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REVIEW ARTICLE

Arthroscopic Versus Open Bone Grafting and Internal Fixation of Scaphoid Nonunion—A Systematic Review

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Abstract

Background Scaphoid nonunion often requires surgical management involving the combination of a bone graft and internal fixation to restore the carpal alignment and length. While traditionally, the scaphoid waist nonunions have been treated with open bone grafts, with the advent of arthroscopy, bone graft reconstruction can now be carried out as an arthroscopic assisted minimally invasive procedure. We aimed to compare outcomes between open and arthroscopic bone grafting in the treatment of scaphoid nonunion.

Methods A review protocol was established according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement. PubMed/Medline, Cochrane, Embase, and Google Scholar were searched for articles on open and arthroscopic bone grafting for scaphoid nonunion with a minimum 12 month follow-up. The primary outcome was union rates in the two techniques. Secondary outcomes were changes in pain scores, complications, functional outcomes using different scoring systems, grip strength, range of motion at the wrist, and radiological parameters for restoring normal carpal alignment.

Results Forty studies reporting on 1534 wrists were included (1152 open, 382 arthroscopic). The union rate was 93.4% and 93.2% with open and arthroscopic techniques, respectively. The functional scores were comparable between the two techniques. All patients had a reduction in their pain scores. The radiological outcome parameters were not reported by any of the studies in the arthroscopic group.

Conclusion While bone grafting with both open and arthroscopic techniques for scaphoid nonunion showed comparable union rates and functional scores, further research is needed to assess the radiological outcomes of the arthroscopic technique.

Keywords Scaphoid non-union · Bone grafting · Open · Arthroscopic · Outcome · Systematic review

Introduction

Scaphoid nonunion often requires surgical management involving the combination of bone graft and internal fixation to restore carpal alignment and length [1]. Untreated scaphoid nonunion may progress to carpal instability and subsequent degenerative changes in the wrist [2]. Restoring normal carpal kinematics is paramount in preventing this progression [3].

Various techniques for graft reconstruction of scaphoid nonunion have been described. Traditionally, the scaphoid waist nonunions have been treated with nonvascularised bone grafts harvested from the iliac crest, distal radius, or the olecranon; vascularised bone grafts are preferred for proximal pole nonunion or after a failed procedure for the waist nonunion [4]. All these procedures were described as open techniques. However, with the advent of arthroscopy,

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bone graft reconstruction can now be carried out as an arthroscopic-assisted minimally invasive procedure [5]. As is the trend elsewhere in the body, there has been a shift in treatment approach from the conventional open technique to the arthroscopic assisted method, with the purported advantages of the latter being potentially less invasive and faster time to the bony union because of minimal trauma to the ligament structures, joint capsule, and the tenuous blood supply [6, 7]. Compromise of scaphoid vascularity, destabilisation of the ligament attachments, and postoperative stiffness are the reported disadvantages of open surgery [5]. While arthroscopic wrist surgery appears promising, it involves a steep learning curve, longer operative time, and the need for specialized training and equipment [8]. Secondly, the degree of carpal alignment restoration may be inadequate with arthroscopic bone grafting, although the clinical outcomes may be acceptable [9].

This systematic review aimed to find if arthroscopic bone grafting gives a better union rate and functional outcome than open bone grafting in the treatment of scaphoid nonunion.

Methods

The systematic review was registered with PROSPERO, International Prospective Register of Systematic Reviews (CRD42023399012) [10] and was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and recommendations [11]. We included all types of studies—randomised controlled trials, comparative observational studies, cohort, and case series of either arthroscopic and/ or open technique published in the English literature, not restricted to a specific date. We excluded cadaveric and biomechanical studies. The references of the included papers were also reviewed to ensure that no relevant studies were missed. Where a report of an earlier study existed, the most recent published paper was retrieved.

Types of Study Included

Inclusion Criteria

1. Studies in which adult patient cohorts suffered scaphoid nonunion.
2. Available in English literature
3. Randomised controlled trials, comparative observational studies, cohort, and case series of either arthroscopic and/ or open technique
4. Reporting data for union rate
5. Reporting patient-reported outcome
6. Follow-up of at least 12 months or longer

Exclusion Criteria

1. Non-English language literature
2. Conference presentations, methodology studies, reviews, case reports, and expert opinions

Intervention

All studies testing arthroscopic treatments for scaphoid nonunion with osseous fixation and bone grafting through an arthroscopic approach.

Comparator

All studies testing open treatments for scaphoid nonunion using osseous fixation and bone grafting.

Literature Search

We performed electronic searches using Medline, Cochrane Library Databases, Embase, and Google Scholar in August 2023. Medline search string was (((((((scaphoid nonunion[Title/Abstract]) AND (bone grafting[Title/Abstract])) AND (outcome[Title/Abstract])) NOT (vascularised[Title/Abstract])) NOT (cadaveric[Title/Abstract])) NOT (biomechanical study[Title/Abstract])) NOT (vascularized[Title/Abstract])) NOT (ring fixator[Title/Abstract])) NOT (skeletally immature[Title/Abstract]). Cochrane search strings were 'Population "Fracture Of Scaphoid Bone Of Wrist" AND "Nonunion Of Fracture" AND Intervention "Autogenous Bone Graft" AND Comparison ("Arthroscopic Procedure" OR "Open Surgical Procedure") AND Outcome "Clinical Outcome"'; and 'Population "Fracture Of Scaphoid Bone Of Wrist" AND "Nonunion Of Fracture" AND Outcome "Time To Bone Union" AND "Clinical Function" AND Intervention "Arthroscopic Procedure" OR Comparison "Open Surgical Procedure"'. EMBASE search string was (Scaphoid AND Nonunion OR Scaphoid nonunion) AND ((Arthroscopic) OR (Open) Bone grafting) AND (Outcome) OR (Result). Google Scholar search string was 'Arthroscopic|Arthroscopic Surgical Procedure|Surgery, Arthroscopic|open bone grafting|Grafting, Bone|Transplantation, Bone Scaphoid Nonunion|ununited fracture|fracture, ununited result|outcome'.

Study Selection

Titles and abstracts were screened for eligibility by two reviewers (JAS and PA) before proceeding to the full text: inconsistencies between reviewers were resolved by discussion based on full-text articles.

Data Extraction

All saved search records were downloaded into Rayyan (https://rayyan.ai/) [12] for cataloguing decisions on inclusion and exclusion and then transferred to a Microsoft Excel spreadsheet for data extraction, which included study details like article title, author(s), year of publication, journal, country of origin, study type, level of evidence, number of participants recruited and evaluated, study design, location of nonunion, characteristics of the intervention—arthroscopic or open, graft source, fixation method, time to follow-up, loss to follow-up, outcome, union rate, visual analogue score (VAS) for pain—preoperative and at follow-up, functional score—preoperative and at follow-up, any complications, grip strength—preoperative and at follow-up, pinch strength—preoperative and at follow-up, range of movement—preoperative and at follow-up, radiographic parameter, failure, disabilities of arm, shoulder and hand (DASH) score—preoperative and at follow-up.

Methodological Quality

All the included studies were assessed for quality and rigour against the methodological index for nonrandomised studies (MINORS) [13], and a global score was assigned to each. The MINORS score is a summation of individual item scores (zero to two for each item), with a maximum of 24 for comparative studies and 16 for noncomparative studies.

Data Analysis

Descriptive statistics were used to present quantitative data. Primary outcome measures were union rates in the two methods. Secondary outcome measures were changes in pain scores, complications, functional outcomes using different scoring systems, grip strength, range of motion at the wrist, and radiological parameters for restoring normal carpal alignment.

Results

Medline search returned 27 articles, Cochrane database returned 0 articles, EMBASE search returned 75 studies, and Google Scholar search returned 588 articles. The search results were imported into Rayyan, and the inclusion and exclusion criteria were applied. After applying the selection criteria and searching the included studies' references, 40 studies were shortlisted for the review (Fig. 1). All the included studies were published between 1991 and 2023.

Twenty-five studies reported the outcome of open bone grafting, 14 reported the outcome of arthroscopic bone grafting, and one was a comparative study of arthroscopic versus open bone grafting. One thousand one hundred fifty-two patients were treated with open bone grafting, while 382 were treated with arthroscopic bone grafting.

Quality Assessment

All studies included clear aims and outcomes, but the design was prospective in just around 15% of the studies. The MINORS scores can be seen in Table 1.

Clinical Effectiveness

The union rate was 93.4% (1076/1152) with the open bone grafting technique and 93.2% (352/382) with the arthroscopic bone grafting technique. Twelve studies in the open group reported preoperative functional scores, whereas 22 reported functional scores in the follow-up. Ten studies in the arthroscopic group reported preoperative functional scores, whereas 12 reported functional scores at follow-up. Fourteen studies in the open group reported preoperative grip strength, whereas 23 studies reported grip strength at follow-up. In the arthroscopic group, 10 studies reported preoperative grip strength and 12 studies reported grip strength at follow-up. Only three studies, all in the open group, reported on pinch strength. In the open group, 15 studies reported preoperative range of motion, whereas 23 reported range of motion at follow-up. In the arthroscopic group, 10 studies reported on the preoperative range of motion, whereas 13 studies reported the range of motion at follow-up. Among the open bone grafting studies, 9 studies reported preoperative functional results; modified Mayo wrist score (MMWS) was reported in 5 studies (average 46), and patient-rated wrist evaluation (PRWE) in 4 studies (average 47). Functional score at follow-up was reported in 21 studies; scaphoid outcome score in one (12 excellent, 13 good, 6 fair, and 5 poor), Cooney wrist score in 5 (good to excellent in most studies), MMWS in 10 (average 84), PRWE score in 4 (average 22). One study did not mention the scoring system used. Fourteen studies reported preoperative grip strength, and 10 reported grip strength in percentage, an average of 64% of the uninjured hand. Twenty-three studies reported grip strength at follow-up, an average of 89% of the uninjured hand. Five studies reported preoperative disabilities of the arm, shoulder, and hand (DASH) or QuickDASH score (average 47), and 10 studies reported DASH or QuickDASH at follow-up (average 17).

In the arthroscopic group, 9 studies reported preoperative MMWS (average 58). Among these, 2 studies also reported PRWE (average 36). 12 studies reported functional assessment at follow-up; MMWS in 11 studies (average 87), and four studies reported PRWE (average 7.1). Eleven studies in the open group reported preoperative

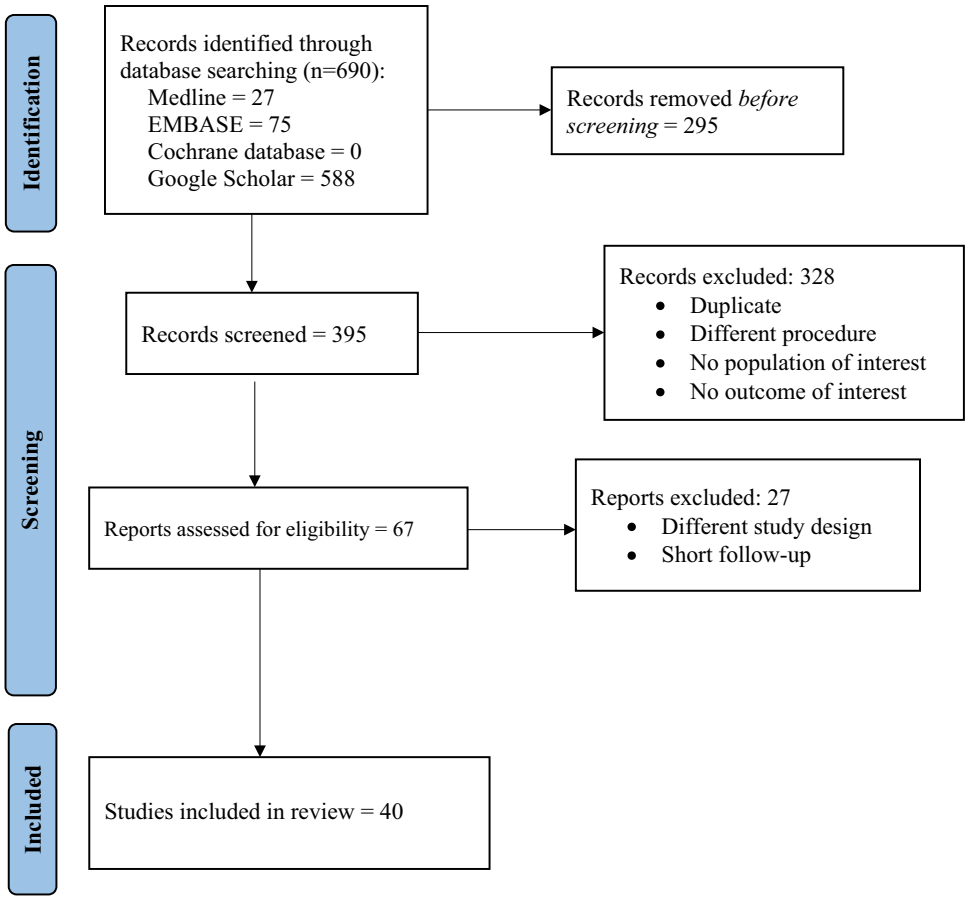

Fig. 1 PRISMA flow diagram

pain scores, whereas 18 studies reported pain during follow-up.

All studies reported a reduction in pain score except one, which reported severe pain in 2 patients at follow-up [20]. Twelve studies in the arthroscopic group reported preoperative and follow-up pain scores. All patients had a reduction in their pain scores. The pre- and post-operative functional scores, grip strength, VAS score for pain and range of motion for all the included studies are shown in Table 2.

Sixteen studies in the open group reported complications, including three at the donor site. In contrast, only one study reported complications, which were transient neuropraxia of the superficial radial nerve and pin irritation.

Twenty studies reported radiographic parameters in the open group, whereas none of the studies in the arthroscopic group reported on radiographic parameters (Table 3).

Only studies with a minimum of 12 months postoperative follow-up were included. In the open group, follow-up ranged from 12 to 384 months; three studies reported nine patients lost to follow-up, while two studies did not report on this. In the arthroscopic group, follow-up ranged from 12 to 120 months; two studies reported five patients who were lost to follow-up, while one did not report on this.

Bone graft was most frequently harvested from the iliac crest, followed by the distal radius in both techniques. Bone graft from the olecranon, with or without iliac crest, was used in one case series in each technique. A comparison of fixation techniques could not be performed owing to the wide variability in the implants used (Kirschner wires, screws, plates, and biodegradable implants) and their combinations.

Discussion

When comparing the studies reporting open bone grafting with those reporting arthroscopic bone grafting, we found no significant difference in the union rates and clinical outcomes. The open and arthroscopic bone grafting techniques for scaphoid nonunion resulted in high union rates and comparable functional results.

The studies included in this review were a heterogeneous group, with the majority being retrospective without any uniformity regarding the location of nonunion, choice of bone graft or implant. Comparison of outcomes based on the location of nonunion was not feasible due to the limited information reported in most of the included studies.

Table 1 Methodological items for non-randomized studies (MINORS) scores of the included studies

S. No.	Author	A clearly stated aim	Inclusion of consecutive patients	Prospective collection of data	Endpoints appropriate to the aim of the study	Unbiased assessment of the study endpoint	Follow-up period appropriate to the aim of the study	Loss to follow up less than 5%	Prospective calculation of the study size	An adequate control group	Contemporary groups	Baseline equivalence of groups	Adequate statistical analyses
1	Duyvenbode et al. [14]	1	0	0	2	2	2	0	0				
2	Nakamura et al. [15]	1	2	1	2	0	2	2	0				
3	Inoue et al. [16]	1	2	0	2	0	2	2	0				
4	Beris et al. [17]	1	1	0	2	0	2	2	0				
5	Chen et al. [18]	1	1	1	2	2	2	1	0				
6	Takami et al. [19]	1	1	0	2	1	2	2	0				
7	Eggli et al. [20]	1	1	1	2	2	2	2	0				
8	Akmaz et al. [21]	0	1	0	2	1	2	2	0				
9	Murase et al. [22]	2	2	2	2	1	2	2	0				
10	Finsen et al. [23]	1	0	0	2	0	2	2	0				
11	Huang et al. [24]	1	0	0	2	0	2	2	0				
12	Zoubos et al. [25]	1	2	0	2	1	2	2	0				
13	Watanabe [26]	2	2	0	2	0	2	2	0				
14	Reigstad et al. [27]	1	2	0	2	1	2	1	0				
15	Euler et al. [28]	1	2	0	2	1	2	2	0	2	2	2	1
16	Allon et al. [29]	2	1	1	2	0	2	2	0				
17	Mani and Acharya [30]	0	2	2	2	0	2	0	0				
18	Putnam et al. [31]	2	1	1	2	1	2	2	0				
19	Schormans et al. [32]	2	2	2	2	1	2	2	0				
20	Yeh et al. [33]	2	1	2	2	1	2	2	0				

Table 1 (continued)

S. No.	Author	A clearly stated aim	Inclusion of consecutive patients	Prospective collection of data	Endpoints appropriate to the aim of the study	Unbiased assessment of the study endpoint	Follow-up period appropriate to the aim of the study	Loss to follow up less than 5%	Prospective calculation of the study size	An adequate control group	Contemporary groups	Baseline equivalence of groups	Adequate statistical analyses
21	Hegazy et al. [34]	2	2	2	2	2	2	2	2	2	2	2	1
22	Cagnolati et al. [35]	2	2	2	2	2	2	2	0				
23	Welle et al. [36]	2	2	1	2	0	2	2	0				
24	Zhang et al. [1]	2	2	1	2	0	2	2	0				
25	Ma et al. [37]	2	2	1	2	0	2	2	0				
26	Oh et al. [3]	2	2	0	2	1	2	2	0	2	2	2	2
27	Kang et al. [38]	2	1	0	2	2	2	2	0	1	1	2	0
28	Lee et al. [39]	2	1	1	2	0	2	2	0				
29	Liu et al. [40]	1	2	1	2	0	2	2	0				
30	Wang et al. [41]	2	1	1	2	1	2	2	0				
31	Lamon et al. [5]	2	2	1	2	2	2	2	0				
32	Ecker et al. [42]	1	0	0	2	1	2	2	0	0	0	0	0
33	Lee and Jung [43]	2	1	2	2	2	2	2	0				
34	Waitayawinyu et al. [44]	2	0	2	2	2	2	2	0				
35	Waleed et al. [45]	2	1	2	2	0	2	2	0				
36	Wu et al. [46]	1	2	0	2	1	2	2	0				
37	Bezirgan et al. [47]	2	0	1	2	0	2	2	0				
38	Lin et al. [48]	2	1	0	2	1	2	2	0				
39	Shih et al. [49]	2	2	1	2	1	2	2	0				
40	Cheng et al. [50]	2	2	1	2	2	2	2	0				

Items are scored as 0 (not reported), 1 (reported but inadequate), or 2 (reported and adequate). The maximum score for non-comparative studies is 16, and for comparative studies is 24

Table 2 Pre-operative and post-operative functional scores, grip strength, VAS for pain and range of motion

S. No.	Article	MMWS		PRWE		Cooney wrist score		Other scores	Grip strength		DASH/QuickDASH		VAS		ROM/FE arc (% or deg)	
		Pre	Post	Pre	Post	Pre	Post	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	Duyvenbode et al. [14]	–	–	–	–	–	–	Good—Subjective 35, Objective 31, Radiographic 11	–	88%	–	–	–	–	–	74%
2	Nakamura et al. [15]	–	–	–	–	–	Excellent 14, good 15, fair 20, poor 1	–	78%	91%	–	–	–	–	76%	86%
3	Inoue et al. [16]	–	–	–	–	–	<6 wks immobilisation 89 >6 wks 83	–	–	–	–	–	–	–	–	–
4	Beris et al. [17]	–	–	–	–	–	–	–	–	–	–	–	–	Persistent pain 6	–	–
5	Chen et al. [18]	–	Excellent 18, Good 8	–	–	–	–	–	–	–	–	–	–	1/5 in 2	–	Some limitation in ROM in 3
6	Takami et al. [19]	–	–	–	–	–	–	–	85%	99%	–	–	All had pain	35 no pain, 8 slight pain after strenous use of the wrist	103	132
7	Eggli et al. [20]	–	Poor 3	–	–	–	–	–	–	88	–	–		Severe pain 2	–	107
8	Akmaz et al. [21]	20.8	80	–	–	–	–	–	19.1 kg	31.5 kg	–	–	7 pain at rest, 5 moderate pain with ADL	8 complete relief in pain	86.1	Improved by 57%
9	Murase et al. [22]	–	–	–	–	–	89	–	–	80 to 100% (av 90%) of contralateral	–	–	–	–	–	138
10	Finsen et al. [23]	–	–	–	–	–	–	Scaphoid Outcome score—excellent 12, good 13, fair 6, poor 5	–	52 kg (4% > contralateral)	–	–	–	3/100	–	120
11	Huang et al. [24]	–	–	–	–	–	Excellent 29, good 17, satisfactory 2, poor 1	–	–	96.3% of contralateral hand	–	–	–	5 mild pain	122.5	154.1
12	Zoubos et al. [25]	–	–	–	–	–	Excellent 74%, good 26%	–	48%	80%	–	–	–	–	–	120
13	Watanabe [26]	–	Excellent 23, good 13, fair 2	–	–	–	–	–	83%	100%	–	–	–	–	80%	93%
14	Reigstad et al. [27]	–	93	–	–	–	–	–	–	46 kg	–	9.1	–	7/100	–	186

Table 2 (continued)

S. No.	Article	MMWS		PRWE		Cooney wrist score		Other scores	Grip strength		DASH/ QuickDASH		VAS		ROM/FE arc (% or deg)	
		Pre	Post	Pre	Post	Pre	Post	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
15	Euler et al. [28]	–	–	Early 30, delayed 28	Early 14, delayed 52	–	–	–	Early 24; delayed 22	Early 42; delayed 16	48	30.5	6	1	Early 90; delayed 91	Early 104; delayed 64
16	Allon et al. [29]	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
17	Mani and Acharya [30]	58.6	84.4	–	–	–	–	–	20.6 kg	31.1. Kg	–	–	–	–	78.6	132.8
18	Putnam et al. [31]	50.7	74.4	–	–	–	–	–	77.50%	90.50%	27.3	11.8	6.7	2.1	70.3	101
19	Oh et al. [3] (Open)	56.2	84.9	–	–	–	–	–	68.50%	86.10%	–	83.9	51	6	97.5	103.2
20	Schormans et al. [32]	–	–	35	12	–	–	–	52%	79%	–	–	PRWHE pain score 26	PRWHE pain score 13	89	124
21	Yeh et al. [33]	42.5	84.4	–	–	–	–	–	51%	86%	32.8	12.4	–	–	56%	86%
22	Hegazy et al. [34]	–	–	–	–	–	–	–	49%	91%	70	25	64	4	61%	89%
23	Cagnolati et al. [35]	–	–	68	31	–	–			Not assessed	56	34	Pain at rest 3, at movement 8	Pain at rest 1.5, during movement 5.3	90	107
24	Welle et al. [36]	–	–	–	–	–	–	–		36.4 kg vs 42.4 kg healthy hand (85%)	–	10.1	6	2.2	–	–
25	Zhang et al. [1]	–	86.4	–	–	–	–	–		92.30%	–	19.3	–	1.6/10	–	92.30%
26	Ma et al. [37]	–	–	56	14	–	–	–	50%	83%	–		7	3	76	118
27	Kang et al. [38]	55.4	89.8	–	–	–	–	–	33	48.4	26.9	3.5	4.6	0.6	96.1	110
28	Lee et al. [39]	60.2	83.5	–	–	–	–	–	32.75 kg	37.75 kg	–	–	6.38	1.59	167	178
29	Oh et al. [3](Arthroscopic)	55	88.9	–	–	–	–	–	67%	81.40%	–	87.5	4.8	0.6	99.8	108
30	Liu et al. [40]	–	97	–	3	–	–	–	–	–	–	–	–	–	–	96%
31	Wang et al. [41]	–	–	–	–	–	–	–	9.6 kg	24.7 kg	52.4	21.4	4.6/10	2.1/10 during activity	116.8	139.1
32	Lamon et al. [5]	–	–	–	41	–	–	–	–	83%	–	29	1	8	–	125
33	Ecker et al. [42]	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
34	Lee and Jung [43]	58.3	80	–	–	–	–	–	79.40%	88.60%	–	–	5.7	1.3	80%	85%
35	Waitayawinyu et al. [44]	58.4	90.7	–	–	–	–	–	32.68 kg	46.41 kg	29.53	5.3	5	1.09	99.45	106.5
36	Waleed et al. [45]	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
37	Wu et al. [46]	75	95	18.5	5	–	–	–	37	44	18	0	3	0	82	95
38	Bezirgan et al. [47]	–	83.5	–	–	–	–	–	–	78% of contralateral			6.5/10	1.7/10	–	75%
39	Lin et al. [48]	53.9	81.3	–	–	–	–	–	50.60%	95.40%	48.7	9.6	4.7	1.7	111.9	130
40	Shih et al. [49]	50.2	88.5	–	–	–	–	–	56.80%	88.70%	32.3	5.9	5.3	1.2	103.5	106.4
41	Cheng et al. [50]	61.7	83.6	53.7	9.4	–	–	–	27 kg	42.86 kg	27.29	5.57	5.57	1.71	103.15	120.86

Pre preoperative, *Post* postoperative, *VAS* visual analog scale, *MMWS* modified Mayo wrist score, *PRWE* patient-reported wrist evaluation, *DASH* disability of arm, shoulder and hand, *ROM* range of motion, *FE* flexion–extension

Table 3 Radiographic parameters of studies reporting open bone grafting for scaphoid nonunion

S.No.	Study ID	Number of patients	LISA (degrees)		SLA (degrees)		RLA (degrees)		Remarks
			Preoperative	Follow-up	Preoperative	Follow-up	Preoperative	Follow-up	
1	Duyvenbode et al. [14]	77							Increased incidence of osteoarthritis of the RC, STT and other mid-carpal joints
2	Nakamura et al. [15]	50							Unsatisfactory DISI reduction in 6 patients
3	Inoue et al. [16]	160							Pre-existent OA, DISI, RLA, AVN of proximal fragment
4	Beris et al. [17]	28							Not assessed
5	Chen et al. [18]	26	55.4	41.2	62.7	52.7			
6	Takami et al. [19]	43			67	54	15	2	
7	Eggli et al. [20]	37				45			Mild or moderate degenerative changes in 30, restored CHI, ulnar translation, and scaphoid length—comparable, DISI corrected in all cases
8	Akmaz et al. [21]	12							Not assessed
9	Murase et al. [22]	7			69.4	49.1	6	2.8	
10	Finsen et al. [23]	39							8 arthrosis
11	Huang et al. [24]	49			61.1	56			
12	Zoubos et al. [25]	23							Mild OA at RS jt. at 2 .5 years postoperatively
13	Watanabe [26]	38	31	16	63	51	3	− 15	
14	Reigstad et al. [27]	50			63	47			CHR 1.51, STT arthrosis 5/42
15	Euler et al. [28]	26			52	51	19	14	
16	Allon et al. [29]	44							Not assessed
17	Mani and Acharya [30]	45							Scaphoid Index Pre 0.66, post 0.60
18	Putnam et al. [31]	34							Not assessed
19	Oh et al. [3] (Open)	34	39.2	22.6	32.6	46.8	8.8	4	Preop. HLR 0.65, FU HLR 0.55
20	Schormans et al. [32]	33							
21	Yeh et al. [33]	18	43.7	30	61.6	51.3	25.8	11.3	CHR Preop. 46% FU 52%
22	Hegazy et al. [34]	116	68	36	81	51	30	11	
23	Cagnolati et al. [35]	8							Not assessed
24	Welle et al. [36]	13	58.9	45.1	59.7	43.9			Height of Scaphoid Preop. 21.8 mm, FU 23.0 mm
25	Zhang et al. [1]	103		34.5					HLR 0.67
26	Ma et al. [37]	18	56	32	71	50			

LISA lateral intra-scaphoid angle, *SLA* scapho-lunate angle, *RLA* radio-lunate angle, *RC* radio-carpal, *STT* scapho-trapezio-trapezoid, *DISI* dorsal intercalated segment instability, *AVN* avascular necrosis, *OA* osteo-arthritis, *RS* radio-scaphoid, *CHR* carpal height ratio, *HLR* height-to-length ratio, *Preop.* preoperative, *FU* follow-up

The definition for inclusion of patients regarding the duration since injury was not uniform across the studies in both groups, with patients included as early as 8 weeks after injury to 6 months after injury. However, all patients had a postoperative follow-up of at least 12 months.

Patients treated with the open bone grafting were almost three times those treated with the arthroscopic technique. The studies of open bone grafting, which included 1152 patients, were published between 1991 and 2023, while the studies of arthroscopic bone grafting, which included 382 patients, were published between 2016 and 2023. It is expected that these numbers will see a dramatic change as surgeons pursue arthroscopic surgical techniques in the treatment of wrist disorders increasingly and more studies of arthroscopic bone grafting are published.

With the inclusion of observational studies, which were the main study type available on this topic, the strengths and weaknesses of this systematic review are not unique and are subject to confounding factors and bias. There is a need to conduct well-designed multi-centre randomised controlled trials with rigorous inclusion and exclusion criteria with the use of uniform radiological and functional outcome assessment on this topic to determine the superiority of one technique over the other, if any.

Conclusion

We systematically reviewed the available literature for evidence of better union rate and functional outcome with arthroscopic bone grafting compared to the open technique for scaphoid nonunion at a minimum of 1-year postoperative follow-up. Bone grafting with both open and arthroscopic techniques for scaphoid nonunion showed comparable union rates and functional scores. However, the radiological outcome parameters were not reported by any of the studies in the arthroscopic group.

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Author Contributions JAS and PB conceived and designed the study. JAS and KR performed the literature search. JAS, PB and PKA analysed the data. JAS wrote the first draft, and all authors commented on previous manuscript versions. All authors read and approved the final manuscript.

Data availability All the relevant data related to the study are presented in the tables.

Declarations

Competing interests The authors report no conflicts of interest in this work.

Ethical Approval The review was prospectively registered at PROSPERO—the International prospective register of systematic reviews—CRD42023399012.

Informed Consent For this type of study, informed consent is not required.

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