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ORIGINAL ARTICLE

Comparative analyses of arthroscopic and open repairs of lateral ligament complex injuries of the ankle: a systematic review and meta-analysis of the medium-term outcomes

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Abstract

Purpose Little is known regarding the comparative analyses of the medium-term outcomes (with a mean minimum follow-up period of 24 months), between arthroscopic and open repairs of lateral ligament complex (LLC) injuries of the ankle. Thus, in this study, we aimed to explore the comparative analyses regarding the medium-term follow-up outcomes of these repairs, by conducting a systematic review and meta-analysis.

Methods The systematic review and meta-analysis were performed as per the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines; data were extracted from the PubMed and Google Scholar databases. From an initial search, a total of 1182 abstracts (280 and 902 abstracts, from PubMed and Google Scholar, respectively) were found and screened in accordance with the eligibility criteria. Subsequently, six articles were found to be eligible for further review.

Results A total of 419 patients underwent surgical repairs; 205 and 214 patients underwent arthroscopic and open repairs, respectively. The mean minimum follow-up period was 29.2 months. The medium-term follow-up for arthroscopic LLC repairs was found to be superior to that of open LLC repairs, with more favorable outcomes; as evidenced by better clinical scores, lower pooled complication rates, earlier return times to pre-injury sport, and higher early sport ratios.

Conclusions The findings of this systematic review and meta-analysis support near-future developments validating arthroscopic repair as the new gold standard for LLC repairs, similarly to arthroscopic ligament and tendon repairs, as well as arthroscopic reconstruction surgeries, of the knee and shoulder.

Keywords Ankle instability · Chronic ankle sprain · Arthroscopy · Lateral ligament complex repair · Open modified Broström–Gould procedure

Introduction

Ankle sprains are one of the most common lower extremities injuries worldwide. In the USA, approximately 30,000 ankle sprain injuries occur per day, and more than 3 million cases occur annually [1]. The most common type of ankle sprain injury is the lateral ligament complex (LLC) injury, with 85% involving the anterior talofibular ligament (ATFL) that is caused by supination, described as a combination of inversion, adduction, and plantarflexion [2–4]. With proper conservative treatment, Grade I and II ankle sprains can be treated with excellent results [4, 5]. Nevertheless, 10–40% of patients have failed functional treatment of the complete rupture of LLC and have developed chronic ankle instability [6, 7].

The modified Broström repair is the most common procedure used in the treatment of chronic ankle instability [8].

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This procedure was proposed in 1966 to anatomically repair the ATFL [9, 10] and was modified by Gould in 1980, with reinforcement of the inferior extensor retinaculum after ATFL repair [10, 11]. With excellent and reliable results, the open modified Broström–Gould procedure is now considered the gold standard treatment for chronic ankle instability [8–10].

The arthroscopic repair of ATFL was first proposed by Hawkins in the 1990s [9]. With the advantage of being minimally invasive and resulting in smaller wounds and quicker recovery periods, this procedure has become increasingly popular [9, 12]. The clinical outcomes comparing arthroscopic and open LLC repairs determined for a short-term period of less than 24 months explored in several studies [13–15]. Currently, little is known regarding the comparative analyses of the medium-term outcomes (with a mean minimum follow-up period of 24 months), between arthroscopic and open repairs of LLC injuries of the ankle. Therefore, in this study, we aimed to explore the comparative analyses regarding medium-term follow-up outcomes of these repairs, by conducting a systematic review and meta-analysis.

Materials and methods

This systematic review and meta-analysis was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [16]. We have conducted this study and written this manuscript in accordance with the PRISMA checklist (Supplement file). We performed study searches on the PubMed and Google Scholar databases, for the years 2017 to 2022. The search terms were as follows: “ankle instability,” “lateral,” “arthroscopic,” “arthroscopy,” “repair,” and “anterior talofibular ligament.” Relevant studies from other sources were reviewed as well (Fig. 1). The inclusion criteria for eligible articles included clinical studies comparing arthroscopic and open LLC repairs, with a minimum follow-up period of more than 24 months. The articles were required to have preoperative and postoperative outcome scores. All studies had to be published in full-text English language. Regarding the exclusion criteria, we excluded review articles, case reports, technical-related articles, cadaveric studies, animal studies, and in vivo basic science studies. Articles with level of evidence I, II, or III based on a previous study by Wright et al. [17] were considered in this study. We also searched the reference sections of previous reviews.

For study selection and data extraction, two independent researchers screened the study titles and abstracts according to the eligibility criteria. Subsequently, all of the eligible studies were reviewed, and data were extracted for analysis. The final consensus and all methodological steps were implemented under a senior author.

Risk of bias

The assessment of the methodological quality of included studies and risk of bias was conducted using two different tools. The risk of bias 2 (RoB2) tool was used to assess the bias caused by randomization process, intended intervention, missing data, measurement of outcome, and selection report bias [18]. The bias was divided into “low risk”, “high risk”, and “some concern”. Other cohort studies were determined using the Newcastle-Ottawa scale (NOS) [19]. This

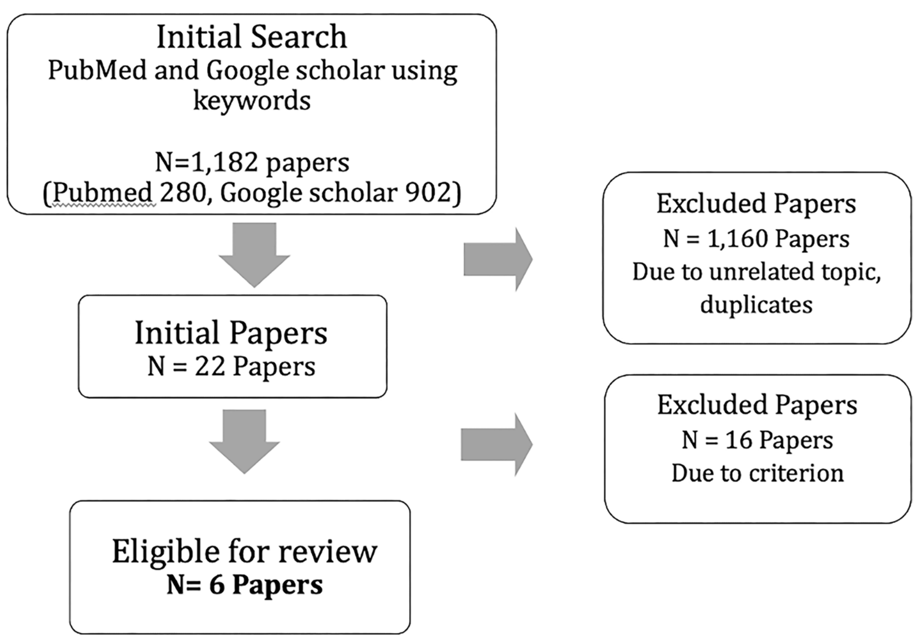

Fig. 1 Flow diagram of study selection algorithm using PRISMA guidelines

tool comprises selection of subjects, group comparison, and outcome assessment for the quality of assessment. The quality of study was rated as low (0–3), moderate (4–6), or high (7–9). Two reviewers (S.T. and H.R.H.) graded the risk of bias and quality assessment independently and compared their results. Any discrepancy was judged by consulting the corresponding author.

Data analysis

We analyzed the demographic and complication rates data using mean differences (MD) and the unpaired t-tests. Meta-analysis of the clinical outcomes was performed using the Review manager 5.3 software, provided by Cochrane Collaboration and supplemented by GraphPad Prism 5.1 software (GraphPad Software, Inc., La Jolla, CA, USA), for calculation and plotting. A 95% confidence interval (CI) was performed for each statistical data. The fraction of variance due to heterogeneity was estimated by the statistic I^2. If $I^2 < 25\%$, the heterogeneity was considered to be low. Conversely, $I^2 > 75\%$ revealed high heterogeneity. $P < 0.05$ was considered statistically significant.

Results

Study selection

For the study selection process, a total of 1182 relevant articles were found, as a result of our searching, with 280 and 902 articles, from PubMed and Google Scholar, respectively. We excluded 1106 articles that contained unrelated topics or were duplicated papers. Subsequently, we explored the remaining 22 articles and sorted out 16 articles based on eligibility criteria. Finally, we included six studies [20–25] that were eligible for review. These studies included a randomized controlled trial, two prospective, and three retrospective cohort studies (Table 1).

Risk of bias

One RCT study [20] was assessed using the RoB2 tool [26]. The result has low risk of bias (Fig. 2). The Newcastle–Ottawa Scale (NOS) for assessing the quality of studies and risk of bias of remaining cohort studies [21–25] in meta-analyses with a mean score of 8 is shown in Table 2.

Table 1 Summary of all studies

Study	Study design	Level of study	Clinical outcome
Hou et al. 2022 [20]	Randomized controlled trial	II	AOFAS, VAS, ADL score, FAAM, FAAM sport score
Li et al. 2017 [21]	Prospective cohort study	III	AOFAS, Karlsson, Tegner
Su et al. 2021 [22]	Retrospective cohort study	III	AOFAS, Karlsson, JSSF (Jersey Shore Science Fair)
Xu et al. 2020 [23]	Retrospective cohort study	III	AOFAS, Karlsson, VAS, Tegner activity score
Zeng et al. 2019 [24]	Prospective cohort study	III	AOFAS, Karlsson
Zhou et al. 2021 [25]	Retrospective cohort study	III	AOFAS, Karlsson, VAS, Tegner

AOFAS American Orthopaedic Foot and Ankle Society score, *VAS* Visual Analogue Scale, *ADL score* Activities of daily life score, *FAAM* Foot and Ankle Ability Measure score

Fig. 2 Risk of bias assessment of RCT study [18]

Table 2 Quality assessment of the Studies by the Newcastle-Ottawa Scale

Study	Selection				Comparability		Outcome			Total (9/9)
	Representative of the exposed cohort	Selection of external control	Ascertainment of exposure	Outcome of interest not present at the start of the study	Main factor	Additional factor	Assessment of outcomes	Sufficient follow-up time	Adequate of follow-up	
Li et al. 2017 [21]	*	0	*	*	*	*	*	*	*	8/9
Su et al. 2021 [22]	*	0	*	*	*	*	*	*	*	8/9
Xu et al. 2020 [23]	*	0	*	*	*	*	*	*	*	8/9
Zeng et al. 2019 [24]	*	0	*	*	*	*	*	*	*	8/9
Zhou et al. 2021 [25]	*	0	*	*	*	*	*	*	*	8/9

Characteristics of the included studies

Regarding the data extraction of eligible studies, we collected a total data for 371 patients for final review. The arthroscopic and open repair cohorts consisted of 179 and 192 patients, respectively. There were no statistically significant differences in the age and sex between the two cohorts (Table 3). The five clinical outcomes that were reviewed are as follows: the American Orthopaedic Foot and Ankle Society score (AOFAS), Karlsson–Peterson ankle score, Tegner score, Visual analog scale (VAS), and time to return to pre-injury sport. The mean minimum follow-up period was 29.2 months. Main data of all six studies are demonstrated in Tables 1 and 3.

Clinical outcomes

The meta-analysis results revealed that all six studies reported the clinical outcomes, as per the AOFAS [20–25]. In particular, a summary of all studies, as analyzed using forest plots, revealed no statistically significant results between the two cohorts, the findings tended to be more favorable results for the arthroscopic repair than that of the open repair (Fig. 3).

The Karlsson–Peterson ankle scores were reported in five studies [21–25]. The summary of studies revealed no statistically significant results between the two cohorts; however, the arthroscopic repair cohort showed more favorable results than that of the open repair cohort (Fig. 4).

The Tegner scores were reported in three studies [21, 23, 25]. A summary of these three studies revealed that there were no statistically significant differences between the two cohorts (Fig. 5).

Visual analog scales were described in three studies [21, 23, 25]. Although, a summary of these three studies revealed that there were no statistically significant differences between the two cohorts, the results for the arthroscopic repair cohort were more favorable than that of the open repair cohort (Fig. 6).

The rate of return to sport was demonstrated in a study by Hou et al. [20]. The study revealed a statistically significant earlier time of return to pre-injury sport and a statistically significantly higher early sport ratio in the arthroscopic repair cohort than that of the open repair cohort (Table 4).

Regarding the radiographic and biomechanical-related tests, a retrospective cohort study by Su et al. [22] showed comparably similar postoperative results of the anterior displacement and tilt angle of the talus between the two cohorts (Table 5).

Complications were reported in both cohorts. Regarding the pooled data, the open and arthroscopic repair cohorts had complication rates of 9.38% and 7.82%, respectively. However, we found no statistically significant differences in

Table 3 Demographic data; *N* Number of patients

Study	Number of patients	Age					Sex				
		Open group	N	Scope group	N	P value	Open group		Scope group		P value
							Male	Female	Male	Female	
Hou et al. 2022 [20]	70 (open 34, scope 36)	28.6 ± 4.8	34	28.3 ± 5.4	36		17	17	17	19	
Li et al. 2017 [21]	60 (open 37, scope 23)	28.7 ± 8.7	37	30.3 ± 10.1	23		29	8	18	5	
Su et al. 2021 [22]	80 (open 40, scope 40)	34.27 ± 15.73	40	38.68 ± 14.23	40		18	22	23	17	
Xu et al. 2020 [23]	67 (combined 35, scope 32)	35.8 ± 8.5	35	33.7 ± 2.3	32		25	10	24	8	
Zeng et al. 2019 [24]	27 (open 10, scope 17)	27.7 ± 9.7	10	30.9 ± 6.0	17		7	3	15	2	
Zhou et al. 2021 [25]	67 (open 36, scope 31)	31.36 ± 7.79	36	33.42 ± 6.40	31		23	13	20	11	
	Total	31.58 ± 9.99	192	32.98 ± 8.71	179		119	73	117	62	0.87

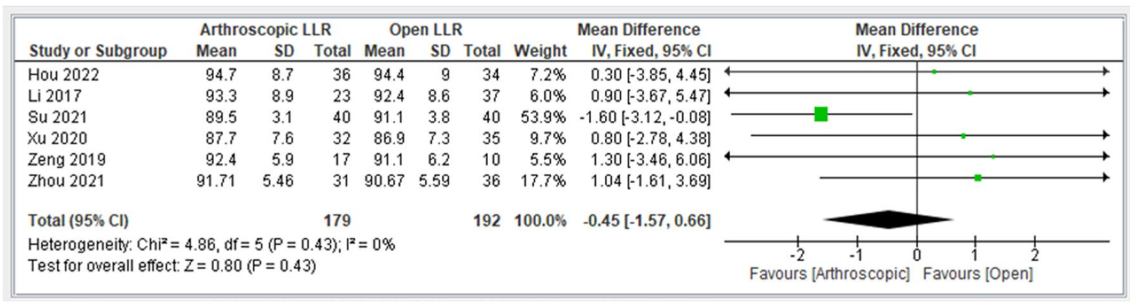

Fig. 3 Forest plot comparison: Arthroscopic VS Open lateral ligament repair, AOFAS score (6 studies); *S.D.* Standard deviation, *IV* Weight mean difference, *CI* Confidence Interval, *Chi*^{2} Chi-square statistic, *df* Degrees of Freedom, *P* P-value, I^2 I-square heterogeneity statistic, *Z* Z statistic

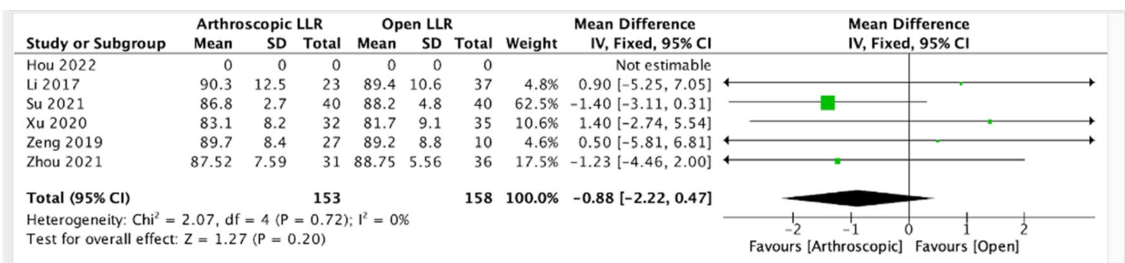

Fig. 4 Forest plot comparison: arthroscopic versus Open lateral ligament repair, Karlsson score (5 studies)

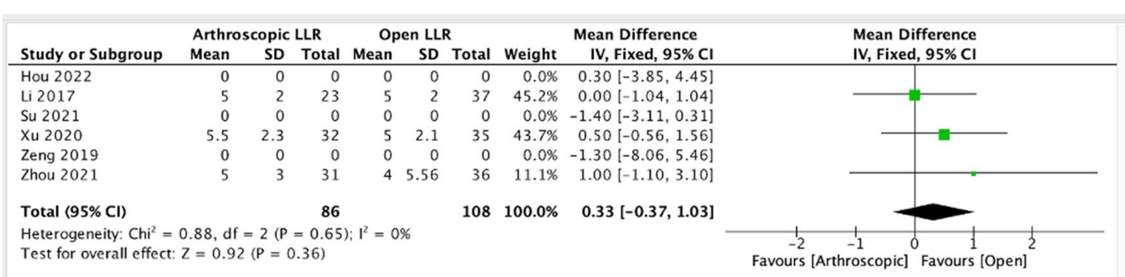

Fig. 5 Forest plot comparison: arthroscopic versus Open lateral ligament repair, Tegner score (3 studies)

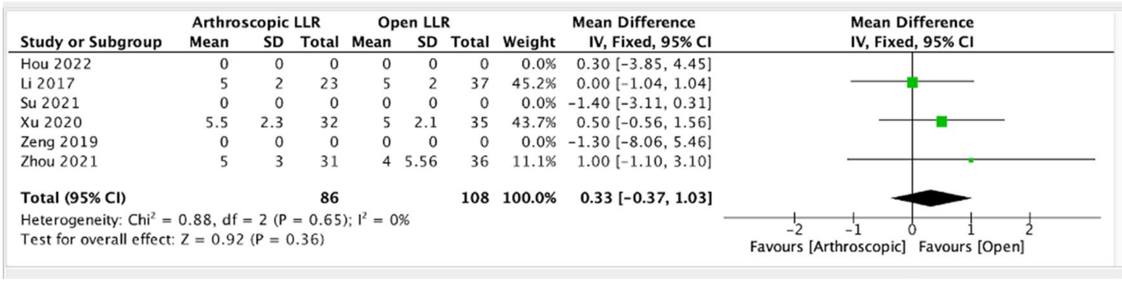

Fig. 6 Forest plot comparison: arthroscopic versus Open lateral ligament repair, VAS score (3 studies)

Table 4 Return to sport ratio from Hou et al. 2022 [20]; *n.s.* No significant difference

Outcomes	Open group	Arthroscopic group	*P* value
FAAM sport scores at 24 months	88.4 ± 9.2	88.9 ± 8.9	n.s
Time to preinjury sport (weeks)	18.7 ± 3.1	13.2 ± 2.4	0.023*
Time to jogging (TRJ)	7.7 ± 4.2	8.2 ± 3.3	n.s
Early sport ratio (%)	61.8 (21/34)	80.6 (29/36)	0.011*

Table 5 Talus anterior displacement and tile angle from Su et al. 2021 [22]

Outcomes	Combined arthroscopic—open group	All-arthroscopic group	*P* value
Anterior displacement of talus at 24 months (mm)	3.5 ± 0.2	3.4 ± 0.4	0.376
Tile ankle of talus at 24 months (degree)	3.1 ± 0.2	3.4 ± 0.5	0.216

the complication rates between the two cohorts. Tables 6 and 7 depict the details of the complication rates, as described by the studies.

Discussion

In this systematic review and meticulous meta-analysis, we highlighted that arthroscopic LLC repairs were superior to open LLC repairs; as evidenced by better clinical scores, lower pooled complication rates, earlier times of return to pre-injury sport, and higher early sport ratios, with a mean minimum follow-up period of 29.2 months [27].

Historically, LLC repairs using the open modified Broström–Gould procedure has been acknowledged as the gold standard treatment of chronic ankle instability, yielding excellent results and reliability [8–10]. However, open LLC repairs have exhibited a few complications, such as scar and knot tenderness, superficial wound infection, nerve irritation, and recurrence of instability [5, 8, 9, 28]. Recently, the advantages of the minimally invasive arthroscopic repair has popularized this procedure, thus overcoming the disadvantages of an open repair. Wittig et al. [9] reviewed eight studies with 217 and 203 patients in the open and arthroscopic repair cohorts, respectively. The clinical outcomes

Table 6 Complication between two groups

Study	Total	Complication				
		Open group	*N*	Arthroscope group	*N*	*P* value
Hou et al. 2022 [20]	70 (open 34, scope 36)	3	34	1	36	
Li et al. 2017 [21]	60 (open 37, scope 23)	2	37	1	23	
Su et al. 2021 [22]	80 (open 40, scope 40)	2	40	3	40	
Xu et al. 2020 [23]	67 (combined 35, scope 32)	4	35	5	32	
Zeng et al. 2019 [24]	27 (open 10, scope 17)	3	10	2	17	
Zhou et al. 2021 [25]	67 (open 36, scope 31)	4	36	2	31	
	Total	18 (9.38%)	192	14 (7.82%)	179	0.95

Table 7 Details of complication among two groups (SPN; superficial peroneal nerve)

Study	Complication			
	Open group (%)	N	Arthroscope group (%)	**N**
Hou et al. 2022 [20]	ROM restriction 1 (2.94%)	34	Joint instability 1 (2.77%)	36
	Joint instability 2 (5.88%)			
Li et al. 2017 [21]	Painful after surgery 2 (5.4%)	37	Painful after surgery 1 (4.3%)	23
Su et al. 2021 [22]	Temporary numbness of foot and ankle 2 (5%)	40	Thread reaction 1 (2.5%)	40
			Temporary numbness of foot and ankle 2 (5%)	
Xu et al. 2020 [23]	SPN injury 2 (5.71%)	35	SPN injury 3 (9.38%)	32
	Wound infection 2 (5.71%)		Knot pain 2 (6.25%)	
Zeng et al. 2019 [24]	Poor healing 2 (20%)	10	Poor healing 1 (5.88%)	17
	Painful nodules 1 (10%)		Nerve injury 1 (5.88%)	
Zhou et al. 2021 [25]	Sensory disturbance 1 (2.7%)	36	Neuritis of SPM 1 (3.2%)	31
	Knot irritation 1 (2.8%)		Recurrent instability 1 (3.23%)	
	Recurrent instability 2 (5.56%)			
	18 (9.38%)	192	14 (7.82%)	179

and complication rates were similarly comparable in both cohorts. Zhi et al. [10] reviewed nine studies with a total of 473 patients (223 and 250, in the open and arthroscopic repair cohorts, respectively). There were statistically significant differences in the AOFAS and VAS scores between the two cohorts, and the arthroscopic repair cohort showed more favorable outcomes than that of the open repair cohort. However, there were no statistically significant differences in the complication rates between the two cohorts [10]. Attia et al. [13] reviewed eight studies with 408 patients (193 and 215, in the open and arthroscopic repair cohorts, respectively), in a 6-month mean follow-up. Regarding postoperative AOFAS, VAS scores, and time to return to weight-bearing, findings revealed that the arthroscopic repair cohort is superior to the open repair cohort [13]. In addition, Moorthy et al. [15] reviewed six studies and found that the arthroscopic repair cohort demonstrated superior AOFAS, Karlsson, and VAS scores than that of the open repair cohort. No statistically significant differences in the complication rates were observed between both cohorts. However, none of these studies revealed medium-term follow-up outcomes, defined as a mean follow-up period of more than 24 months. Our study exhibited the same trends as the previous studies. Furthermore, our findings confirmed that arthroscopic repair was still superior to open repair; however, in a longer follow-up, medium-term period.

Apart from the clinical outcomes, comparable radiographic and biomechanical-related outcomes were shown between the arthroscopic and open repair cohorts [22]. These comparisons were adequately able to synergistically augment other positive effects of the arthroscopic repair, such as less soft-tissue injury during the procedure. These findings might explain why patients with arthroscopic repair had earlier return times to pre-injury sport and higher early sport ratios [20]. These results were in accordance with the findings of previous studies by Drakos et al. [29] and D'Hooghe et al. [30].

Our study had some limitations. The first one was that we included only PubMed and Google Scholar as the main databases for searching. Nevertheless, the combination of these two databases was sufficient to cover most related literature in accordance with the supporting evidence [26, 31]. Google scholar covered between 85 and 98% of the universe of bioscience articles compared to other gold standard databases and has been used in previous systematic reviews [26, 31–33]. The heterogeneity of study designs, with a randomized-controlled trial, two prospective, and three retrospective cohort studies. However, our meta-analysis demonstrated very low levels of I^2 that ensured the levels of heterogeneity of the collected studies were very low. In addition, the RoB2 and NOS tools for assessing the risk of bias and quality of studies in meta-analyses, with a low risk of bias and mean score of 8, referred to the high quality of included studies in this review. Therefore, the results of this meta-analysis were of high validity. This meta-analysis could be a useful platform for the continuous development of arthroscopic repair studies in the further validation of this procedure as the gold standard for the treatment of chronic lateral ankle instability in the near future. In addition, this continuous development should essentially be conducted in the form of well-designed randomized-controlled trials on long-term clinical outcomes. These future studies can be subsequently collected and analyzed for further systematic reviews and meta-analyses with further accurate conclusions.

Conclusions

The medium-term follow-up of arthroscopic LLC repairs was insignificantly superior to that of open LLC repairs, with more favorable outcomes; as evidenced by better clinical scores, lower pooled complication rates, earlier return times to pre-injury sport, and higher early sport ratios. These findings support near-future development validating arthroscopic repair as a new gold standard for LLC repairs, similarly to arthroscopic ligament and tendon repairs, as well as arthroscopic reconstruction surgeries of the knee and shoulder.

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Declarations

Conflict of interest The authors declare no potential conflict of interest in this study.

Ethical standards This article does not contain any studies with human participants performed by any authors.

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