

Comparison of outcomes of retrograde intramedullary nailing versus locking plate fixation in distal femur fractures: A Systematic Review and Meta-analysis of 936 patients in 16 studies

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ABSTRACT

Background: The surgical treatment for distal femur fractures has evolved over time, and it depends upon certain factors; open or closed fracture type, the pattern of fracture, presence of metaphyseal comminution, intra-articular extension, and the bone quality are some of the crucial ones. Both retrograde intramedullary nails (RIMN) and locking plates (LP) can be used for the fixation of these fractures. However, the optimal method among the two devices is still a topic of debate, the superiority of one over the other being unclear. Hence, this systematic review and meta-analysis was conceptualized to compare the outcomes of RIMN with distal femur LP. **Methods:** The primary electronic search was conducted on Medline (PubMed), Scopus, Embase, Cinahl, and Cochrane Library databases for the published literature from the inception to 25th February 2022. The studies compared outcomes of RIMN versus LP fixation of the acute supracondylar or distal femur fracture (AO/OTA type-33A, B, and C) and reported at least one primary (mean fracture union time, complications, implant-related complications, and re-operation rate) or secondary outcome (duration of surgery, intra-operative blood loss, and knee range of motion), were included.

Results: Six randomized control trials, 2 prospective and 8 retrospective studies with 936 patients with 8 bilateral cases (467: RIMN; 477: LP) were included. Our analysis demonstrated no statistically significant difference in terms of mean fracture union time, overall complications, implant-related complications, re-operation rates, and duration of surgeries. Although a better knee range of motion was seen in the LP group, however, it also showed more nonunion and infection than the RIMN group.

Conclusion: The present review shows that there are significantly lesser nonunions and infections, in the RIMN group as compared to LP for distal femur fractures, although a better postoperative knee range of motion was seen in the latter. However, in terms of fracture union time, the overall rate of complications, re-operation rates, and duration of surgeries, there is no difference between the two surgical options.

1. Background

Low-energy trauma in elderly patients with osteoporotic bones and high-energy trauma in young adults causes distal femur fractures, which comprise of 0.4% of all fractures and 3–6% of femur fractures.^{1,2} Distal femur fracture treatment remains challenging, and they must be surgically treated to achieve an optimal outcome.^{1–3} Surgical treatment

options have evolved over time, and the choices are dependent on factors like open or closed fracture types, the pattern of fractures, the presence of metaphyseal comminution, intra-articular extension, and bone quality.⁴

Earlier, open reduction and internal fixation with extramedullary implants were considered as the standard treatment for these fractures; and have a high incidence of postoperative complications in view of

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excessive intraoperative soft tissue stripping. Frequent secondary interventions like bone grafting were required to augment healing or attain fracture union.⁵ With the advent of LP, the ease of fracture fixation and the complications were minimized with excellent results, and currently, these are the most commonly used implants for periarticular distal femur fractures.^{4,6}

Green et al.⁷ in 1988 introduced the RIMN for the fixation of distal femur fractures, with advantages like indirect reduction and internal fixation, which avoid soft tissue damage and disruption of blood supply and give excellent union rates in distal femur fractures.^{8,9} Being intramedullary, nails are load-sharing devices that remain close to the femoral axis, with better stress distribution than an eccentrically placed plate and screws construct; nailing also requires a short operative time, and there is less perioperative blood loss, and patients can be mobilized early.^{4,10}

However, the optimal method among the two devices is still a topic of debate, with the superiority of one over the other being unclear in terms of advantages and disadvantages.^{11,12} In literature, there have been reviews, but with a limited number of studies, some of which also included results of dynamic condylar screws.^{13,14} Hence, this systematic review and meta-analysis was carried out to include as many eligible studies as possible and to compare the outcomes of RIMN with distal femur LP in terms of fracture union time, complications, duration of surgeries, intra-operative blood loss, and knee range of motion.

2. Methods

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines [15]. A protocol of the systematic review was formulated and registered at the International Prospective Register of Systematic Reviews (PROSPERO) vide registration id: **CRD42021258496**.

3. Literature search

Three authors (RKR, PK, and AS) used a pre-formulated well-defined search strategy without initial limitation to the language and country of publication to conduct a primary search of the electronic databases of Medline (PubMed), Scopus, Embase, Cinahl, and Cochrane Library (an additional database was searched which was not mentioned in PROSPERO protocol registration) from the inception to 25th February 2022 [Table 1]. A manual search of the bibliography of the review articles and the included articles was done to find any potentially missed relevant articles. Additionally, we looked for other relevant studies in the electronic databases of a few pertinent peer-reviewed publications. Finally, a total of 1945 results were obtained.

4. PICO framework for the study

Participants: Adult humans with distal femur fractures.

Intervention: Retrograde intramedullary nailing.

Control: Open reduction and internal fixation with locking plate.

Outcomes: Mean fracture union time, complications, duration of surgery, implant-related complication, re-operation rate, intra-operative blood loss, and knee range of motion.

5. Inclusion and exclusion criteria

Randomized control trials (RCTs) or non-randomized studies in the English language that compared outcomes of RIMN versus LP fixation of acute supracondylar or distal femur fractures (AO/OTA type-33A, B, and C), and reported at least one outcome interest of the review were included. Single cohort arm studies that have not compared the outcomes of RIMN versus LP for distal femur fracture fixation or those included patients aged <18 years, periprosthetic fractures, fracture non-

Table 1
Literature search strategy used for the study.

Database	Period -from inception to 25 th February 2022 with keywords	Results
MEDLINE (PubMed)	((("distal"[All Fields] OR "distalization"[All Fields] OR "distalize"[All Fields] OR "distalized"[All Fields] OR "distalizer"[All Fields] OR "distalizers"[All Fields] OR "distalizes"[All Fields] OR "distalizing"[All Fields] OR "distally"[All Fields] OR "distals"[All Fields]) AND ("femoral fractures"[MeSH Terms] OR ("femoral"[All Fields] AND "fractures"[All Fields]) OR ("femur"[All Fields] AND "fracture"[All Fields]) OR "femur fracture"[All Fields])) OR ("supracondylar"[All Fields] AND ("femoral fractures"[MeSH Terms] OR "femoral"[All Fields] AND "fractures"[All Fields]) OR "femoral fractures"[All Fields] OR "femur"[All Fields] AND "fracture"[All Fields]) OR "femur fracture"[All Fields])) AND ((("retrograde"[All Fields] OR "retrogradely"[All Fields]) AND ("fracture fixation, intramedullary"[MeSH Terms] OR ("fracture"[All Fields] AND "fixation"[All Fields] AND "intramedullary"[All Fields]) OR "intramedullary fracture fixation"[All Fields] OR "nailing"[All Fields] OR "nail s"[All Fields] OR "nailed"[All Fields] OR "nailings"[All Fields] OR "nails"[MeSH Terms] OR "nails"[All Fields]) AND ((("bone plates"[MeSH Terms] OR "bone"[All Fields] AND "plates"[All Fields]) OR "bone plates"[All Fields] OR "plate"[All Fields] OR "plate s"[All Fields] OR "plated"[All Fields] OR "plates"[All Fields] OR "plating"[All Fields] OR "platings"[All Fields]) AND ("fixate"[All Fields] OR "fixated"[All Fields] OR "fixates"[All Fields] OR "fixating"[All Fields] OR "fixation"[All Fields] OR "fixational"[All Fields] OR "fixations"[All Fields] OR "fixator"[All Fields] OR "fixator s"[All Fields] OR "fixators"[All Fields]))	130
Embase	((('distal femur fracture' OR (supracondylar AND femur AND fracture)) AND 'locking plate fixation' OR 'locking compression plate') AND 'retrograde intramedullary nailing' OR 'retrograde nailing'	290
Scopus	(ALL(distal AND femur AND fracture) OR ALL (supracondylar AND femur AND fracture) AND ALL (locking AND plate AND fixation) OR ALL (locking AND compression AND plate AND fixation) AND ALL (retrograde AND nailing) OR ALL (retrograde AND intramedullary AND nailing))	753
Cinahl	TX distal femur fracture OR TX supracondylar fracture femur AND TX locking plate fixation OR TX locking compression plate AND TX retrograde intramedullary nailing OR TX retrograde nailing	432
Cochrane Library	Cochrane Reviews matching distal femur fracture in All Text OR supracondylar femur fracture in All Text AND retrograde intramedullary nail in All Text OR retrograde nailing in All Text AND plate fixation in All Text - (Word variations have been searched)	340
Total		1945

union, pathological fracture, the study included the fixation of distal femur fracture other than RIMN and LP were excluded. Conference abstracts, book chapters, case reports, e-posters, review articles, cadaveric studies, biomechanical studies, and articles in languages other than English were also excluded.

6. Study selection

Based on the title of the article and abstracts, three authors (RKR, SA, and PK) independently screened the studies, and those found eligible for the study outcome were chosen. After the assessment of the full text of all selected studies, based on the inclusion and exclusion criteria, relevant studies were included in the current review. A disagreement among the authors was settled through mutual agreement.

7. Data extraction

Three authors (PK, RUH, and AS) extracted data from the studies and entered it into an excel spreadsheet with the names of the authors, the year the article was published, the level of evidence, the total number of

patients, implants used, the number of patients in the individual group, pertinent demographic data, and the primary and secondary outcomes. This information was compiled in a table [Table-2] and outcome of interests in Table 3 and 4. To eliminate any potential operator-dependent bias, all the writers of the current review studied and discussed each of

Table 2
Characteristics of included studies.

Sl no.	Study	Study design	Level of evidence	Implant used	Number of patients/cases	Male/Female	Mean age in years (range/SD)	AO -Classification A1/A2/A3/B/C1/C2/C3	Open/closed fracture	Mean follow up (months)	
1	Markmiller et al. 2004 ¹⁹	Prospective	III	RIMN	16 (Overall total case = 39 (7 cases bilateral)	14/2	43.7 (20–77)	A-11/C-8 one loss to follow up	High energy trauma-7	Overall 12	
				LP	16	6/10	57.2 (17–83)	A-10/C-10	High energy trauma-9		
2	Thomson et al. 2008 ²⁰	Retrospective	III	RIMN	11	6/5	50.5	Type-C	NR	Overall 80	
				LP	11 (one bilateral) = 12 cases	7/4	49.9	Type-C	NR		
3	Henderson et al. 2010 ²¹	Retrospective	III	RIMN	12	4/8	63 (23–87)	A1-2, A2-2, A3-3 C1-1, C2-3, C3-1	High energy-2	16.75	
				LP	12	3/9	65(25–96)	A1-2, A2-2, A3-3 C1-1, C2-3, C3-1	High energy-3	14.25	
4	Hierholzer et al. 2011 ²²	Retrospective	III	RIMN	59	NR	Overall-54 (17–89)	A1:31, C:28	High energy-31, Open-19	13	
				LP	56	NR		A1:21, C:35	High energy—37, Open-31	15	
5	Gao et al. 2012 ²³	Retrospective	III	RIMN	17	13/4	50.6 ± 16.3	A1/A2/A3-6/8/3	High energy trauma-13	26.29 ± 12.71	
				LP	19	12/7	54.7 ± 16.1	A1/A2/A3-8/7/4-	Multiple injury-5 High energy trauma-12, Multiple injury-3	23.37 ± 5.33	
6	Demirtas et al. 2014 ¹¹	Retrospective	III	RIMN	13	11/2	31.1	A1/A2/A3-4/5/4	High energy-12, open-6	26.7	
				LP	15	13/2	36	A1/A2/A3-3/5/7	High energy-14, open-7	31.3	
7	Chander et al. 2015 ²⁴	Prospective		RIMN	24	NR	Overall 21-70	A/C only	NR	Overall 12	
8	Ciloglu et al. 2017 ²⁵	RCT	I	RIMN	23	16/7	37.2 ± 12.7	A1/A2/A3-5/14/4	NR	High energy-15, Open-7	40
				LP	24	18/6	42.6 ± 13	A1/A2/A3/B1/C1-5/10/7/1/1	High energy-17, Open-8	35	
9	Gill et al. 2017 ¹²	RCT	I	RIMN	20	13/7	36.0 ± 14.1	A1/A2/A3-7/10/3	high-energy-14, Open-5	27.8 ± 7	
				LP	22	16/6	38.7 ± 15.6	A1/A2/A3-9/8/5	high-energy-14, open-7	29.2 ± 92	
10	Aggarwal et al. 2018 ⁴	RCT	I	RIMN	20	15/5	39.6	A3-6/C2-7/C3-2, rest unknown	high-energy-17, Open-7	Overall 11.34	
				LP	20	16/4	37.4	A3-4/C2-7/C3-5, rest unknown	high-energy-19, open-9		
11	Rollo et al. 2019 ²⁶	Retrospective	III	RIMN	15	11/4	42.67 ± 18.32	A/B/C-5/5/5	high-energy-10	Overall 16.24 ± 0.44	
				LP	15	11/4	42.84 ± 18.32	A/B/C-5/5/5	high-energy-10		
12	Gupta et al. 2021 ²⁷	RCT	I	RIMN	20	Overall	Overall 47 (28–70)	NR	Overall High energy-35	Overall 12	
				LP	20	35/5		NR			
13	Ahmed et al. 2021 ²⁸	RCT	I	RIMN	80	56/24	33.9 ± 10.26	NR			
				LP	80	49/31	33.2 ± 48.61	NR			
14	Mahar et al. 2021 ²⁹	RCT	I	RIMN	50	30/20	20–60	A1-32, A2-11 A3-7	31-high velocity	Minimum 6	
				LP	50	35/15	20–60	A1-32, A2-11 A3-7	31-high velocity	Minimum 6.	
15	Meccariello et al. 2021 ³⁰	Retrospective	III	RIMN	30	22/8	42.67 ± 18.32	A1-4, A2-4, A3-2 B1-4, B2-2, B3-4, C1-4, C2-4, C3-2	RTA-16	17.32 ± 0.42	
				LP	30	20/10	42.84 ± 18.32	A1-4, A2-5, A3-2 B1-5, B2-1, B3-5, C1-3, C2-4, C3-1	RTA-19	16.45 ± 0.47	
16	Vemulapalli et al. 2022 ³¹	Retrospective	III	RIMN	50	Overall	51 (21–86)	AO/OTA 33-C type	Overall 50-open, 56-closed	11	
				LP	56	55/51	51 (21–86)	AO/OTA 33-C type		12.7	

RIMN-Retrograde intramedullary nail, LP-locking plate, NR-Not reported.

Table 3

Data reporting duration of surgery, fracture union time, blood loss, and knee range of motion.

Sl no.	Study	Implant used	Duration of surgery in minutes	Mean fracture union time (weeks)	Blood loss (ml)	Knee ROM
1	Markmiller et al. 2004 ¹⁹	RIMN LP	NR NR	14.6 13.8	NR NR	103 110
2	Thomson et al. 2008 ²⁰	RIMN LP	NR NR	NR NR	NR NR	121 ⁰ 102 ⁰
3	Henderson et al. 2010 ²¹	RIMN LP	NR NR	NR NR	NR NR	2–97 ⁰ 0–99 ⁰
	Hierholzer et al. 2011 ²²	RIMN LP	NR NR	NR NR	NR NR	NR NR
5	Gao et al. 2012 ²⁴	RIMN	87.4 ± 13.2 79.7 ± 14.3	NR	298 ± 65.2 200 ± 48.9	103.5 ± 11.0 98.2 ± 21.5
6	Demirtas et al. 2014 ¹¹	RIMN LP	NR NR	22.3 ± 10 25.7 ± 15	NR NR	NR NR
7	Chander et al. 2015 ²⁴	RIMN LP	NR NR	18 14	NR NR	NR NR
8	Ciloglu et al. 2017 ²⁵	RIMN	NR	25.3 ± 5.7 22.3 ± 9	NR	102.6 ± 16.5 115.8 ± 18.3
9	Gill et al. 2017 ¹²	RIMN LP	102.3 ± 20.6 88.4 ± 17.6	22.6 ± 13.1 26.5 ± 12.9	323.0 ± 74.3 228.2 ± 45.8	107.0 ± 9.9 112.0 ± 9.8
10	Aggarwal et al. 2018 ⁴	RIMN LP	105 110	14.6 16.2	NR	Mean flexion 113.4 Mean flexion 106.3
11	Rollo et al. 2019 ²⁶	RIMN LP	52.8 ± 15.6 60.8 ± 20.4	20.29 ± 2.24 20.43 ± 2.06	NR	NR
112	Gupta 2021 ²⁷	RIMN LP	NR NR	15.2 ± 4.83 18.4 ± 1.23	NR	109.5.2 ± 11.46 104.75 ± 8.19
13	Ahmed et al. 2021 ²⁸	RIMN LP	83.29 ± 7.48 106.62 ± 7.69	NR	NR	NR
14	Mahar et al. 2021 ²⁹	RIMN LP	NR NR	25.36 ± 6.32 24.16 ± 3.4	NR	NR
15	Meccariello et al. 2021 ³⁰	RIMN LP	51.6 ± 17.6 62.7 ± 21.3	20.64 ± 2.27 20.46 ± 2.01	NR	NR
16	Vemulapalli et al. 2022 ³²	RIMN LP	NR NR	23.2 ± 13.6 26.4 ± 18.4	NR	NR

RIMN-Retrograde intramedullary nail, LP-locking plate, NR-Not reported.

the publications that were ultimately chosen. The current review included 16 studies that were relevant to the current systematic review and meta-analysis [Fig. 1].

8. Outcome measure

The primary outcomes of interest were the mean fracture union time, complications (delayed union, non-union, malunion, knee stiffness, knee pain, infection, limb shortening >1.5 cm, and implant-related

complications), and re-operation rate. The secondary outcomes were duration of surgery, intra-operative blood loss, knee range of motion, and functional outcome.

9. Statistical analysis

The qualitative data from individual studies were presented in tabular form for comparison purposes and included the baseline study characteristics as well as the primary and secondary study outcomes. If a specific outcome of interest was reported in two or more studies, a meta-analysis was performed. The effects measures for continuous variables were expressed with mean Difference or standard mean difference, and for dichotomous variables, it was expressed with odds ratio or relative risk. All of the findings were accompanied by 95% confidence intervals. Heterogeneity was evaluated by the use of the I² test. Any cause of clinical heterogeneity was also investigated. If the heterogeneity was found low (I² close to 0%) a fixed-effects model was used; otherwise, a random-effects model. Wherever possible, non-RCTs and RCTs were subjected to subgroup analysis. For the visual presentation of each outcome of interest, a forest plot was plotted and shown. All statistical analyses were carried out using Review Manager Software version 5.4. (RevMan 5.4.1).¹⁶

10. Risk of bias assessment

Assessment of the risk of bias was done by two independent observers (RKR and KR). MINORS tool¹⁷ was used for the assessment of the risk of bias in non-randomized comparative studies, and for RCTs, the Cochrane Collaboration's risk of bias tool¹⁸ was used. Any discrepancy was resolved by mutual agreement among the observers. The risk of bias and publication bias was assessed by Rev Man 5.4.1 software.¹⁶

11. Results

11.1. Search and screening

For each of the five searched databases, the results of the search strategy have been summarized in the table-1 using the PRISMA flow-chart. Combining the results of all five databases yielded a total of 1945 results. 1687 articles were excluded after removing duplicates and articles not relevant to the current review. The remaining 258 studies were further reviewed. Following the screening through the titles and abstracts, 28 articles were identified, and the full text of all these articles was evaluated for eligibility. Finally, 16 articles^{4,11,12,19–31} were included in the current systematic review and meta-analysis [Fig. 1].

11.2. Characteristics of the included studies

8/16 included studies were prospective in design,^{4,12,19,24,25,27–29} with 6 being RCTs^{4,12,25,27–29} and the remaining 8 being retrospective.^{12,21–24,27,31,32} The current study included 936 patients with 944 distal femur fractures. The RIMN was used in 467 fractures, while the LP was used in 477 fractures. The gender of the patients was reported in only 14/16 studies for the two groups treatment, with 472 males and 261 females. The patients' mean age ranged from 20 to 65 years, and the average follow-up period was 6–80 months.

11.3. Assessment of risk of bias

There were ten non-randomized comparative studies^{11,19–24,26,30,31} and six RCTs.^{4,12,25,27–29} For 7/10 non-randomized comparative studies, the MINORS tool Score was 16.^{19,22–24,26,30,31} The risk of bias summary and graph of all included articles is shown in Figs. 2 and 3 respectively. For the assessment of publication bias, a funnel plot was used. The funnel plot revealed a skewed distribution, indicating possible publication bias (Fig. 4).

Table 4
Complications during the follow-up period.

Sl no.	Study	Implant used	Non-union	Delayed union	Mal-union	Knee Stiffness	Knee pain	Re-operation	Implant related complications	Infection (superficial or deep)	Others	Overall complications
1	Markmiller et al. 2004 ²⁰	RIMN	1	NR	2	NR	7	2	NR	1	NR	11
		LP	2	NR	3	NR	6	2	NR	0	NR	11
2	Thomson et al. 2008 ²¹	RIMN	1	NR	0	NR	NR	1	NR	0	NR	1
		Plate	4	NR	5	NR	NR	8	NR	3	NR	12
3	Henderson et al. 2010 ²²	RIMN	1	0	1	NR	NR	4	NR	0	NR	2
		LP	2	1	4	NR	NR	2	NR	0	NR	7
	Hierholzer et al. 2011 ²³	RIMN	5	NR	NR	NR	NR	42	36	1	1	43
		LP	6	NR	NR	NR	NR	18	4	5	3	18
5	Gao et al. 2012 ²⁴	RIMN	1	0	2	NR	3	1	0	0	NR	6
		LP	3	4	1	NR	1	4	2	1	NR	12
6	Demirtas et al. 2014 ¹²	RIMN	1	2	3	8	3	NR	0	NR	NR	17
		LP	2	3	4	9	3	NR	1	NR	NR	22
7	Chander et al. 2015 ²⁵	RIMN	1	NR	NR	NR	NR	8	1	0	NR	2
		LP	1	NR	NR	NR	NR	3	4	2	NR	7
8	Ciloglu et al. 2017 ²⁶	RIMN	NR	0	10	9	4	0	NR	0	NR	23
		LP	NR	1	3	3	2	1	NR	0	NR	9
9	Gill et al. 2017 ¹³	RIMN	2	1	6	NR	1	1	0	3	NR	13
		LP	2	5	3	NR	4	2	1	5	NR	20
10	Aggarwal et al. 2018 ⁶	RIMN	0	0	3	2	NR	0	0	NR	2	7
		LP	0	1	2	5	NR	2	4	NR	3	15
11	Rollo et al. 2019 ²⁷	RIMN	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
		LP	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
12	Gupta 2021 ²⁸	RIMN	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
		LP	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
13	Ahmed et al. 2021 ²⁹	RIMN	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
		LP	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
14	Mahar et al. 2021 ³⁰	RIMN	0	5	NR	NR	NR	NR	NR	0	NR	5
		LP	0	2	NR	NR	NR	NR	NR	0	NR	2
15	Meccariello et al. 2021 ³¹	RIMN	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
		LP	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
16	Vemulapalli et al. 2022 ³²	RIMN	4	NR	NR	NR	NR	8	NR	1	NR	5
		LP	11	NR	NR	NR	NR	18	NR	3	NR	14

RIMN-Retrograde intramedullary nail, LP-locking plate, NR-Not reported.

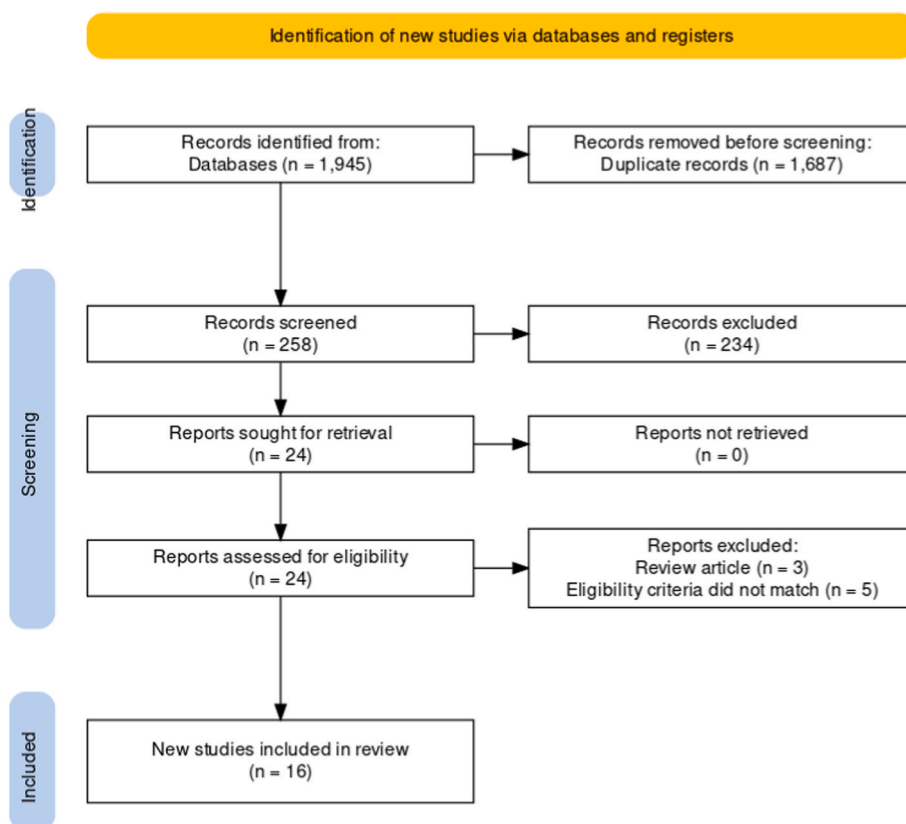


Fig. 1. PRISMA flow diagram of study selection.

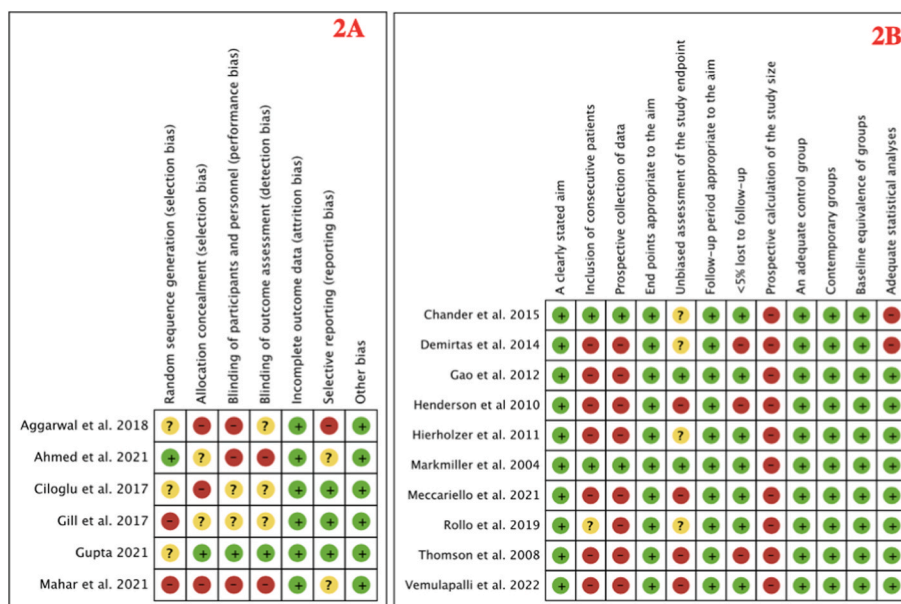


Fig. 2. (a) Risk of bias summary for a non-randomized, and (b) Randomized studies.

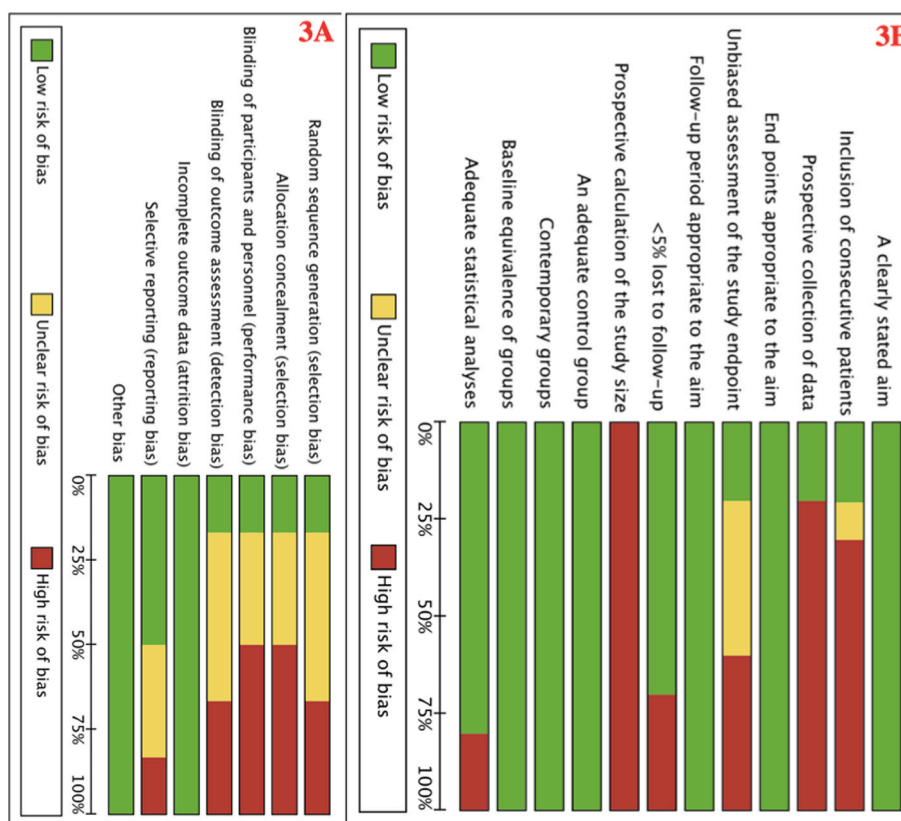


Fig. 3. (a) Risk of bias graph for nonrandomized, and (b) Randomized studies.

11.4. Primary outcomes

1. Mean fracture union time:

11/16 studies^{4,11,12,19,24,27,29-31} reported mean fracture union time for two treatment groups individually. Overall the mean fracture union time ranged between 7.4 to 22 and 6.8–25.7 weeks for RIMN and LP groups respectively. However, only 8 studies, 4 non-RCTs^{11,26,30,31} and 4

RCTs^{12,25,27,29} were included in this analysis, as 3 studies^{4,19,24} have not reported the standard deviation. With a mean difference of -0.38 (95% CI $-1.7, 0.93$, $p = 0.57$; $I^2 = 50\%$), the meta-analysis did not find a difference in fracture union time between the two treatment groups. Similarly, no difference was observed between non-RCTs and RCTs with the effect of the estimate being -0.02 (95% CI $-0.9, 0.85$, $I^2 = 0\%$) and -0.41 (95% CI $-3.65, 2.83$, $I^2 = 75\%$) respectively. The test for subgroup difference had $p = 0.2$ as shown in Fig. 5.

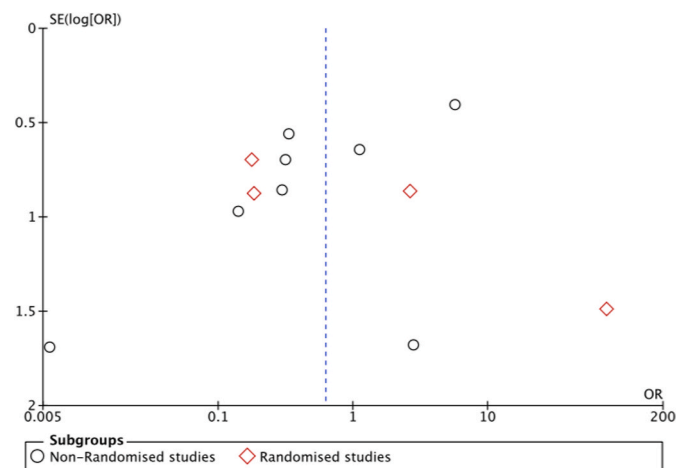


Fig. 4. Funnel plot showing a skewed distribution suggestive of possible publication bias.

2. Overall complications:

Complications were reported in 12/16 studies^{4,11,12,19-25,29,31} which included 8 non-RCTs^{11,19-24,31} and 4 RCTs^{4,12,25,29} for the two treatment groups separately. The rates of overall complications were 42.9% and 44.9% for RIMN and LP groups respectively, which was higher for the LP

group, with an odds ratio of 0.63 [95% CI 0.22, 1.80, p = 0.38; I² = 82%], we did not find a statistically significant difference between the two. The effect of estimates for non-RCTs was 0.47 (95% CI 0.13,1.69, I² = 83%), and for RCTs, it was 1.28 (95% CI 0.12,13.87, I² = 86%). The test for subgroup difference had a value of p = 0.47, shown in Fig. 6.

We further analyzed some specific complications between the two treatment groups as well:

2.1. **Nonunion:** Comparative non-union rates were reported by 11/15 studies, with 8 non-RCTs^{11,19-24,31} and 3 RCTs.^{4,12,29} The incidence was 5.8% and 10.7% for RIMN and LP groups respectively, with less events in RIMN group; analysis demonstrated a significantly lower nonunion rate in RIMN group with an odds ratio of 0.49 (95% CI 0.26, 0.91, p = 0.02; I² = 0%). The effect of estimates for non-RCTs was 0.45 (95% CI 0.24, 0.86, I² = 0%), which favored RIMN while for RCTs effect of the estimate was 1.11 (95% CI 0.14, 8.72, I² = 0%) with no statistical significance (the test for subgroup difference p = 0.41) shown in Fig. 7.

2.2. **Delayed union:** The delayed union was reported in 7/16 studies, 3 non-RCTs^{11,21,23} and 4 RCTs^{4,12,25,29} for two treatment groups individually. The incidence was 5.2% and 9.9% in RIMN and LP groups respectively. With an odds ratio of 0.53 (95% CI 0.24, 1.18, p = 0.42; I² = 0%), we did not find a statistically significant difference between the two treatment groups. Similarly, there was no statistical difference between non-RCTs and RCTs with the effect of estimates of 0.32 (95% CI 0.08,1.29, I² = 0%) and

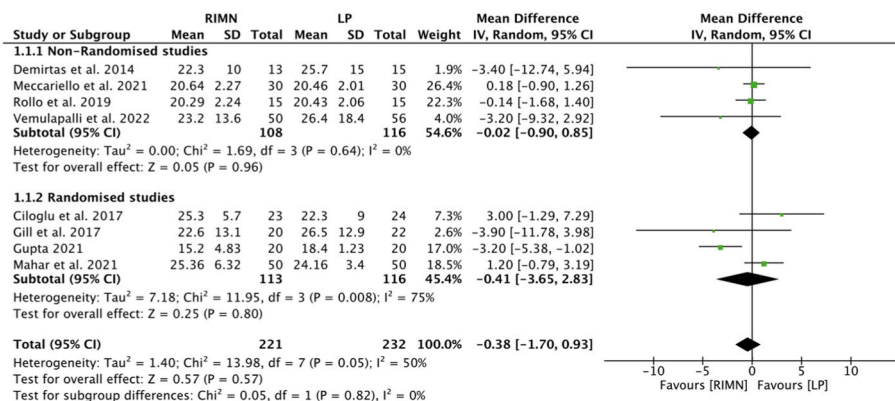


Fig. 5. Forest plot comparing mean fracture union time.

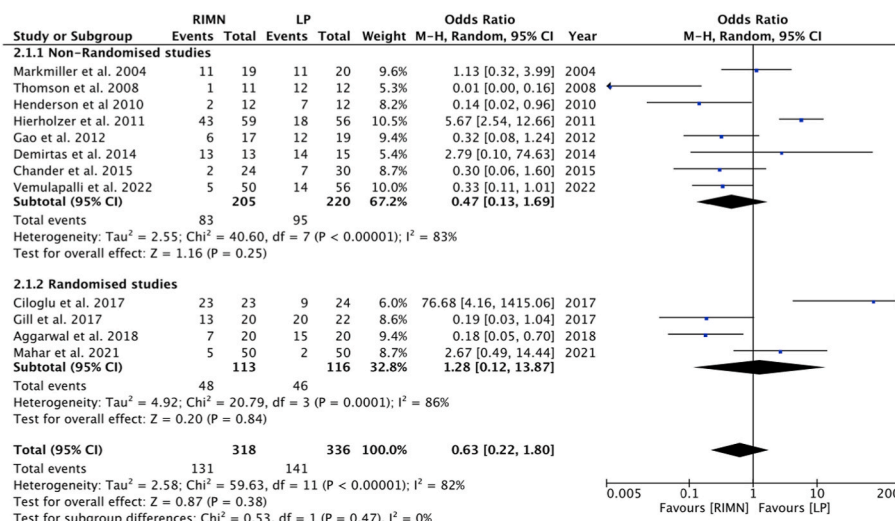


Fig. 6. Forest plot comparing overall complications.

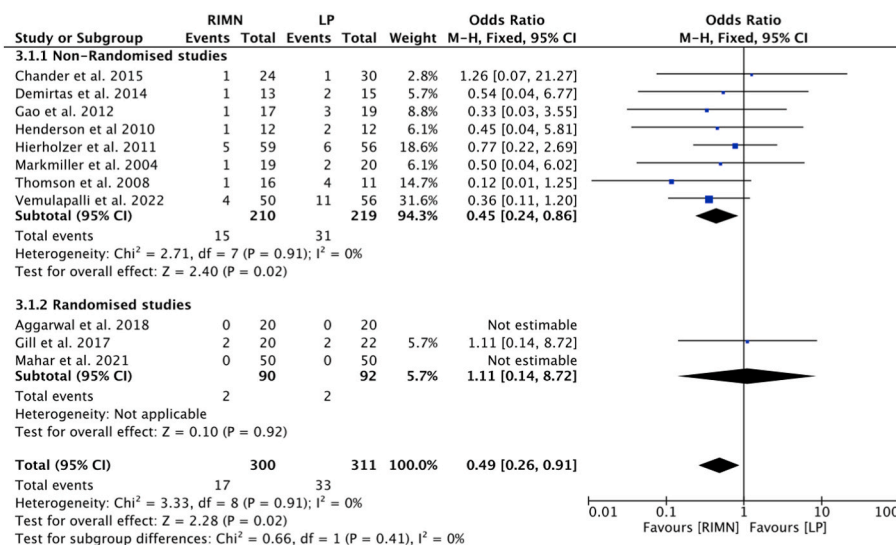


Fig. 7. Forest plot comparing nonunion.

0.71 (95% CI 0.26,1.93; I² = 29%) (the test for subgroup difference $p = 0.82$) show in Fig. 8.

- 2.3. Malunion:** malunion was reported in 8/16 studies including 5 non-RCTs^{11,19–21,23} and 3 RCTs^{6,12,25}. The incidence was 19.4% and 17.1% in RIMN and LP groups respectively. A meta-analysis demonstrated a statistically non-significant difference between the two groups of treatments with an odds ratio of 1.12 (95% CI 0.63, 2.01, $p = 0.69$; I² = 50%). There was no significant difference between the two treatment groups among the non-RCTs, with an effect of estimates of 0.43 (95% CI 0.18,1.02; I² = 29%). However, in RCTs, there was lesser malunion among the RIMN group, with an effect of the estimate of 3.24 (95% CI 1.3, 8.09; I² = 0%). The test for subgroup difference showed $p = 0.002$, as shown in Fig. 9.
- 2.4. Knee stiffness:** Knee stiffness was reported by 3/16 studies^{4,11,12} for individual treatment groups. The incidence of stiffness was 33.9% and 28.8% in the 2 groups with no statistically significant difference and an odds ratio of 0.89 (95% CI 0.39, 1.99, $p = 0.77$; I² = 0%) as shown in Fig. 10.
- 2.5. Knee pain:** Knee pain was reported in 5/16 studies, 3 non-RCTs^{11,19,23} and 2 RCTs^{12,25} for individual groups of treatment. The incidence of knee pain was 15.9% and 10.9% in RIMN and LP groups respectively. We did not find a statistically significant difference between the two groups of treatment with an odds

ratio of 1.28 (95% CI 0.60, 2.73, $p = 0.52$; I² = 0%). The effect of estimates for non-RCTs was 1.60 (95% CI 0.61,4.19; I² = 0%) and for RCTs, it was 0.88 (95% CI 0.25, 3.08; I² 58%). The test for subgroup differences had a p -value of 0.46, as shown in Fig. 11.

- 2.6. Infection:** Either superficial or deep infection was reported by 9/16 studies, 7 non-RCTs^{19–24,31} and 2 RCTs^{12,29} for the two treatment groups separately. The incidence of infection was 2.0% and 6.1% in RIMN and LP groups. A meta-analysis demonstrated a significantly lower rate of infection following RIMN compared to plating with an odds ratio of 0.32 (95% CI 0.12, 0.85; $p = 0.02$, I² = 0%). The effect of estimate for non-RCTs 0.32 (95% CI 0.11, 0.88; I² = 0%) favored the RIMN groups and for RCTs 0.32 (95% CI 0.01, 9.24) with no effect. The test for subgroup differences has a p -value of 0.95 shown in Fig. 12.
- 3. Implant-related complications:** Implant-related complications were reported in 6/16 studies 4 non-RCTs^{11,22–24} and 2 RCTs^{4,12} individually for RIMN and LP groups. The incidence of implant-related complications was 26.8% in RIMN and 7.4% in LP fixation for the distal femur fractures. A meta-analysis demonstrated a statistically non-significant difference between the two treatment groups with an odds ratio of 0.57 (95% CI 0.06, 5.78 $p < 0.0001$; I² = 81%). Similarly, no difference was found in subgroup analysis with the effect of estimates of 0.97 for non-RCTs (95% CI 0.06, 16.74; I² = 84%) and 0.17 for RCTs (95%

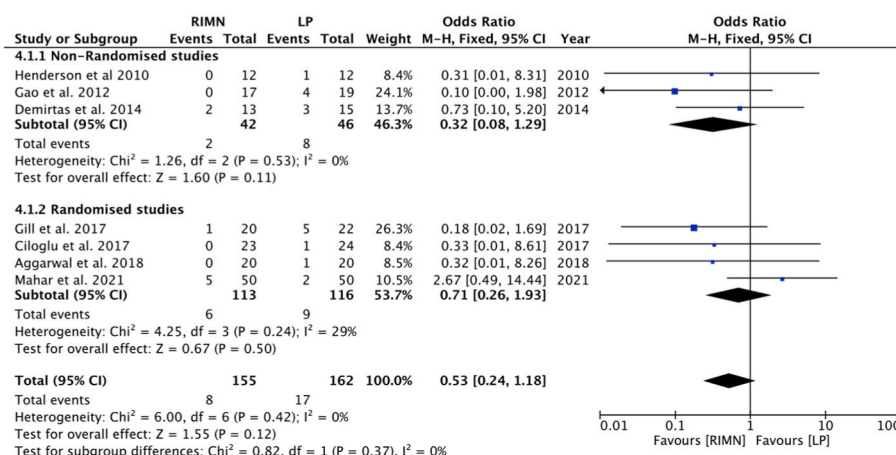


Fig. 8. Forest plot comparing delayed union.

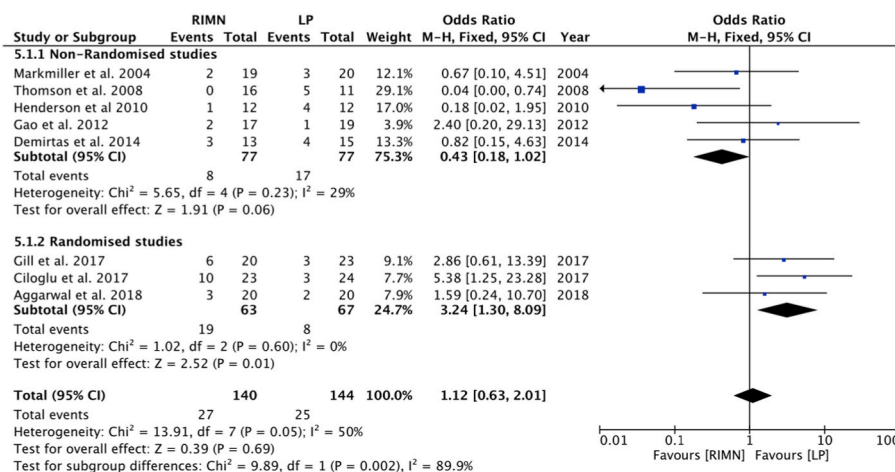


Fig. 9. Forest plot comparing malunion.

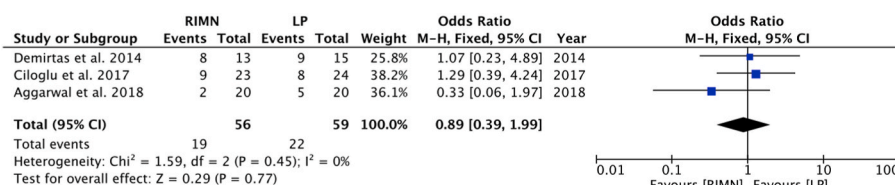


Fig. 10. Forest plot comparing knee stiffness.

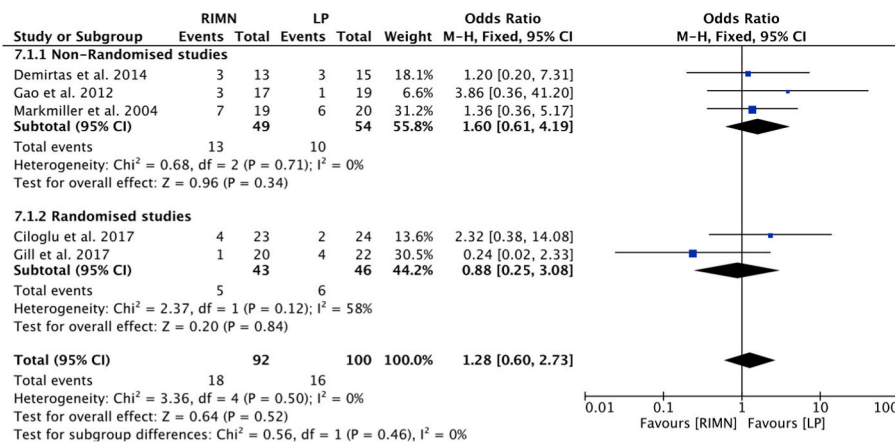


Fig. 11. Forest plot comparing knee pain.

CI 0.02, 1.51; I² = 0%). The test for subgroup difference had a p-value of 0.34, as shown in Fig. 13.

4. **Re-operation rate:** Re-operation due to implant related or any other postoperative complications were reported in 10/16 studies for two treatment groups separately with 7 non-RCTs^{19–24,31} and 3 RCTs.^{4,12,25} The re-operation rate was 26.6% and 22.5% in RIMN and LP treatment groups respectively. The meta-analysis did not show a statistically significant difference between the two groups with an odds ratio of 0.85 (95% CI 0.30, 2.40, p = 0.77; I² = 72%), and for subgroup analysis, the effect of estimate for non-RCTs was 0.99 (95% CI 0.28, 3.44; I² 80%) and for RCTs, it was 0.49 (95% CI 0.1, 2.44; I² = 0%). The test for subgroup difference had a P value of 0.50, as shown in Fig. 14.

11.5. Secondary outcomes

1. **Duration of surgery:** 6/16 studies 3 non-RCTs^{23,26,31} and 3 RCTs^{4,12,28} studies reported the duration of surgery for individual groups. The mean duration of surgery for RIMN was 51.6–105 min and that for the LP group was 60.8–110 min, which was more for LP group than RIMN group. For statistical analysis, we included only 5 studies and one study did not report the standard deviation. No statistically significant difference was found between the two groups with a mean difference of -4.58 (95% CI -19.68, 10.51, p = 0.55; I² = 95%). The effect of the estimate for non-RCTs was -3.72 (95% CI -16.28, 8.85, I² 81%) and for RCTs was -5.17 (95% CI -41.64, 31.3; I² = 97%). The test for subgroup difference had a p-value of 0.94 shown in Fig. 15.
2. **Intra-operative blood loss:** Intra-operative blood loss was reported in only 2/16 included studies^{12,23} for individual groups. Mean blood loss was 323.0–248.13 ml and 200–434.38 ml for RIMN and LP

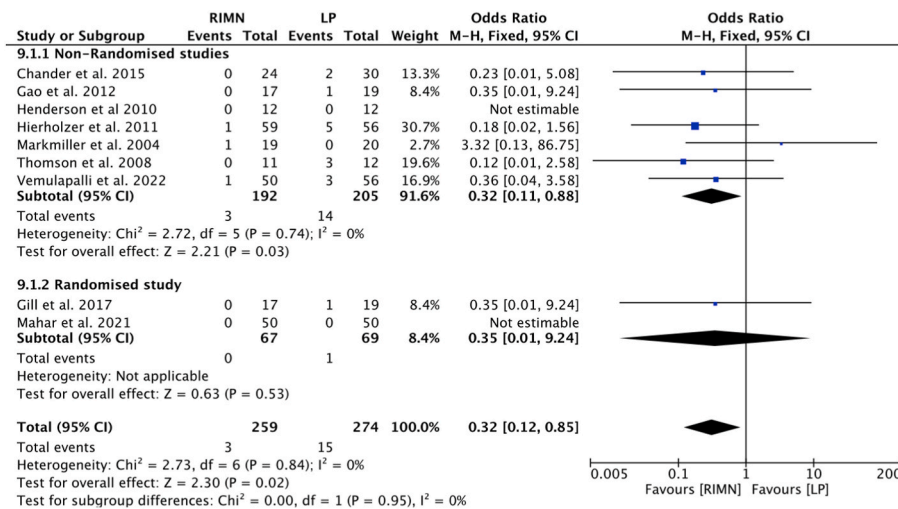


Fig. 12. Forest plot comparing infection.

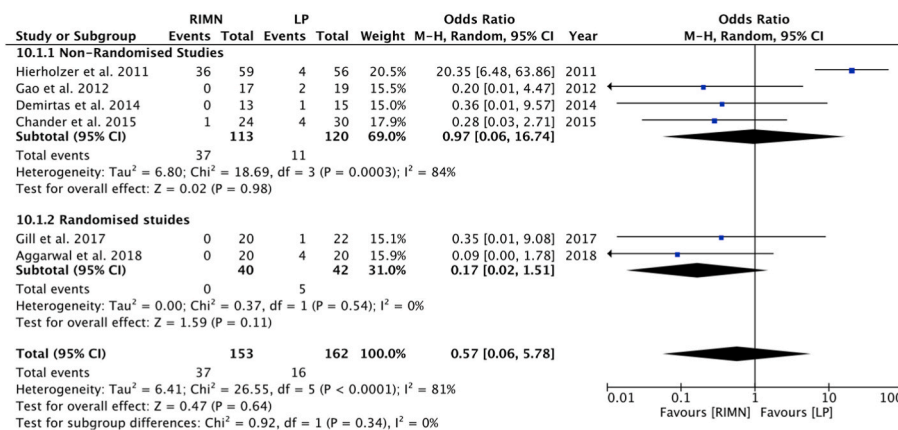


Fig. 13. Forest plot comparing implant-related complication.

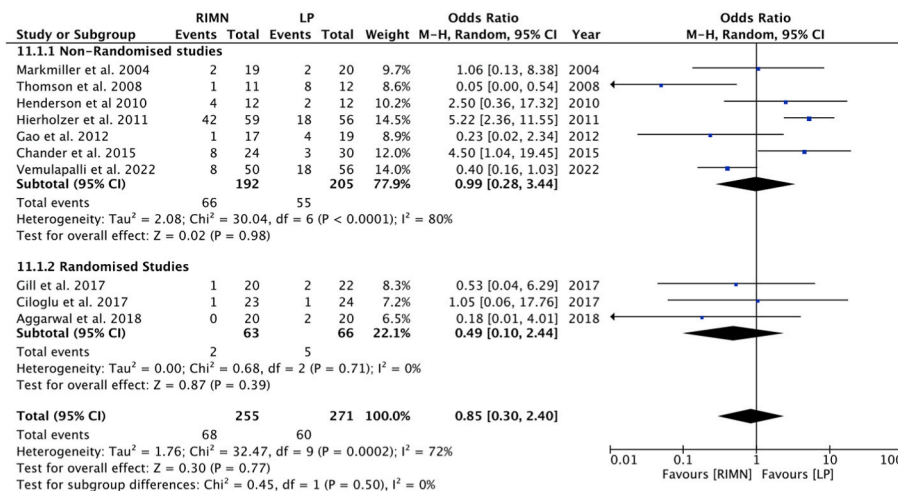


Fig. 14. Forest plot comparing the re-operation rate.

respectively. A statistically significant difference was found between the two treatment groups with a mean difference of 96.39 (95% CI 69.6,123.18, p < 0.00001; I² = 0%) which favors LP group with a lesser amount of blood loss compared to the RIMN group shown in Fig. 16.

3. Knee Range of motion: The knee range of motion was reported in 8/16 studies^{4,12,19–21,23,25,27} individually for two groups however, the mean with a standard difference was given only for 4 studies^{13,24,26,28} which were statistically analyzed. Statistically, a significant difference was found between the two treatment groups,

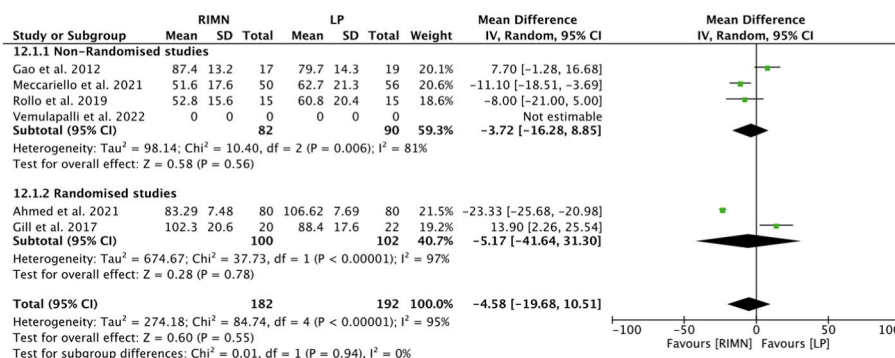


Fig. 15. Forest plot comparing the duration of surgery.

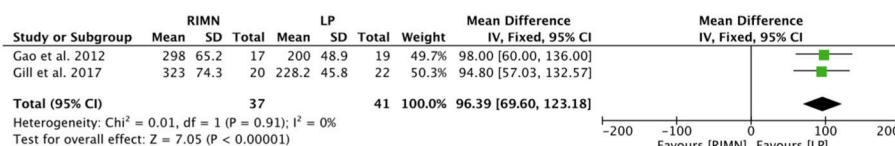


Fig. 16. Forest plot comparing intra-operative blood loss.

which favored the LP group with a mean difference of -5.65 (95% CI $-9.56, -1.74, p = 0.005; I^2 = 53\%$) Fig. 17.

12. Discussion

The RIMN has the advantage of less soft tissue and vascular disruption as compared to LP; these nails are also considered biomechanically superior, being closer to the femoral mechanical axis and acting as load-sharing devices.^{8,9} But, how much of the theoretical advantages work clinically was the study question we strived to answer in the present review.

With the above-mentioned features, theoretically, nailing should be associated with better wound healing, fewer infections, faster surgeries, and lesser blood loss in comparison to plating, which requires open reduction with surgical dissection of the soft tissues and impact on vascularity. However, when we compared these variables in the present review, the results were different. There was no difference between the two surgeries in terms of surgical duration; however, these results may have been skewed as certain nailing cases would have needed open reduction when intraoperative attempts for closed/indirect reduction went unsuccessful. The intra-operative blood loss was significantly lesser in LP group compared to RIMN fixation; this may be attributed to the sequential intramedullary reaming to insert a snugly fitting nail, leading to more amount of bleeding. However, this finding needs to be taken with caution as there were only 2 studies that could be meta-analyzed for this outcome.

The overall rates of complications were also not different between the 2 groups; however, looking at the specific complication of superficial/deep infection, rates were significantly higher in the plating group. Implant-related complications, malunions, and re-operation rates were also similar in both groups; however, subgroup analysis of the RCTs showed lesser malunions in the LP group. This could have been because

of the better quality of reduction in these cases owing to the opening of the fracture site and directly reducing it, than indirect methods in the nailing group.

Another important variable that did favor nailing over plating in distal femur fractures was non-unions which were more in plating cases. The postoperative range of motion was better in the locked plate group. The latter could have been because of the initiation of ROM exercises early in such cases for better healing and lesser stiffness. Also, retrograde nails need to get access through the knee joint, which may cause issues with subsequent articular mobility.

Overall, both the implant choices have shown good outcomes, but the choice in specific case scenarios also depends on certain patient-related factors; pre-injury knee ROM status is an important consideration with certain degrees of flexion essentially needed for RIMN. Also, if an intra-articular extension of the distal femoral fracture is present, nailing becomes technically difficult, and direct reduction of the intra-articular fragments by opening the fracture site is essential. In such scenarios, plating becomes a better option. On the other hand, if there is an associated neck femur fracture with the distal femur fracture, RIMN with DHS/CCS for the proximal femur is a viable option.³² Also, when there is an ipsilateral shaft of tibia fracture co-existing, the same entry point can be used to nail both fractures.³³

The strength of the current study is the fact that we have analyzed a large number of studies as compared to previous reviews. But there are also certain limitations like inclusion of both prospective and retrospective studies; out of 16 studies, only 6 are RCTs, while the remaining 9 are observational studies. In addition to this most of the included studies have less number of patients. However, the total number of studies and number of patients analyzed is much more than any previous work, and we have also done a sub-group analysis of the variables based on the type of studies.

There is still a need for more prospective randomized control trials

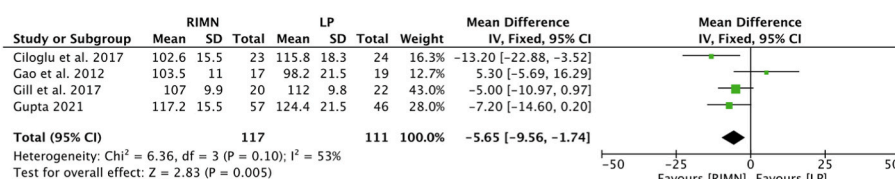


Fig. 17. Forest plot comparing knee range of motion.

with a larger number of patients for robust evidence and further substantiate the findings of this review.

13. Conclusion

The present review shows a significantly lesser nonunion, and infection, in the RIMN group for distal femur fractures. However, we did not find a significant difference in the two treatment groups in terms of fracture union time, overall complications, reoperation rates, and duration of surgery. But a better postoperative knee range of motion was seen in the LP group. Both the options of fixation appear to be feasible options, and specific indications should be considered for making the final choice.

Ethical approval

Not Applicable

Consent to participate

Not applicable.

Consent to publish

Not applicable.

Availability of data and materials

No repositories were used for data.

Informed consent

Does not need for as this is a review article.

Institutional ethical committee approval

Does not need for as this is a review article.

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Authors statement

Rajesh Kumar Rajnish and Amit Srivastava: conceptualization and designing of the study, **Prasoon Kumar, Rehan Ul Haq, and Kuldeep Rathor:** acquisition of data, or analysis of data and its interpretation, **Sameer Aggarwal and Rajesh Kumar Rajnish:** drafting and critically revising the article, and **Sameer Aggarwal:** approval of the final version of the manuscript to be submitted.

Declaration of competing interest

The authors declare no competing interests.

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