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Complications and clinical outcomes with minimally invasive plate osteosynthesis (MIPO) technique for midshaft clavicle fractures: a systematic review and meta-analysis

Vitor La Banca, MD[a,b,*], Guilherme Henrique Vieira Lima, MD[a], Ana Victoria Palagi Vigano, MD[a,c], Felipe Fernandes Gonzalez, MD, MSc[b], Henrique de Lazari Schaffhausser, MD[a], Luiz Henrique Oliveira Almeida, MD[a,c], Luis Gustavo Prata Nascimento, MD, MSc[a], Joel Murachovsky, MD, PhD[a], Roberto Yukio Ikemoto, MD, PhD[a,c]

[a]*Disciplina de Ortopedia - Faculdade de Medicina do ABC, Santo André, SP, Brazil*
[b]*Instituto Brasil de Tecnologia da Saúde, Rio de Janeiro, RJ, Brazil*
[c]*Hospital Ipiranga, São Paulo, SP, Brazil*

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Background: Clavicle fractures are among the most common upper limb fractures in adults, with the midshaft region being the most frequently affected site. Minimally invasive plate osteosynthesis (MIPO) has emerged as an alternative to the traditional open reduction and internal fixation (ORIF) technique, offering potential advantages. The purpose of this study was to conduct a systematic review to explore the results of this technique in the existing literature, with emphasis on the occurrence of surgical complications and functional outcomes and also to provide a comprehensive comparison of MIPO and ORIF in the management of midshaft clavicle fractures.

Methods: We conducted a systematic review to evaluate the complication incidence and clinical outcomes of MIPO for midshaft clavicle fractures. We searched PubMed/Medical Literature Analysis and Retrieval System Online (MEDLINE), Scopus, the Cochrane Database of Controlled Trials, and the Cochrane Database of Systematic Reviews databases without language or date restrictions. Studies focusing on midshaft clavicle fractures treated with MIPO were included, while other clavicle fractures and nonclinical studies were excluded. The risk of bias was assessed using the Methodological Index for Nonrandomized Studies criteria and the Risk of Bias Tool 2 Cochrane tool. Data synthesis included qualitative analysis, and if applicable, quantitative analysis and meta-analysis. Adherence to Preferred Reporting Items for Systematic Reviews and Meta-analyses guidelines ensured reporting quality.

Results: A total of 107 studies were initially identified, after applying inclusion and exclusion criteria, 22 studies were included for data extraction. These studies involved the evaluation of 714 clavicles treated with the MIPO technique. Of the 714 MIPO cases, 11 cases of implant failure, 5 nonunions, 2 infections, and 28 cases with neurological impairment were observed. Quantitative analysis comparing MIPO with ORIF revealed that MIPO had significantly shorter surgery time (mean difference −12.95, 95% confidence interval [−25.27 to −0.63], $P = .04$) and lower occurrence of numbness (odds ratio 0.29, 95% CI [0.15-0.56], $P = .0002$) compared to ORIF. Time to bone union, functional outcomes, and other complications were similar between MIPO and ORIF at the final follow-up. An overall moderate risk of bias was found across the studies.

Conclusion: The MIPO technique yields good and comparable results to ORIF for midshaft clavicle fractures. Additionally, the MIPO technique may offer advantages such as reduced surgical time and lower chances of neurological impairment.

Institutional review board approval was not required for this systematic review and meta-analysis.

*Corresponding author: Vitor La Banca, MD, Rua da Consolação, 222 Cj 2002, São Paulo, SP 01302091, Brazil.
E-mail address: labanca.vitor@gmail.com (V. La Banca).

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Fractures of the midshaft of the clavicle are among the most commonly encountered injuries on the upper extremity, accounting for 75% of all clavicle fractures.[12] The management of midshaft clavicle fractures has historically been nonoperative;[31] however, a significant shift in the treatment approach has occurred, with a growing emphasis on surgical interventions, especially open reduction and internal fixation (ORIF).[7] This approach yields more predictable results in cases of highly displaced fractures,[2] albeit with potential complications related to surgical morbidity, implant failure, and wound-related complications.[18,25,37]

The recognition of complications in the conventional plate ORIF technique has led to the development of alternative surgical techniques, including various nailing methods.

Another surgical technique that has gained attention in recent years is the minimally invasive plate osteosynthesis (MIPO) technique. The MIPO technique involves the use of smaller incisions and the insertion of a low-profile plate along the length of the clavicle, spanning the fracture site and providing stable fixation. This approach offers the potential benefits of reduced soft tissue disruption, lower rates of skin numbness, minimized damage to the periosteal blood supply, and a lower risk of infection or implant-related complications.[25,37]

Despite the growing adoption and study of the MIPO technique for midshaft clavicle fractures, only one other systematic review to our knowledge specifically evaluated its outcomes and compared it with the ORIF technique,[37] and none other was published in the past four years, while a considerable number of related articles have been reported since. With this study, we aim to fill this gap in updating the knowledge by evaluating the surgical procedure time, effectiveness, and complication incidence of the MIPO technique for midshaft clavicle fractures across the existing studies. We hypothesized that the MIPO technique would demonstrate equivalent clinical outcomes (assessed by functional scores), equivalent time to bone union, lower surgical procedure time, and lower complication rates (infection, implant failure, nonunion, and paresthesia) when compared to the ORIF surgical technique.

Methods

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines.[20]

Eligibility criteria

Studies reporting original data on the use of the MIPO technique for the treatment of patients with midshaft clavicle fractures were targeted for this study. The surgical fixation of clavicle fractures through multiple (>1) smaller incisions, employing the bridge plating technique, was classified as MIPO. No other restrictions to MIPO technique variation were applied. Studies reporting on clavicle fractures of other anatomical sections than midshaft and treated exclusively with other surgical techniques were excluded. No restrictions were applied in terms of the type of functional outcome assessed or the type of complications reported. We excluded scoping and systematic reviews, technical notes, letters to the editor, and nonclinical studies such as anatomical and biomechanical studies. There were no other restrictions to study designs. Only studies in English were included. The inclusion and exclusion criteria for this study are summarized in Table I.

Information source and search strategy

Before the initial search, registration of the systematic review with the International Prospective Register of Systematic Reviews was completed (CRD42021262433). A comprehensive literature search was developed by the authors and was run by an experienced medical librarian on 18th January 2023 in the following databases: PubMed/MEDLINE, Scopus, Cochrane Database of Controlled Trials and the Cochrane Database of Systematic Reviews. Both controlled vocabularies (e.g. MeSH terms) and keywords were searched. There were no restrictions on geography, age of participants, or language of publication. Additionally, a hand search was conducted of the reference lists of selected articles.

All identified studies were exported to reference management software (Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia) to remove duplicates and organize the studies for screening. Two reviewers (V.L.B. and A.P.V.) independently screened the studies for eligibility based on the title and abstract, and full-text articles were retrieved for studies that met the eligibility criteria. Disagreements between reviewers were resolved by a third independent reviewer (G.V.L.), as suggested by the reporting guidelines for meta-analysis PRISMA.[20]

Data extraction

Specific information on study design, methods, patient demographics, interventions, and outcomes was collected, accordingly to the Cochrane Handbook for Systematic Reviews of Interventions[5] recommendations. Two authors (V.L.B. and A.P.V.) independently extracted data from the included studies using a standardized data extraction form. A third author (H.L.S.) reviewed the extracted data and decided on conflicts when present. We extracted outcomes if they were present in two or more of the studies included. Outcomes that were not consistently reported in at least two studies were not evaluated. The following outcomes data were extracted from each study: (1) Surgical time in minutes; (2) Time to radiographic bone union in weeks; (3) Implant failure or loosening; (4) nonunion; (5) superficial or deep infection; (6) paresthesia or sensitivity impairment; (7) Constant Murley score[4]; (8) Disabilities of the Arm, Shoulder and Hand (DASH) score[11]; (9) Quick-DASH (q-DASH) score[22]; and (10) surgical technique used as a comparison when present. All of the functional scores (Constant, DASH, Q-DASH) were collected at the final follow-up, as we predicted that intermediate time point evaluations would vary across the studies.

Additionally, patient's age, positioning of the patient (beach chair or supine), number of incisions, reduction method, type of implant used, and time of follow-up were extracted when available.

Study risk of bias

The Methodological Index for Nonrandomized Studies (MINORS)[23] criteria was utilized to objectively score the quality of each study. According to these criteria, comparative studies had a maximum possible score of 24, whereas noncomparative studies had a maximum score of 16. Higher scores indicated a lower risk of bias. The Cochrane Risk of Bias Tool 2[29] was employed for the assessment of the risk of bias in the included clinical trials, and the overall risk of bias was graded as high, somewhat concerning, or low. Risk Of Bias In Nonrandomized Studies—of Interventions[28] tool for non-randomized experimental studies. Two authors independently evaluated the included articles for risk of bias (A.P.V. and F.L.G.) and conflicts were decided by a third independent author (V.L.B.)

Effect measures

Continuous data such as time to bone union (in weeks) and surgical time (in minutes) were evaluated by the mean difference between the MIPO technique and alternative surgical treatments.

Table I
Inclusion and exclusion criteria of the targeted studies.

Inclusion criteria	Exclusion criteria
Clinical trials, cross-sectional studies, and case series reporting original data.	Biomechanical, cadaveric studies, systematic reviews, technical notes, and review articles.
Reporting of MIPO techniques.	Reporting solely other treatment techniques (e.g. conservative, ORIF)
Included patients with midshaft clavicle fractures	Included patients with fractures on different sites of the clavicle (lateral or medial third).

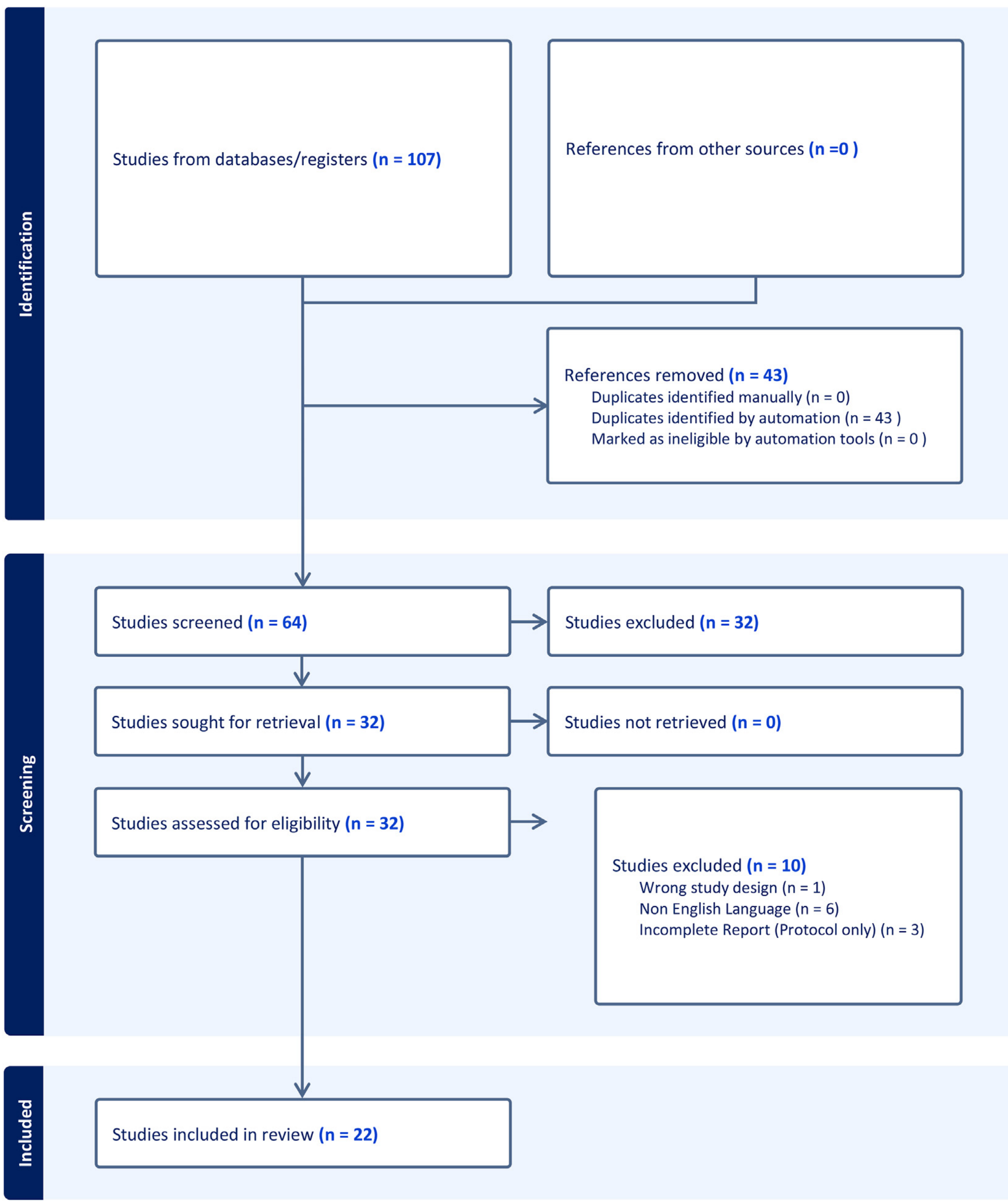

Figure 1 PRISMA flow diagram with study selection. *PRISMA*, preferred reporting items for systematic reviews and meta-analyses.

Risk ratios (RRs) were calculated to determine the relative risk of complications such as implant failure or loosening, nonunion, superficial or deep infection, and numbness associated with the MIPO technique compared to other evaluated treatments. Finally, functional scores, including the Constant Murley score, the DASH score, and the q-DASH score were assessed by calculating the mean difference between treatments at the final follow-up.

Synthesis methods

All selected studies were included in the descriptive analysis regarding patient demographics and surgical technique employed (positioning, number of incisions, reduction methods and types of implants) for the MIPO technique. The incidence of complications associated with the MIPO technique was also

Table II
Individual studies characteristics: MIPO (Minimally Invasive Plate Osteosynthesis); n = Number of clavicles.

Study	Intervention/ Comparison	Study design	n =	Mean age (y)	Number of incisions in MIPO	Patient positioning	Reduction method	Implant type in MIPO technique	Mean follow-up (mo)
Al Sadek et al 2016[1]	MIPO	Case Series	12	47.5	2	Beach Chair	n/a	Clavicle Locking Plate	n/a
Chen et al 2018[3]	MIPO	Randomized Clinical trial	27	37.8	2	Beach Chair	Traction	Clavicle Locking Plate	n/a
	Titanium Elastic Nail		27	39.1					n/a
Delvaque et al 2019[6]	MIPO	Retrospective Cohort	19	37	2	Supine	Joystick	Clavicle Locking Plate	3
	-								n/a
Jiang et al 2012[9]	MIPO	Randomized Clinical trial	32	40	3	Beach Chair	Incision over fracture	Clavicle Locking Plate	n/a
	ORIF		32	45					
Jirangkul et al 2022[10]	MIPO	Case Series	30	42.4	2	Beach Chair	Joystick	Clavicle Locking Plate	15.86
Kim et al 2020[13]	MIPO	Retrospective Cohort	16	14.6	2	n/a	n/a	Clavicle Locking Plate	n/a
	ORIF		33	15.1					
Kim et al 2018[14]	MIPO	Randomized Clinical trial	15	38.1	n/a	Beach Chair	Traction	Clavicle Locking Plate	13.3
	ORIF		15	38.1					13.7
Ko et al 2022[15]	MIPO	Case Control Study	29	48.8	2	Supine	n/a	Clavicle Locking Plate	12.5
	ORIF		30	48.5					12.6
Kundangar et al 2019[17]	MIPO	Nonrandomized experimental study	21		2	Supine	Traction	Clavicle Locking Plate	24
	ORIF		16						24
Kundangar et al 2018[16]	MIPO	Case Series	22	36.1	2	Supine	Traction	Clavicle Locking Plate	n/a
Lee et al 2013[18]	MIPO	Case Series	14	42.9	2	Supine	Joystick	Reconstruction Plate	17.6
Mendes Junior et al 2021[21]	MIPO	Retrospective Cohort	32	41	2	n/a	Traction	Reconstruction Plate	12
Sohn et al 2012[24]	MIPO	Case Series	19	42.3	n/a	Beach Chair	Joystick	Reconstruction Plate	13.8
Sohn et al 2015[25]	MIPO	Retrospective Cohort	19	46.7	2	n/a	Joystick	n/a	n/a
	ORIF		14	44.1					n/a
Sohn et al 2012[26]	MIPO	Case Series	15	42.6	2	Beach Chair	n/a	Reconstruction Plate	13.9
Sohn et al 2015[27]	MIPO	Randomized Clinical Trial	19		n/a	n/a	n/a	n/a	n/a
	ORIF		18						n/a
Tieyi et al 2014[30]	MIPO	Retrospective Cohort	269	40.2	2	Supine	Traction	Reconstruction Plate	40.6
	-								12
You et al 2018[32]	MIPO	Nonrandomized experimental study	38	38.3	3	n/a	Incision over fracture	Clavicle Locking Plate	12
	ORIF		35	36.9					12
Zehir et al 2018[33]	MIPO	Retrospective Cohort	22	32.3	3	Beach Chair	Incision over fracture	Clavicle Locking Plate	14.57
	ORIF		30	34.7					16.50
Zehir et al 2015[34]	MIPO	Randomized Clinical Trial	21	32.4	3	Beach Chair	Incision over fracture	Clavicle Locking Plate	14.4
	MIPO w.Nail		24	33.7					11.8
Zhang et al 2017[35]	MIPO	Case Series	27	32.6	2	Supine	Traction	Clavicle Locking Plate	15.8
Zhang et al 2016[36]	MIPO	Case Series	15	48.3	2	Beach Chair	Traction	Clavicle Locking Plate	16.5

analyzed descriptively. For the outcomes of “Time to bone union” and “Follow-up” time was converted into weeks and months, respectively, to ensure consistency across the studies. When in a study with a comparison group, an outcome of interest wasn’t available, this study was not included in the analysis.

The assessment of heterogeneity was made accordingly to the recommendations outlined in the Cochrane Handbook for Systematic Reviews of Interventions.[8] Heterogeneity among the included studies was evaluated using the Chi-square and I^2 statistic tests. According to the Cochrane guidelines, heterogeneity levels below 40% may be considered unimportant, while levels between 30% and 60% suggest moderate heterogeneity, 50%-90% indicate substantial heterogeneity and above 75% considerable heterogeneity. Funnel plots were employed for assessing publication bias, detecting potential asymmetry in the plot, publication bias and other sources of small-study effects. Statistical analysis was performed with Review Manager software, version 5.4 (RevMan 5.4; The Nordic Cochrane Center, The Cochrane Collaboration, Copenhagen, Denmark)

Results

Study selection

We identified 107 records on database searching (Pubmed/MEDLINE, Scopus, and Cochrane Database of Controlled Trials and the Cochrane Database of Systematic Reviews). After the removal of duplicates, 64 articles were screened through their titles and/or abstracts.

Considering the eligibility criteria, 32 studies were excluded and 32 were retrieved for full-text screening in more detail

Table III
MINORS criteria for assessment of risk of bias. Scores graded as (0) not reported, (1) reported, but inadequately (2) reported and adequate.

	Al Sadek et al[1] 2016	Delvaque et al[6] 2019	Jirangkul et al[10] 2022	Kim et al[13] 2020	Ko et al[15] 2022	Kundangar et al[16] 2018	Lee et al[19] 2013	Mendes Junior et al[21] 2021	Sohn et al[26] 2012	Sohn et al[27] 2015	Sohn et al[24] 2013	Sohn et al[25] 2015	Tieyi et al[30] 2014	Zehir et al[33] 2018	Zhang et al[35] 2017	Zhang et al[36] 2016
A clearly stated aim	1	2	2	2	2	2	2	2	2	2	2	2	1	2	1	2
Inclusion of consecutive samples	2	1	1	0	0	0	0	0	2	1	2	1	0	0	0	2
Prospective collection	0	0	2	1	0	2	2	1	0	2	2	2	0	0	2	2
Endpoint appropriated to the study aim	1	1	2	2	2	2	2	1	1	2	1	2	1	2	1	2
Unbiased evaluation of endpoints	0	1	0	1	0	0	0	0	0	0	1	1	0	1	0	1
Follow-up appropriate to the endpoint	0	2	1	2	2	2	2	2	2	2	2	2	1	2	2	1
Loss to follow-up less than 50%	0	2	2	0	2	2	0	0	0	2	0	2	2	2	0	0
Prospective Calculation of Sample Size	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Additional criteria in case of comparative study																
An adequate control group				2	2					2		2		2		
Contemporary groups				0	2					0		2		0		
Baseline equivalence groups				1	2					2		1		2		
Adequate statistical analysis				2	2					2		1		2		
Total	4	9	10	13	16	10	8	6	7	17	10	20	5	15	6	10

MINORS, methodological index for non randomized studies.

and assessed for eligibility. Of those, 10 studies were excluded due to: 6 were not available in English language, 3 were only study protocols without reporting data, and 1 was a systematic review. Twenty-two studies[1,3,6,9,10,13-17,19,21,24,26,27,30,32,33-36] were included for analysis. A PRISMA flow diagram was used to document the study selection process (Fig. 1).

Study characteristics

Patients

A total of 22 studies[1,3,6,9,10,13-17,19,21,24,26,27,30,32-36] were included in the analysis, comprising 714 patients who underwent the MIPO technique for midshaft clavicle fractures. Among these studies, 11[3,9,13-15,17,25,27,32-34] compared the MIPO group with other surgical techniques, while the remaining studies did not involve a comparator group. In the comparator studies, a total of 294 patients were operated using alternative surgical methods. The mean patient age across both groups was 40.75 (±8.4) years.

Surgical technique MIPO

Regarding the MIPO surgical technique, among the included studies, 10 reported utilizing the beach chair position,[1,3,9,10,14,24,26,33-35] while 7 studies opted for the supine position for patient positioning during the procedure.[6,15-17,19,30,35] A 2-incision technique was described in 15 articles as the standard approach for plate osteosynthesis,[1,3,6,10,13,15-17,21,26,33-35] while an additional incision over the fracture site to aid in reduction with a clamp was employed in 4 articles,[9,19,30,36] resulting in a 3-incision technique. In terms of reduction methods, traction alone was used in 8 reports,[3,14,16,17,21,30,35,36] whereas a joystick maneuver with the assistance of k-wires or pins was employed in 5 reports.[6,10,19,24,25] For the fixation of the fracture, a clavicle-specific locking plate was utilized in 15 reports[1,3,6,9,10,13-16,32-36] while 5 reports mentioned the use of reconstruction plates.[19,21,24,26,30]

Comparison technique

Eleven studies included a comparison group[3,9,13-15,17,25,27,32-34] that underwent a different surgical technique for clavicle fracture treatment. Specifically, one study compared the MIPO technique with titanium elastic nail osteosynthesis,[3] another study compared it with intramedullary nail fixation,[34] while the remaining 9 studies compared the MIPO technique with ORIF using a plate.

Study characteristics can be found in Table II.

Risk of bias in individual studies

The risk of bias in the included studies was evaluated using the Methodological Index for Nonrandomized Studies) criteria. Among the studies without a comparator group, the mean score was 7.72 out of 16, the studies with a comparator group had a higher mean score of 16.2 out of 24 (Table III). Risk of bias in the randomized controlled trials was evaluated using the Risk of Bias Tool 2 tool (Fig. 2, *A* and *B*) and ROBINS-I tool (Fig. 3, *A* and *B*) for nonrandomized experimental studies. The assessment of the evaluated studies indicated an overall high to moderate risk of bias, with only 1 study demonstrating an overall low risk of bias.

Synthesis of results

One study[25] was excluded from the synthesis as it was published by the same author,[27] in the same year and with a very similar cohort (similar demographic value) to another study

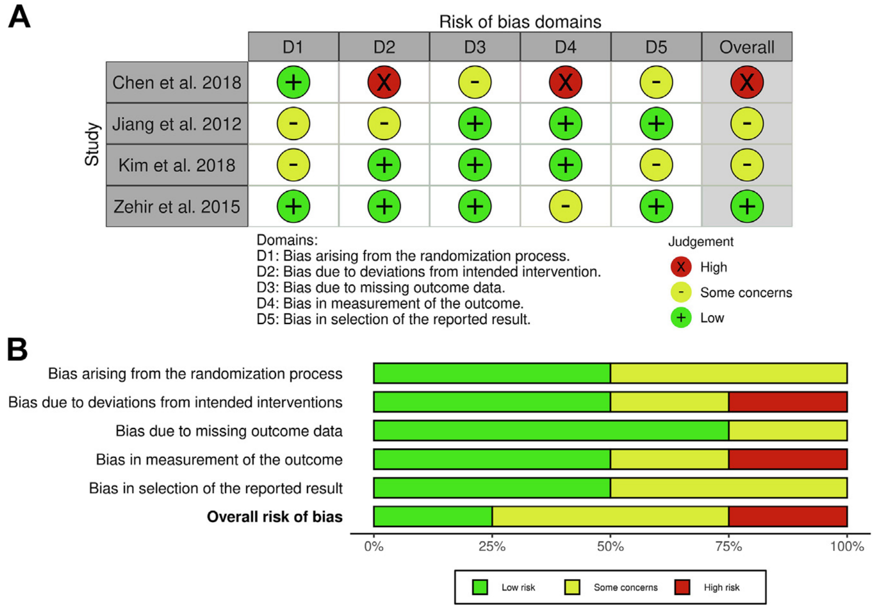

Figure 2 (**A** and **B**): Risk of bias assessment by the RoB2 tool. *RoB2*, risk of bias 2.

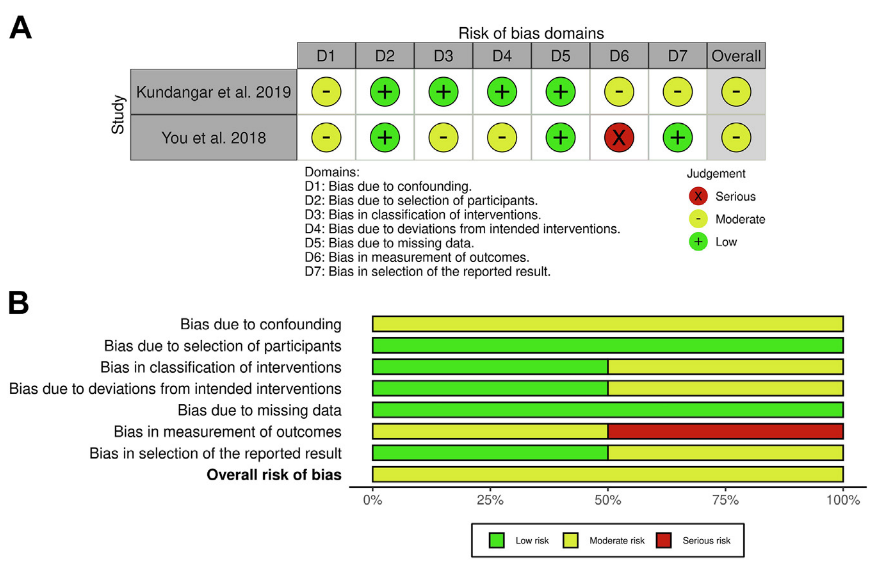

Figure 3 (**A** and **B**): Risk of bias assessment by the ROBINS-I tool. *ROBINS-I*, risk of bias in nonrandomized studies of interventions.

included, leading us to believe that they represent the same group of patients. Studies that compared MIPO with different procedures were excluded from the meta-analysis[3,33] as we aimed to compare with the ORIF procedure.

Surgical time

In the analysis of surgical time, data from 6 studies[9,13,15,16] were included. The results indicated that the MIPO group had significantly shorter surgery times compared to the ORIF group (Mean diff −12.95, 95% CI: −25.27 to −0.63; $P = .04$) (Fig. 4) .

Time to bone union

Seven studies[9,13-16,27,33] reported on the time to union as an outcome measure of comparison. The analysis comparing the MIPO group with the comparison group revealed no significant difference in the time to union between the 2 groups. (Mean diff −1.47, 95% CI: −3.15 to 0.22; $P = .09$) (Fig. 5)

Complications

Complications were reported by 8 studies.[9,13-17,27,33] The results indicated a significantly lower risk of numbness in the MIPO

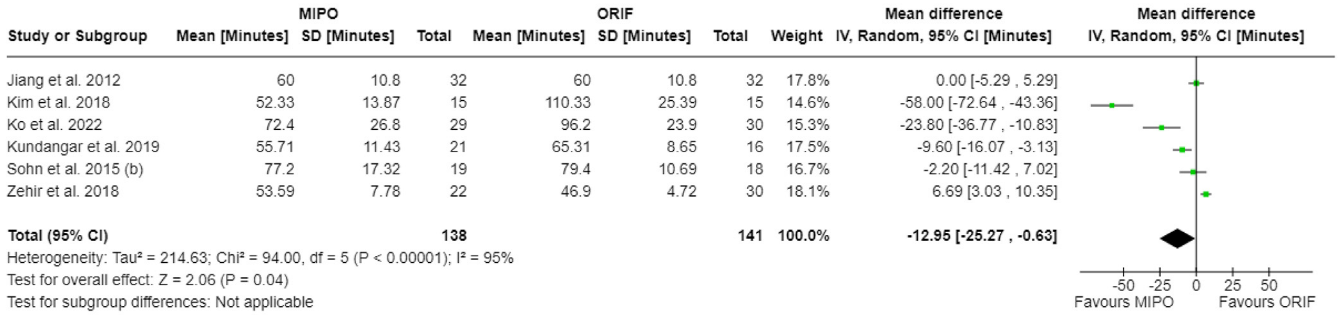

Figure 4 Surgical time compared between MIPO and ORIF groups.

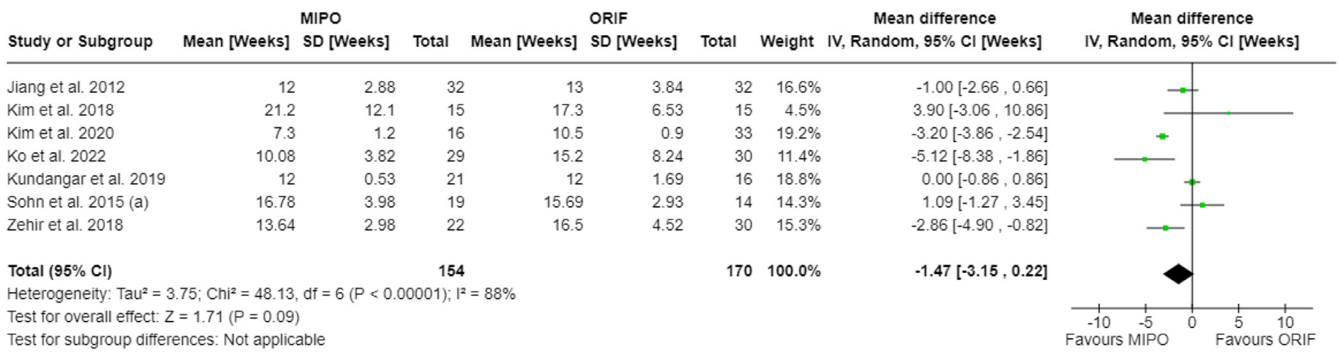

Figure 5 Time to union compared between MIPO and ORIF groups. *MIPO*, minimally invasive plate osteosynthesis; *ORIF*, open reduction and internal fixation; *CI*, confidence interval.

technique group when compared to the comparison procedures (OR 0.29; CI 95% 0.15-0.56; $P = .0002$) (Fig. 6, *A*). The analysis did not reveal any significantly increased risk between the techniques in terms of infection, implant failure, and nonunion rates. (Fig. 6, *B*-*D*)

Functional scores

Regarding the functional scores, 2 studies[17,33] utilized the q-DASH assessment. The mean differences in q-DASH scores between the MIPO group and the comparison group were found to be nonsignificant (Fig. 7, *A*). Similarly, among the 2 studies that used the DASH score[13,32] no significant mean differences were observed (Fig. 7, *B*). The Constant scores, assessed by 6 studies,[13,14,17,25,27,32] also did not show any significant differences (Mean diff: 0.15; CI 95%: −1.71 to 2.00; $P = .88$) between the MIPO technique and the comparison procedures (Fig. 7, *C*).

Risk of bias across studies

There was no clear evidence of reporting bias; the studies included in the quantitative analysis had similar sample sizes and standard deviations. There was no clear evidence of different proportions of larger studies showing either positive or negative differences.

However, this analysis is limited because of the inclusion of only up to eight studies in the meta-analysis.

Additional analysis

One study[25] was excluded from the synthesis of surgical time, time to bone union and complications as it was published by the same author,[27] in the same year and with a very similar cohort (similar demographic value) to another study included, leading us to believe that they represent the same group of patients. To verify if the inclusion of the study would affect the results we implemented a sensitivity analysis for the outcomes of paresthesia, infection, bone nonunion, and implant failure (Fig. 8, *A*-*D*).

It was observed that adding the mentioned study did not affect the direction of the difference between groups. Other analyses such as subgroup or meta-regression were not performed.

Discussion

In this review, we were able to observe some relevant characteristics of the MIPO technique for midshaft clavicle fracture treatment. In our review, most of the studies reportedly used a beach chair positioning, with 2 incisions technique. Most commonly, traction was used for reduction, and a clavicle-contoured locked plate was used.

In the broader context of existing evidence, our study provides valuable insights into the comparison between the MIPO technique and ORIF for midshaft clavicle fractures. A previous systematic review[37] focused on MIPO vs. ORIF studies for midshaft clavicle fractures reported a significant reduction in overall complications in the MIPO group, similar to our findings. However, it analyzed all complications without separately evaluating each complication risk. Our findings align with the previous review in demonstrating a significant reduction in numbness incidence with the MIPO technique compared to ORIF; however, we did not observe significant differences in other complications such as implant loosening, infection, and nonunion suggesting that while MIPO may offer advantages in terms of reduced numbness, these benefits may not extend uniformly across all complications. Notably, our study revealed a significant reduction in surgical time with the MIPO technique, which contrasts with the previous review's findings

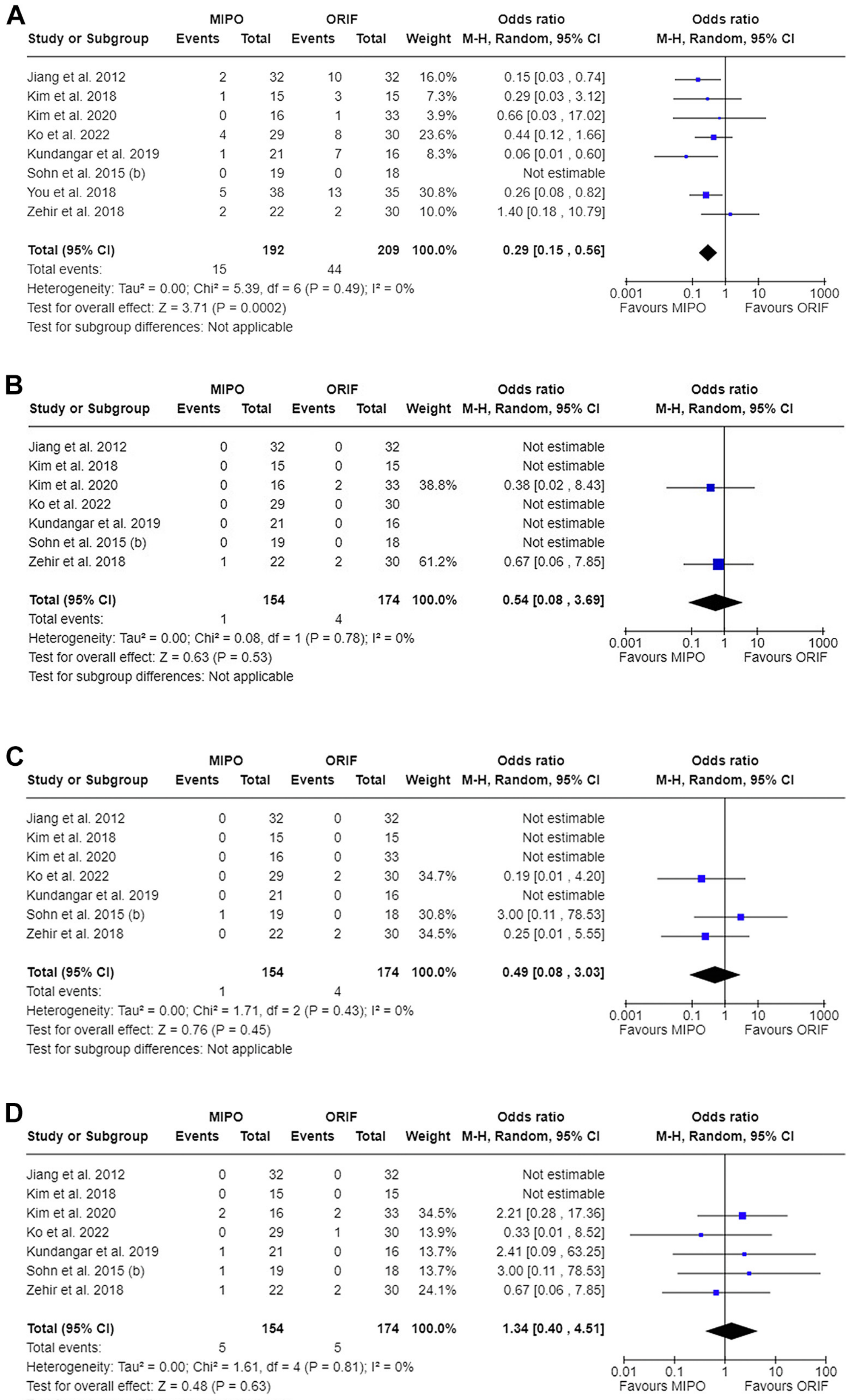

Figure 6 (**A**): Paresthesia compared between MIPO and ORIF groups. (**B**): Infection compared between MIPO and ORIF groups. (**C**): Nonunion compared between MIPO and ORIF groups. (**D**): Implant failure compared between MIPO and ORIF groups. *MIPO*, minimally invasive plate osteosynthesis; *ORIF*, open reduction and internal fixation; *CI*, confidence interval.

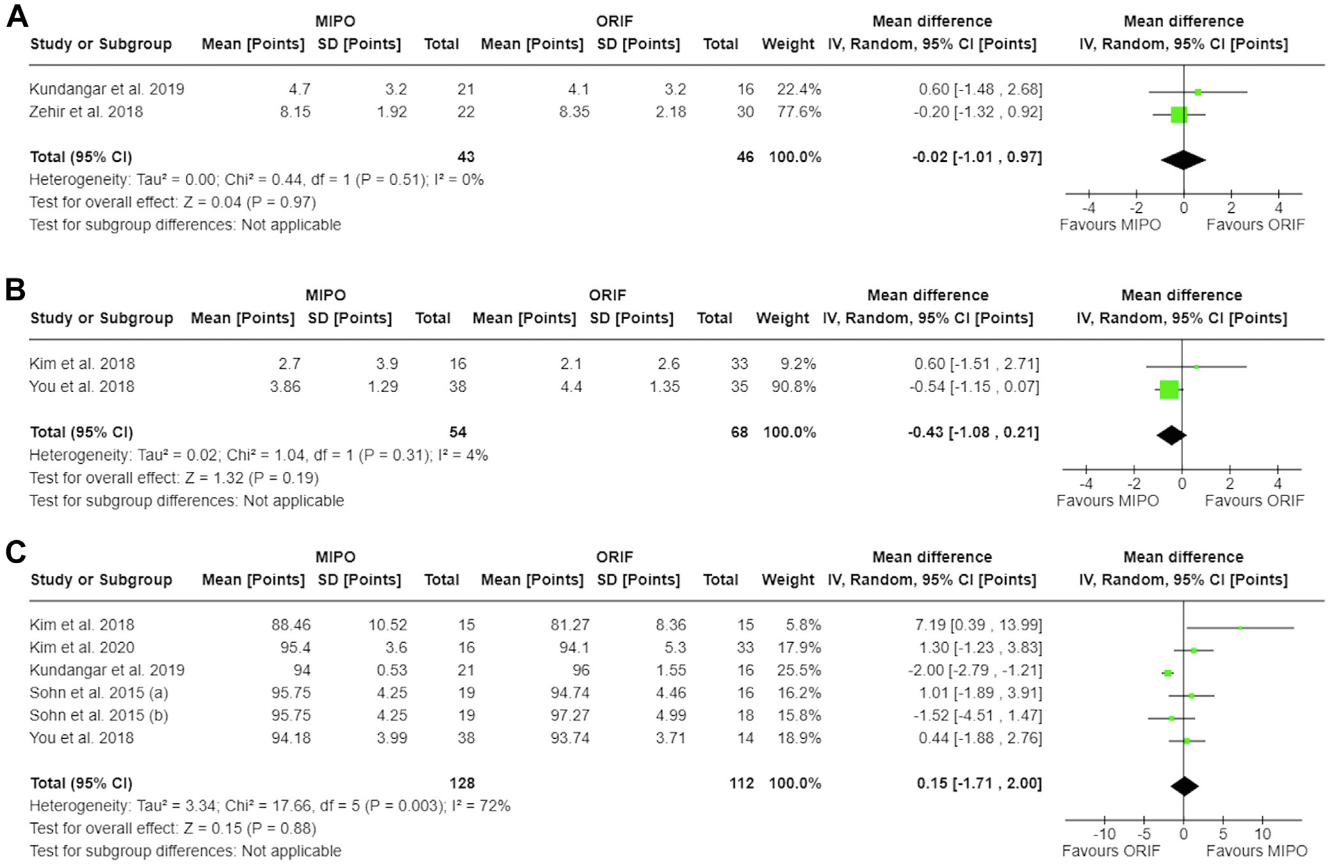

Figure 7 (**A**): q-DASH compared between MIPO and ORIF group. (**B**): DASH compared between MIPO and ORIF groups. (**C**): Constant compared between MIPO and ORIF groups. *q-DASH*, quick disabilities of the arm shoulder and hand score; *DASH*, disabilities of the arm shoulder and hand score; *MIPO*, minimally invasive plate osteosynthesis; *ORIF*, open reduction and internal fixation; *CI*, confidence interval.

which did not observe differences in surgical time.[37] We attribute this discrepancy to variations in study inclusion criteria or differences in the specific populations and surgical techniques evaluated. Furthermore, our analysis showed no significant differences in functional scores between the MIPO and ORIF groups suggesting that the long-term functional outcomes are equivalent between the different surgical approaches.

It is important to acknowledge limitations within the evidence included. One notable limitation is the overall moderate risk of bias observed across the observational, experimental, and clinical trials studies, as revealed by our risk of bias assessment. A significant limitation observed is the lack of detailed descriptions regarding the measurement of clinical endpoints (e.g. What was considered as infection?) and radiological outcomes (e.g. which parameters were considered to confirm bone union) in the majority of the studies. More rigorous and reproducible reporting on measurement methods as well as more detailed patient recruitment and allocation description could contribute to more robust and confident data.

In this study, we opted for broader inclusion criteria, encompassing all reports of MIPO for midshaft clavicle fractures, regardless of study design and comparison group. While this approach aimed to provide a comprehensive view of MIPO outcomes, it resulted in a limited number of studies directly comparing MIPO with surgical techniques other than ORIF with plate, such as titanium elastic nail and Intramedullary nails, which were then not subject to meta-analysis. Therefore, the comparative results between MIPO and these alternative techniques should be interpreted with caution.

Despite not being considered as an outcome of interest for this review, esthetic satisfaction with the surgical scar was not evaluated in the majority of the studies. As we believe that this may be also an advantage of the MIPO technique,[13] future research in this topic may consider including this outcome in their analysis. Finally, as the topic of MIPO for midshaft clavicle fractures is of growing interest, it is possible that relevant articles may have been published since our research began. While we made efforts to conduct a thorough search, it is important to acknowledge the possibility of missing recent studies that could have influenced the overall findings. Furthermore, the lack of standardized and comparable reporting of fracture classifications across all included studies prevented us from conducting subgroup analyses based on fracture types.

Our results contribute to the growing body of evidence supporting the use of the MIPO technique for clavicle fractures, as it demonstrates a low risk of complications and good clinical outcomes in the short and mid-term. Moreover, the MIPO technique offers the advantage of shorter surgical time and potentially reduced risk of local area numbness. It is important to note that further high-quality clinical trials, with a greater emphasis on standardized reporting of methods, are needed to enhance our understanding of the outcomes and optimize the use of MIPO in this context. While this study's findings may suggest that MIPO is comparable to ORIF, the existing data's limitations and lack of consistency across studies prevent us from definitively establishing the equivalence or superiority of both techniques at this point. Continued research efforts will provide more robust evidence to

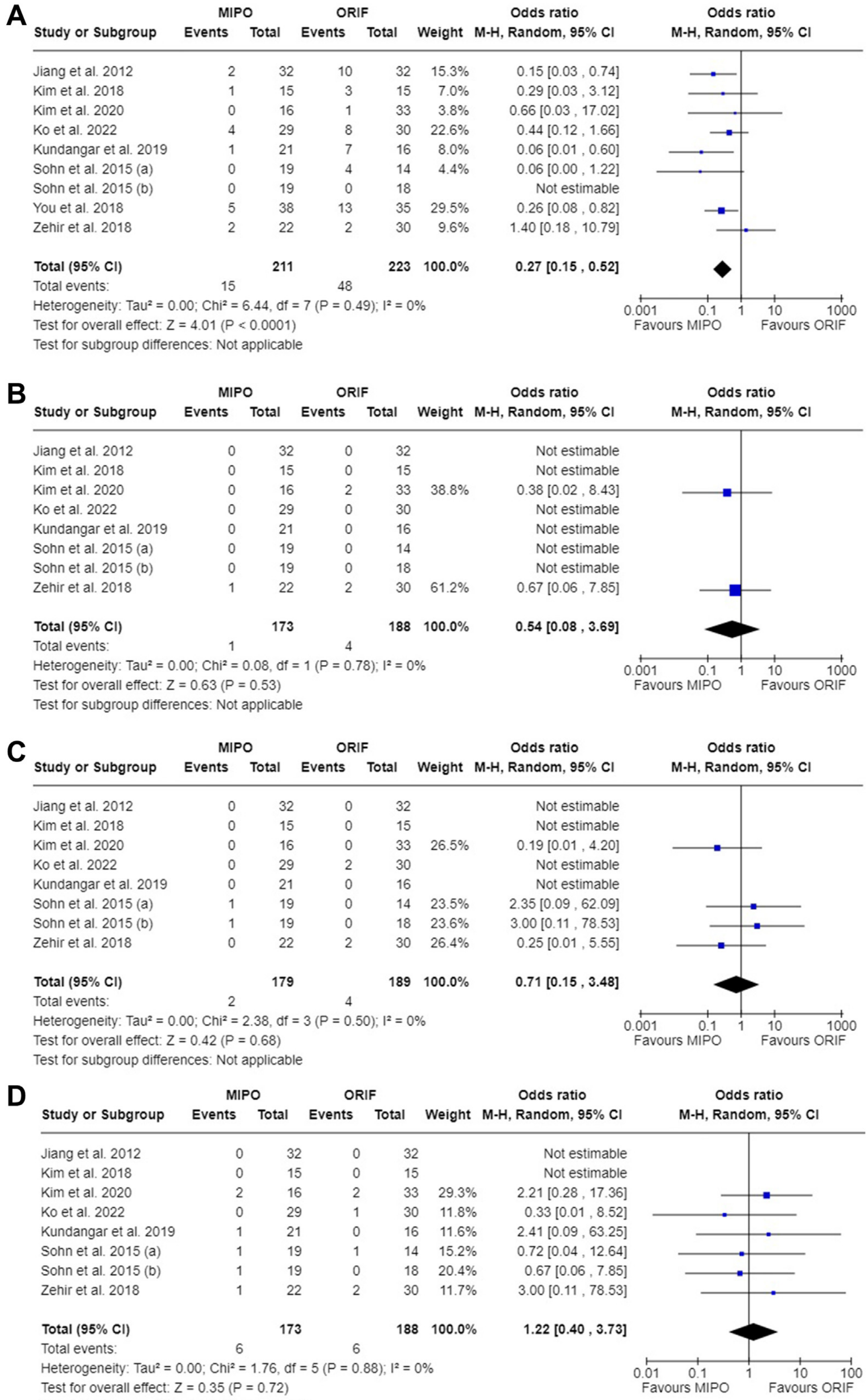

Figure 8 (**A**): Sensitivity analysis including the study by Sohn et al[6] in the comparison of paresthesia between MIPO and ORIF groups. (**B**): Sensitivity analysis including the study by Sohn et al[6] in the comparison of infection between MIPO and ORIF groups. (**C**): Sensitivity analysis including the study by Sohn et al[6] in the comparison of bone nonunion between MIPO and ORIF groups. (**D**): Sensitivity analysis including the study by Sohn et al[6] in the comparison of implant failure between MIPO and ORIF groups. *MIPO*, minimally invasive plate osteosynthesis; *ORIF*, open reduction and internal fixation; *CI*, confidence interval.

guide clinical decision-making and further refine the management of clavicle fractures.

Conclusion

This systematic review indicates that the MIPO technique for midshaft clavicle fractures demonstrates similar clinical outcomes to ORIF, while providing the added benefits of shorter surgical time and potentially lower risk of local area paresthesia. Future research with improved methodological rigor and standardized reporting is necessary to further enhance our understanding of MIPO's effectiveness and refine its application in clinical practice.

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