	24	Amateur sports/ Age ≤50
Rai (2021)[53]	Latarjet	40	N/A	**Zhang (2017)**[33]	Bristow-Latarjet	44	Individualized coracoid osteotomy
Sinha (2021)[1]	Latarjet	49	N/A			34	Classic Bristow-Latarjet
Thon (2021)[25]	Latarjet	10	Seizure disorder	**Beranger (2016)**[54]	Bristow-Latarjet	47	Athletes <50 year
		44	No seizure disorder	**Blonna (2016)**[55]	Bristow-Latarjet	30	N/A

Primary Author (Year)	Treatment	N (shoulders)	Study Population	Primary Author (Year)	Treatment	N (shoulders)	Study Population
Ali (2020)[56]	Latarjet	15	N/A	**Chaudhary (2016)[13]**	Mini-open Latarjet	24	N/A
Cohen (2020)[57]	Latarjet	27	No or minor bone resorption	**Cho (2016)[58]**	Latarjet	35	N/A
		11	Major or total bone resorption	**Jamal (2016)[19]**	Latarjet	77	N/A
Di Giacomo (2020)[59]	Latarjet	358	N/A	**Khater (2016)[60]**	Latarjet	78	Patients w/ tramadol abuse
Domos (2020)[61]	Latarjet	45	Age <17 years	**Li (2016)[62]**	Latarjet	25	Patients w/ chronic locked anterior shoulder dislocation
Elamo (2020)[63]	Latarjet	15	Previous failed arthroscopic Bankart	**Ropars (2016)[64]**	Latarjet	77	N/A
Maman (2020)[65]	Latarjet	27	Age ≤40 years	**Venkatachalam (2016)[66]**	Sheffield Bone Block	75	N/A
Rossi (2020)[11]	Latarjet	66	Athletes/classic arc Latarjet	**Abelhady (2015)[67]**	Latarjet	14	Patients w/ ≥20 recurrences
		79	Athletes/ congruent arc Latarjet	**Arianjam (2015)[68]**	Free bone graft	34	High risk athletes
Werthel (2020)[3]	Latarjet	20	Primary surgery	**Balestro (2015)[69]**	Latarjet	12	N/A
		216	Revision surgery	**Dos Santos (2015)[35]**	Latarjet-Patte	38	N/A
Yapp (2020)[70]	Latarjet	145	Primary surgery	**Flinkkilä (2015)[71]**	Latarjet	49	N/A
		60	Revision surgery	**Gordins (2015)[32]**	Bristow-Latarjet	31	Patients w/ 33-35 years FU
De Carli (2019)[72]	Bristow-Latarjet	40	Athletes	**Ikemoto (2011)[73]**	Latarjet	26	N/A
Ernstbrunner (2019)[37]	Latarjet	39	Age ≥40 years	**Moon (2015)[74]**	Latarjet	44	N/A
Flinkkilä (2019)[75]	Latarjet	47	Primary surgery	**Ruci (2015)[76]**	Bristow-Latarjet	45	N/A
		52	Revision surgery	**Yang (2016)[30]**	Modified Latarjet	54	N/A
Minkus (2019)[77]	Latarjet	38	N/A	**Zimmermann (2016)[78]**	Modified Latarjet	93	N/A
Moroder (2019)[39]	Latarjet	30	N/A	**Tasaki (2015)[79]**	Bristow	40	Competitive rugby players

Primary Author (Year)	Treatment	N (shoulders)	Study Population	Primary Author (Year)	Treatment	N (shoulders)	Study Population
Xu (2019)[29]	Latarjet	52	Higher sports requirement	**Zhu (2015)[14]**	Latarjet	57	N/A
Bah (2018)[80]	Latarjet	43	N/A	**Bessière (2014)[81]**	Latarjet	93	N/A
Baverel (2018)[12]	Latarjet	57	Professional athletes aged 16-30	**Bouju (2014)[82]**	Modified Latarjet-Patte	70	N/A
	Latarjet	49	Recreational athletes aged 16-30	**Mizuno (2014)[83]**	Latarjet	68	≥18 years follow-up
de l'Escalopier (2018)[21]	Latarjet	20	Soldiers	**Atalar (2013)[68]**	Modified Latarjet	35	N/A
Erşen (2018 KSSTA)[84]	Latarjet	36	Subscapularis tenotomy	**Bessière (2013)[85]**	Latarjet	51	N/A
		37	Subscapularis split	**Di Giacomo (2013)[37]**	Modified Latarjet	26	N/A
Frank (2018)[44]	Latarjet	50	N/A	**Holzer (2013)[86]**	Latarjet-Patte	148	N/A
Jeon (2018)[87]	Latarjet	31	N/A	**Lädermann (2013)[88]**	Latarjet	117	≥10 years follow-up
Kawasaki (2018)[89]	Bristow	176	Rugby players	**Aydin (2012)[24]**	Modified Bristow	13	N/A
Kee (2018)[90]	Latarjet	27	Non-collision athletes	**Cerciello (2012)[91]**	Latarjet	28	Soccer players
		29	Collision athletes	**Neyton (2012)[92]**	Laterjet-Patte	37	Rugby players
Lateur (2018)[93]	Latarjet	32	N/A	**Paladini (2012)[94]**	Bristow-Latarjet	376	N/A
Moroder (2018 JSES)[17]	Latarjet or Bristow	29	Age >40 years	**Raiss (2012)[95]**	Latarjet	14	Patients with epilepsy
Privitera (2018)[96]	Latarjet	73	Contact and collision sports athletes	**Schmid (2012)[10]**	Latarjet	49	N/A
Ranalletta (2018 JARS)[97]	Modified Latarjet	65	Athletes	**Shah (2012)[23]**	Latarjet	48	N/A
Ranalletta (2018 AJSM)[97]	Modified Latarjet	49	Competitive rugby players	**Emami (2011)[98]**	Bristow-Latarjet	30	Non-athletes

Primary Author (Year)	Treatment	N (shoulders)	Study Population	Primary Author (Year)	Treatment	N (shoulders)	Study Population
Rossi (2018)[99]	Modified Latarjet	100	Competitive athletes/ Primary surgery	**Hovelius (2011)[28]**	Bristow-Latarjet	97	N/A

veloped only mild postoperative arthritis; however, 16 of the reporting studies found that a portion of patients developed moderate to severe arthritis or arthropathy, two of which were studies of iliac crest autograft[10,24] and 14 of Latarjet. Among DTA studies reporting arthritic changes, none reported any patients developing postoperative arthritis that was either moderate or severe; all were mild (**Supplementary Table 3**).

Twenty-six (26/92, 28.2%) studies reported findings related to postoperative graft position, including issues of medialized and lateralized positions. Four studies, two using iliac crest bone and two using coracoid bone, reported that 100% of operated shoulders showed complete union based on radiographic imaging.[24,26,43,101] Among studies reporting non-union, the highest rate was 31.3% (15/48) in a study of Latarjet[89] (**Supplementary Table 3**).

RANGE OF MOTION (ROM)

ROM was measured and reported in 62 studies (62/92, 67.4%). The 46 studies (46/92, 50.0%) reporting mean postoperative ER differed in how they measured this outcome, with some studies measuring ER with the arm at the side, others with the arm in 90 degrees, and the remaining studies with the arm position unspecified. Mean postoperative ER measurements were reported in 38 studies using the coracoid bone and ranged from 39.4[57] to 70.3[105] degrees with the arm at the side, 60.3[106] to 90[107] degrees with the arm in 90 degrees, and 32[108] to 85.9[70] degrees with the arm position unspecified. Among studies using iliac crest[10,23,25,27] and DTA[28–31] that evaluated this outcome, findings did not appear to differ meaningfully, with the exception of one DTA study of revision patients with previous failed Latarjet that found a mean postoperative ER with the arm at the side of 37.6 degrees.[30] Studies measuring changes in mean ER frequently found that patients frequently experienced a loss of ER postoperatively. Mean postoperative external rotation is summarized in **Table 2**. Additional details are shown in **Supplementary Table 3**.

Among 11 studies reporting mean postoperative changes in IR, all studies reported decreases except for a study of tramadol-induced seizures.[110] Results for forward flexion were more varied, with 10 studies reporting mean postoperative increases, and 13 reporting losses. Changes in mean abduction postoperatively ranged from a decrease of 32 degrees in a Latarjet study,[56] to an increase of 28 degrees in a DTA study.[30] **Supplementary Table 3** includes additional details on ROM.

RECURRENT INSTABILITY

Nearly all studies (87/92, 94.6%) reported whether patients experienced postoperative instability. Nine studies reported the rate of recurrent instability without specifically defining instability as redislocation.[40,46,50,64,69,76,90,100,106,111] Among the 69 studies that used the coracoid bone and specifically reported redislocations, the majority (47/69,75.3%) reported patients experiencing either a single redislocation or no redislocation. Noticeably higher rates of postoperative instability were reported in studies of at-risk patient populations; 42.9% (6/14) of patients with epilepsy,[33] 33.3% (3/9) of patients with seizure disorders,[34] and 48.0% (12/25) of patients with chronic locked anterior shoulder dislocations experienced postoperative instability.[46] Studies using the iliac crest bone also reported low rates of redislocation, with two of six studies reporting 0 redislocations and four of six reporting 1-2 postoperative redislocation.[10,23–27] Three of four DTA studies reported 0 postoperative redislocations with one study reporting 1 redislocation.[28–31] (**Supplementary Table 3**)

PATIENT-REPORTED OUTCOMES (PROMS)

Rowe Score (RS)[16] was the most frequently reported PROM (58/92 studies, 63.0%), with universal reporting of improvement in mean scores across the 31 studies (31/58, 53.4%) where changes were measured. The RS consists of a total of 100 points divided into three domains: (1) stability, which corresponds to a total 50 points; (2) mobility, which corresponds to 20 points; (3) function, which corresponds to 30 points.[112] Among the four iliac crest bone studies that reported RS, 100% of the studies reported a mean postoperative RS above 90, indicating excellent stability.[10,23–25] Mean postoperative RS among coracoid bones was more variable ranging as low as 67[97] among a group of patients with complications to as high as 98.3 among a group of patients with no complications.[97] Ten studies using the coracoid bone also reported a mean postoperative RS below 80. None of the DTA studies reported RS. Other less consistently reported scores included the Western Ontario Shoulder Index,[17] Subjective Shoulder Value,[19] Walch-Duplay Score,[18] American Shoulder and Elbow Surgeons score,[20] and the Constant score.[21] Patient-reported outcomes and RS are summarized in **Table 2**. Additional details are in **Supplementary Table 3**.

Eighteen studies (18/92, 19.6%) measured changes in preoperative to postoperative mean VAS, with declines ranging from 0[105] to 4.4.[43] Twenty-four studies (24/92, 26.1%) reported patients' level of satisfaction with surgery. Postoperative satisfaction was particularly high among iliac crest bone studies that measured this outcome with 100% satisfaction in all studies.[10,24,27] Satisfaction was more varied among coracoid bone studies, ranging from 72.7 to 100%.[12,87] No DTA studies measured levels of postoperative satisfaction (**Supplementary Table 3**).

SURGICAL COMPLICATIONS

Infection, hematoma, graft fracture, pain, nerve injury, and screw-related complications were the most commonly reported postoperative complications, with nerve-related and screw-related complications of special interest in this review. Three of the iliac crest bone autograft studies (3/5, 60.0%) reported sensory disturbances, hypoesthesia, or nerve palsy around the donor site at rates ranging from 10.6 to 26.7%[10,23,24]; no nerve-related injuries at the site of the bone augmentation were noted in any of the studies. One of the six iliac crest bone studies (1/6, 16.7%) reported screw fatigue fracture, though at a low rate (1/40 patients,

Table 2. Summary of Select Patient Reported Outcomes and Mean Postoperative External Rotation by Surgical Procedure

	Patient Reported Outcomes				Mean Postoperative External Rotation (degrees)					
	# studies reporting	Mean Postoperative Rowe Score (points out of 100)	# studies reporting	Satisfaction (% very/extremely satisfied or satisfied)	# studies reporting	Position unspecified	# studies reporting	Arm at side	# studies reporting	Arm at 90°
Iliac Crest Autograft/ Allograft	3	91[39]-94.3[43]	3	100[17,27,43]	1	63<[39]	3	57[40]-62.9[17]	2	75[27]-76.7[17]
Distal Tibia Allograft	0	N/A	0	N/A	1	49.5[20]	1	37.5[109]	1	81.5[44]
Coracoid Bone Graft	56	67[51]-98[51]*	21	72.7[69]-100[32]	15	32[76]-85.9[53]	20	39.4[49]-70.3[93]	13	60.3[4]-90[79]

* Among patients with no complications (Rowe Score: 67) and among patients with complications (Rowe Score 98)

2.5%).[26] No DTA studies reported nerve-related or screw-related complications, though it is unclear whether these were explicitly assessed. For coracoid procedures, screw-related complications were reported in over a third of studies or study arms (34/84, 4.5%) and included irritation,[64] malposition,[54] bending,[87] fracture,[34] general "irregularity,"[97] and loosening[37]; these complications occurred at low rates, but some were severe enough to require revision surgery.[23] Nerve-related injury at the site of bone augmentation was reported in 16 of the 84 coracoid bone studies (19.0%); pathologies included neuropraxia,[113] nerve palsy,[51] paresthesia,[96] and transient lesion on a nerve.[40] Complications are described in detail in **Supplementary Table 3**.

DISCUSSION

This systematic review found that in recent literature glenoid augment options performed through an open procedure continue to provide satisfactory outcomes in patients. In addition free bone graft options through an open surgical procedure provided safe and effective outcomes in both the primary and revision setting when treating recurrent anterior shoulder instability. Free bone graft augment included iliac crest autograft, cryopreserved iliac crest allograft, or DTA. Coracoid transfer through an open surgical procedure such as the open Laterjet also remains a viable option in the management of recurrent anterior shoulder instability with glenoid deficiency and is much more published in data. Subjective PROMs showed significant improvement, recurrent instability and surgical complication rates were low, and patients generally reported satisfaction with the results of their surgery. As more surgeons move towards arthroscopic management of anterior shoulder instability with glenoid deficiency, our results suggest that performing glenoid reconstruction through an entirely open technique continues to provide a reasonable and safe option. Furthermore free bone graft may be considered in both the primary and/or revision setting whereas an open coracoid transfer may have otherwise been previously considered.

While the bone augmentation procedures investigated here performed similarly well, differences were documented that may be informative when selecting treatment for individual patients. In the Latarjet procedure, the sling effect of the conjoint tendon crossing the subscapularis has a significant effect on the shoulder stability.[114] This added soft-tissue stabilizing effect is not present when free bone-block transfers are performed using the iliac crest or tibia.[94] While this may be an advantage in terms of stabilization, the procedure results in significant distortion of normal anatomy, which can be associated with a loss of ROM.[48,115] The current study confirms glenoid bone augmentation procedures frequently result in a loss of ER. This loss of ROM has been linked to a higher incidence and severity of osteoarthritis, though it is difficult to determine if the limitation of ER contributes to or is the result of glenohumeral arthritis.[39,91] Additionally, revision after prior coracoid transfer can be technically challenging.[116]

Iliac crest bone grafting may be advantageous over Latarjet in terms of arthropathy, though there are risks associated with the donor site when using autografts. A cadaveric model of glenoid bone loss showed that iliac crest bone grafting optimally restores glenohumeral contact pressure, which may reduce the risk of arthropathy.[79] A recent systematic review also found that iliac crest bone block techniques in contemporary practice are safe and effective in the short-term,[53] and a study with longer-term follow-up of 8 years found low redislocation rates and only moderate progression of arthropathy.[24] In a randomized, controlled, prospective study, Moroder et al. did not find significant differences in subjective outcomes between patients who underwent Latarjet compared to the J-shaped iliac crest bone graft, indicating they are comparable in terms of satisfaction.[23] Clinical and radiographic findings were also equivalent except for lower IR capacity in the Latarjet group.[23] A potential drawback of iliac crest bone autografting is donor site morbidity, which has been associated with gait disturbance during the initial post-surgery period, pain, risk of nerve injury or infection, and results in an additional scar.[23,117,118] The current study found that some studies of iliac crest bone autografting did report donor-site sensory disturbances, confirming that this is a risk.

The tibia allograft has the advantage of no donor site morbidity and has a similar radius of curvature to the native glenoid; additionally, it is a dense bone capable of bearing weight.[27,30,63] While several studies have demonstrated promising results using this technique, it is relatively new and reports in the literature remain relatively scarce.[2] In a matched cohort comparison of DTA with the Latarjet procedure, Frank et al. found no significant difference in outcomes or postoperative ROM, even though DTA patients had significantly greater preoperative bone loss.[28] In a 2021 meta-analysis that included both open and arthroscopic procedures, Gilat et al. found no significant differences between free bone block procedures using the iliac crest, tibia, or coracoid bone compared to the Latarjet in rates of recurrent instability, complications, osteoarthritis progression, or return to sports.[117] The findings from the current study suggest that when only studies using open procedures are included, all three bone graft sources continue to be associated with good clinical and subjective results. However, to determine more subtle differences in the outcomes of bone augmentation using different graft sources, well-designed multiple-arm studies are necessary and would allow appropriate direct comparisons between techniques.[117]

Notably, this review identified some potential limitations among bone augmentation study design and reporting. The extent of bone loss is an important factor when determining if a bone augmentation procedure is appropriate for anterior shoulder instability.[4,80] Nonetheless, relatively few studies in this review reported using the magnitude of bone loss as an inclusion or exclusion criteria. Two cadaver studies have indicated that there is a 'critical' bone defect ratio after which bone augmentation is necessary, and that it likely lies somewhere between 20 and 25%.[119,120] A 2019 computational study using finite element models found an

even lower threshold of 16% was the appropriate defect size to determine if bone augmentation was necessary.[121] Treatment choice is often based on training and tradition rather than available evidence,[62] which may leave high-risk patients vulnerable to recurrent instability, poor satisfaction, and additional procedures. The limited use of bone loss as a screening criterion for bone augmentation surgery may be an indication that patients are not adequately assessed for bone block procedures.

This review also found inadequate reporting of surgical complications and radiographic findings. Many studies failed to report graft position or to quantify postoperative arthritis or arthropathy. Lateral overhang of the coracoid graft is significantly associated with postoperative arthritis, and a medialized coracoid position is associated with recurrent instability,[60,78] so it is possible to anticipate these outcomes with appropriate imaging. Given the importance of graft placement on the risk of arthritis----one of the primary long-term risks of glenoid bone augmentation----this information should be reported universally in glenoid bone augmentation studies. Additionally, surgical complications including nerve damage and screw-related complications were reported inconsistently throughout the studies. Surgical complications play a large role in patient satisfaction and outcomes, particularly in patients that develop paresthesia or require revision surgery.

Patient dissatisfaction is often the primary complaint leading to surgery for anterior shoulder instability,[74] so it is critical to assess patient satisfaction and other subjective judgments following intervention. This review identified a great deal of variation in the tools used to measure and report subjective assessment; the most common was the RS, though even this was used by only a slight majority of studies. Studies also reported the VAS, Western Ontario Shoulder Index, American Shoulder and Elbow Surgeons score, Walch-Dupray score, and Constant score, among others. The lack of consistency in tools used to quantify subjective outcomes makes it difficult to assess and compare procedures, which becomes even more critical as technique improvements are introduced and evaluated.[74]

The development of arthroscopic glenoid bone augmentation procedures continues to gain popularity but require a significant investment of training new surgeons.[59] A recent study found that complications, screw placement inaccuracy, persistent apprehension, and recurrent instability rates were higher with arthroscopic compared to open Latarjet, and 10 procedures were needed to reduce the need for conversion from arthroscopic to open, while 20 procedures were needed to have similar operating times.[59] A 2019 meta-analysis comparing open and arthroscopic Latarjet found that the techniques had comparable outcomes, but concluded it may be advisable to perform the arthroscopic procedure only in high-volume centers with experienced arthroscopists.[88] The current study indicates that open techniques are associated with patient satisfaction, few complications, and good functional outcomes; therefore, this remains a reasonable treatment option for glenoid bone augmentation among surgeons preferring an open rather than arthroscopic surgical approach.

LIMITATIONS

The main limitation of this study is the low level of evidence of studies included in this review. There was also substantial variability in study design, surgical technique, subjective outcomes, and clinical outcomes reported, which makes direct comparison difficult. Additionally, only two studies[23,28] included in this review directly compared the outcomes of procedures using two different bones of interest. As technology and techniques continue to develop, it will be necessary to revisit and reevaluate the relative advantages, disadvantages, and recommendations for performing each procedure.

CONCLUSION

Bone augmentation procedures using free bone graft such as iliac crest autograft, cryopreserved iliac crest allograft, and DTA to treat recurrent anterior shoulder instability are reasonable and safe options for glenoid bone reconstruction in the primary and revision setting. Additionally continued utilization of open surgical management for bone augmentation procedures in the treatment of recurrent anterior shoulder instability provides safe and efficacious results.

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SUPPLEMENTARY MATERIALS

Supplementary Table 1. Search strings used for identifying relevant studies.

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Supplementary Table 2. Study and Sample Characteristics

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Supplementary Table 3. Study Outcomes and Conclusions

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Supplemental Table 4. Study Inclusion and Exclusion Criteria

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