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Review

Intramedullary versus extramedullary fixation for the treatment of subtrochanteric fracture: A systematic review and meta-analysis

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ABSTRACT

Purpose: This meta-analysis was performed to investigate the outcomes of intramedullary fixation versus extramedullary fixation in the treatment of subtrochanteric fracture from the current literature.
Methods: The electronic literature database of PubMed, Embase, Cochrane library, CNKI and Wanfang were searched in December 2018. The data operation time, intraoperative blood loss, length of incision, length of stay, union time, rate of infection, rate of fixation failure, rate of refracture, rate of reoperation, rate of nonunion and rate of excellent and good results were extracted. Stata 14.0 software was used for our meta-analysis.
Results: A total of 11 studies including 8 RCTs and 3 cohort studies met our inclusion criteria. This meta-analysis showed that intramedullary fixation could achieve significantly shorter operation time (P = 0.000), less intraoperative blood loss (P = 0.000), shorter length of incision (P = 0.000) and length of stay (P = 0.001) with evidently lower rate of fixation failure (P = 0.001), rate of reoperation (P = 0.003) and higher rate of excellent and good functional results (P = 0.003) than extramedullary fixation for subtrochanteric fractures. However, no significant difference was found regarding union time (P = 0.17), rate of infection (P = 0.99), rate of refracture (P = 0.98) and rate of nonunion (P = 0.42) between the two groups.
Conclusion: Our meta-analysis suggested that intramedullary fixation for subtrochanteric fracture might be superior to extramedullary fixation in term of shorter operation time, less intraoperative blood loss, shorter length of incision, length of stay and better functional outcomes. Meanwhile, intramedullary fixation had lower rate of fixation failure and reoperation. Therefore, we recommend intramedullary fixation as the treatment of subtrochanteric fracture. More large multi-center and high-quality RCTs are required for further research.

1. Introduction

Subtrochanteric fractures can be described as those occurring below the lesser trochanter to 5 cm distally in the shaft of the femur [1]. They occur at the junction between the trabecular bone and the cortical bone where the mechanical stresses are highest in the femur and constitute about 10–34% of all hip fractures [2]. Subtrochanteric fractures have a bimodal age distribution. In young adults, they are frequently caused by high energy trauma and in old age, osteoporotic low-energy is the usual cause. Pathological and periprosthetic fractures constitute a good number of the aging population [1]. Such fractures are associated with high complication rates, and include non-union and implant failure, which occur regardless of the fixation method, because of the unique anatomical and biomechanical features of the subtrochanter [3,4]. Its cortex is thinner than the rest of the femoral shaft, it starts with the cancellous bone at the distal end of the intertrochanteric region and extends into the thick cortical bone of the proximal diaphysis [5]. High compressive medial stresses and tensile lateral stresses were placed on fracture fixation devices [6,7]. A medial buttress is important to minimise implant stress and fatigue failure [8].

Therefore, it is difficult to treat these fractures conservatively and surgical management is the current standard of care [9]. Surgical fixation maintains good anatomical alignment, limb length and avoids complications of prolonged bed rest as early mobilization and weight bearing is possible with the implants presently available. The challenge of treating subtrochanteric fractures can be gauged from the fact that there is a dearth of implants available and they are still evolving. Basically, the implants include extramedullary and intramedullary devices. Previous studies have advocated the use of intramedullary nailing as the current treatment of choice in patients with subtrochanteric

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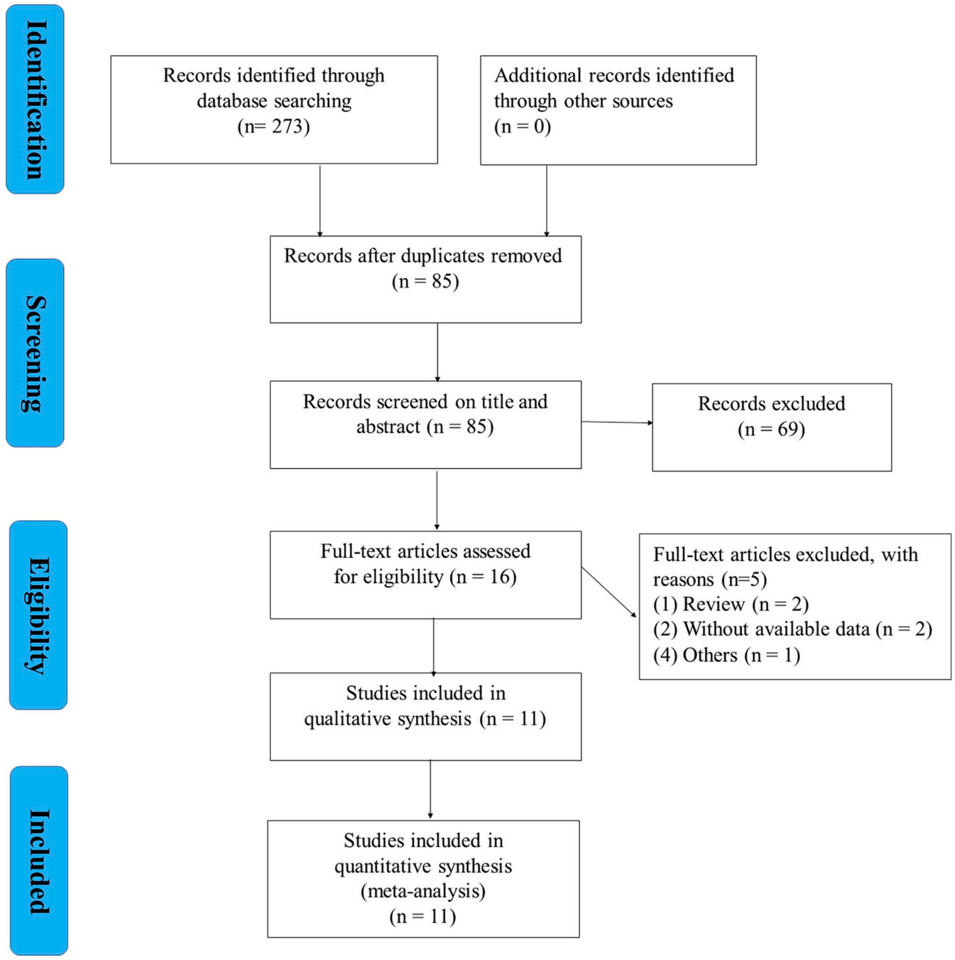

Fig. 1. Flowchart of study selection.

Table 1
The characteristics of the included studies.

Study	Country	Study design	Cases (IF/EF)	Age (years)	Gender (M:F)	Intervention	Follow-up term (months)
Yang 2018 [15]	China	RCT	36/36	55.7/53.6	21:15/20:16	PFNA VS DHS	12
Qin 2017 [16]	China	RCT	46/46	52.1/53.1	25:21/28:18	GN VS Reversed LISS plate	12
Yadav 2014 [17]	India	RCT	15/15	NA	NA	PFN VS DHS and DCS	12
Ekstrm 2007 [18]	Sweden	RCT	18/13	77/83	15:3/10:3	PFN VS MSP	12
Lee 2007 [19]	Taiwan	RCT	34/32	35.4/36.8	25:9/26:6	RTRN VS DCS	24
Rahme 2007 [5]	Australia	RCT	29/29	73/67	13:16/12:17	PFN VS DCS	12
Miedel 2005 [20]	Sweden	RCT	16/12	84.6/82.7	3:13/3:9	GN VS MSP	12
Sadowski 2002 [21]	Switzerland	RCT	20/19	80/77	7:13/5:14	PFN VS DCS	12
Xie 2017 [22]	China	Cohort study	36/34	58.0/60.9	24:12/23:11	InterTan VS PFLP	12
Shin 2017 [23]	Korea	Cohort study	50/31	51.0/55.2	32:18/20:11	PFNA, InterTan and GN VS Reversed LCP	17.2 months in IF group 18.5 months in EF group
Saarenpaa 2006 [24]	Finland	Cohort study	43/15	76.8/74.1	13:30/3:12	GN VS DHS	12

IF: intramedullary fixation group; EF: extramedullary fixation group; M/F: male/female; RCT: randomized controlled trial; PFNA: proximal femoral nail antirotation; PFN: proximal femoral nail; DHS: dynamic hip screw; DCS: dynamic condylar screw; GN: Gamma nail; LISS: less invasive stabilization system; MSP: Medoff sliding plate; RTRN: Russell-Taylor reconstruction nail; PFLP: proximal femoral anatomical locking plate; LCP: locking compression plate; NA: not available.

fracture because of the biomechanical superiority and closed reduction technique, which can minimise soft tissue dissection and preserve vascularity around the fracture site, enhancing callus formation [5,8,10]. However, the extramedullary fixation such as plating technique has been reported to have good surgical outcomes for the treatment of subtrochanteric fractures since the concept of minimally invasive percutaneous plate osteosynthesis, which was called “biologic plating” was introduced [11]. Although orthopedic surgeons should contemplate many factors to select the fixation method, it is still debatable whether intramedullary or extramedullary fixation is more appropriate for the surgical management of subtrochanteric fractures.

Recently, several clinical trials have evaluated the outcomes of

Table 2
Risk of bias assessment of the RCTs.

Study	Randomization	Allocation concealment	Blinding of participants	Blinding of outcome assessment	Incomplete outcome data	Selective reporting	Other bias
Yang 2018 [15]	Low risk	Low risk	High risk	Low risk	Low risk	Low risk	Unclear risk
Qin 2017 [16]	Low risk	High risk	Low risk	Low risk	Low risk	Low risk	Low risk
Yadav 2014 [17]	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Ekstrm 2007 [18]	Low risk	Unclear risk	Low risk	Low risk	Low risk	Low risk	Unclear risk
Lee 2007 [19]	Unclear risk	Low risk	Low risk	Low risk	Unclear risk	Low risk	Low risk
Rahme 2007 [5]	Low risk	Low risk	Low risk	High risk	Low risk	Low risk	Low risk
Miedel 2005 [20]	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Sadowski 2002 [21]	Low risk	Unclear risk	Low risk	Low risk	Low risk	Low risk	Unclear risk

Table 3
Quality assessment according to the Newcastle-Ottawa scale.

Study	Selection				Comparability	Outcome			Total score
	Exposed cohort	Nonexposed cohort	Ascertainment of exposure	Outcome of interest		Assessment of outcome	Length of follow-up	Adequacy of follow-up	
Xie 2017 [22]	*	*	*	*	*	*	*	*	8
Shin 2017 [23]	*	*	–	*	*	*	*	*	7
Saarenpaa 2006 [24]	*	–	*	*	**	*	*	*	8

Risk of bias was assessed with use of the Newcastle–Ottawa Scale. "*" means a score of 1; "**" means a score of 2; the total score of this scale is 9. A higher overall, score corresponds to a lower risk of bias; a total score of 5 or less indicates a high risk of bias.

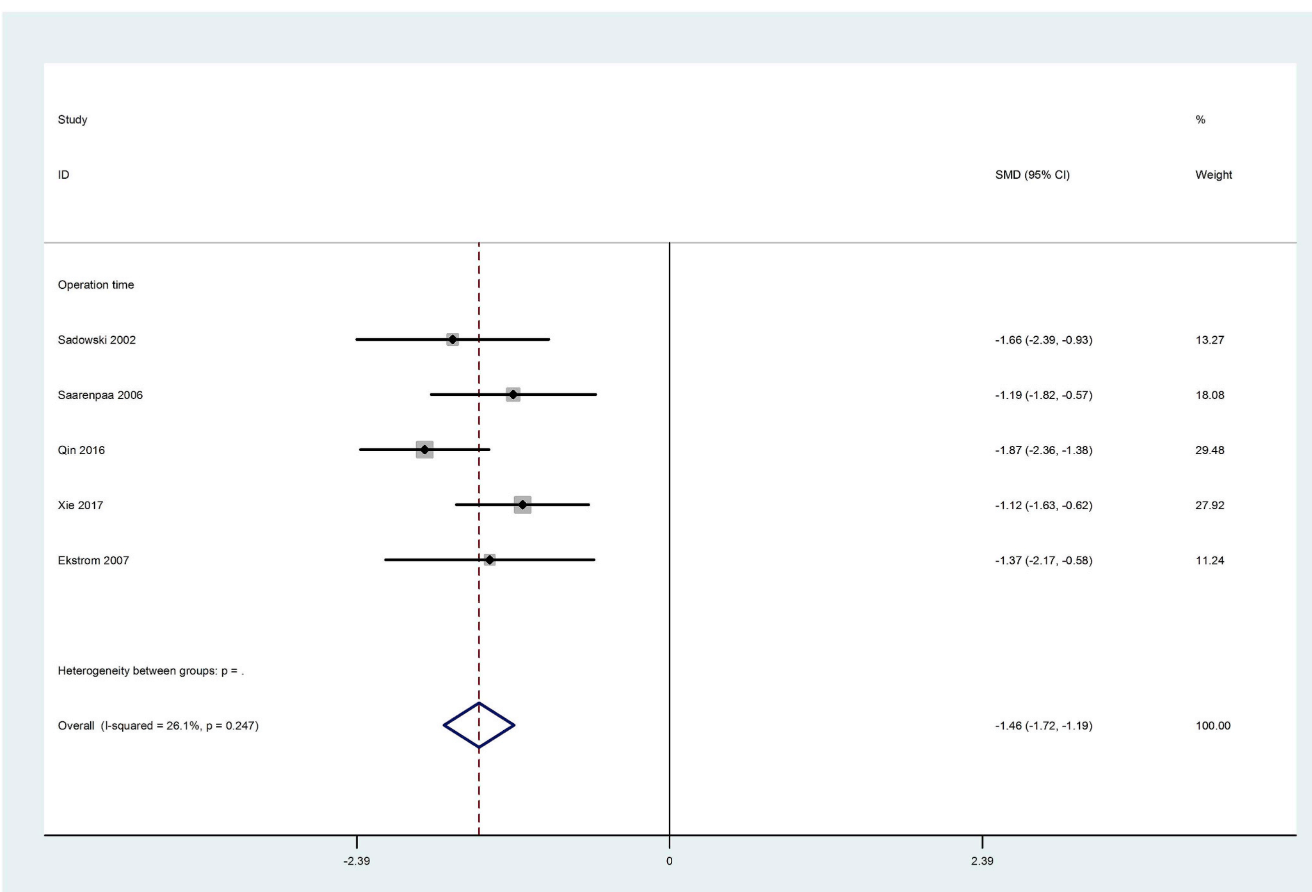

Fig. 2. Forest plot showing operation time.

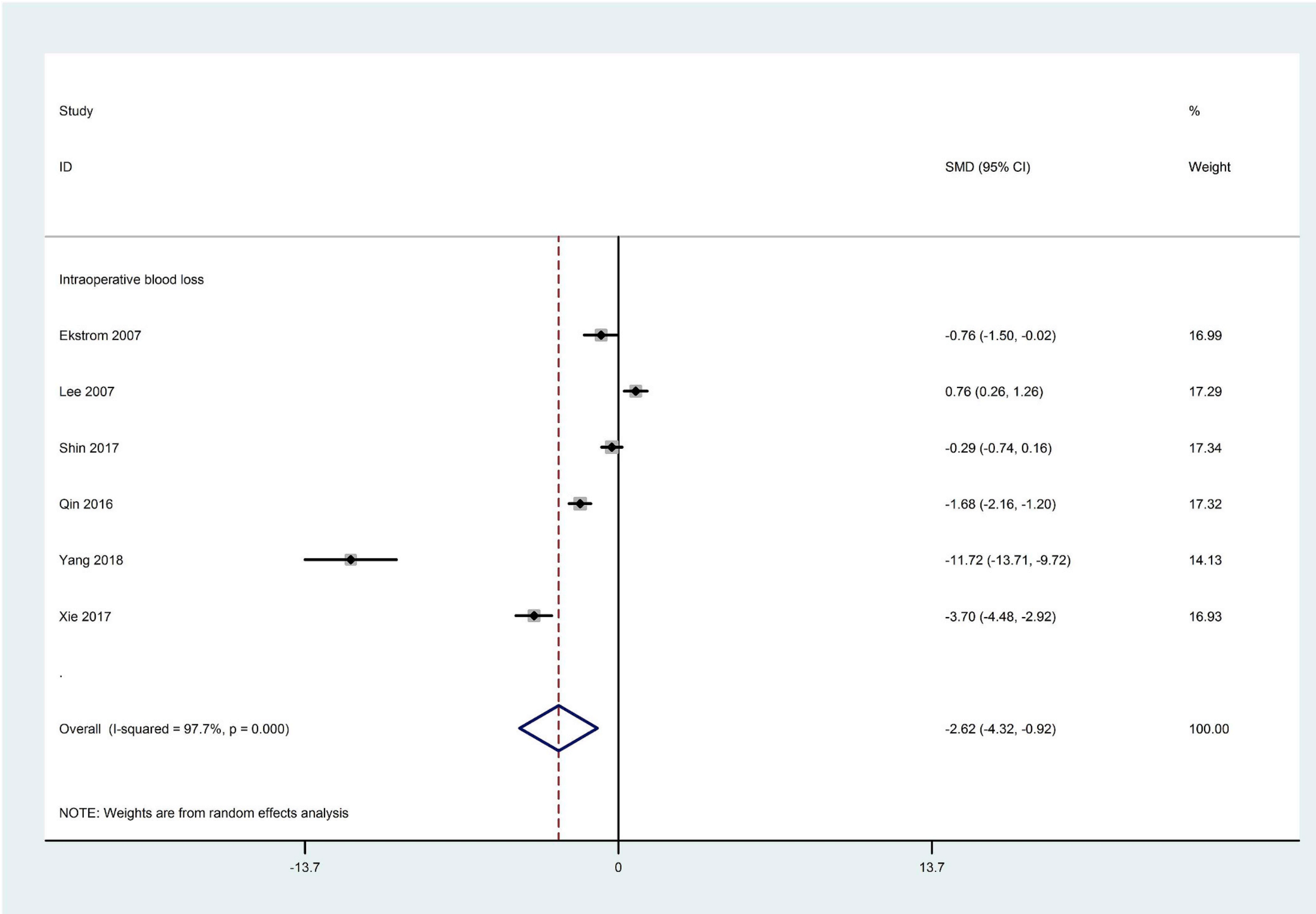

Fig. 3. Forest plot showing intraoperative blood loss.

Table 4
Subgroup analysis for intraoperative blood loss.

Stratified analysis	Number of study	Cases (IF/EF)	I^2 (%)	Heterogeneity (P)	SMD	95% CI	Z test (P)
Age (years)							
≥55	2	54/47	96.5	0.000	−2.156	−2.693 to −1.620	0.000
< 55	4	166/145	98.2	0.000	−0.645	−0.917 to −0.374	0.000
Study type							
RCT	4	134/127	98.2	0.000	−0.831	−1.140 to −0.522	0.000
Cohort study	2	86/65	98.2	0.000	−1.148	−1.538 to −0.758	0.000
Country							
China	3	118/116	98.0	0.000	−2.611	−3.009 to −2.212	0.000
Non-China	3	102/76	86.2	0.001	0.018	−0.287 to 0.323	0.910
Follow-up term (months)							
≤12	4	84/63	97.5	0.000	−2.195	−2.546 to −1.844	0.000
> 12	2	136/129	89.3	0.002	0.177	−0.158 to 0.512	0.300

IF: intramedullary fixation group; EF: extramedullary fixation group; RCT: randomized controlled trial.

intramedullary fixation versus extramedullary fixation in surgical treatment of subtrochanteric fracture. However, the results in these studies are inconsistent and there was no meta-analysis conducted to test which fixation method is better in surgical treatment of subtrochanteric fracture. Therefore, we conducted a meta-analysis of some published randomized controlled trials (RCTs) and cohort studies to explore the outcomes of intramedullary fixation versus extramedullary fixation for subtrochanteric fracture by comparing their clinical results. The outcomes including operation time, intraoperative blood loss, length of incision, length of stay, union time, rate of infection, rate of fixation failure, rate of refracture, rate of reoperation, rate of nonunion and rate of excellent and good results.

2. Methods

This systematic review and meta-analysis has been reported in line with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) [12] and AMSTAR (Assessing the methodological

Table 5
Subgroup analysis for patient age.

Outcomes	Age (years)	Number of study	Cases (IF/EF)	I^2 (%)	Heterogeneity (P)	SMD or RR	95% CI	Z test (P)
Operation time	≥60	3	81/47	0	0.640	−1.387	−1.796 to −0.978	0.000
	< 60	2	82/80	76.9	0.037	−1.508	−1.860 to −1.156	0.000
Intraoperative blood loss	≥60	1	18/13	NA	NA	−0.761	−1.501 to −0.022	0.044
	< 60	5	202/179	98.2	0.000	−0.976	−1.232 to −0.720	0.000
Length of incision	≥60	1	20/19	NA	NA	−2.922	−3.837 to −2.007	0.000
	< 60	2	70/68	0	0.442	−2.292	−2.725 to −1.860	0.000
Length of stay	≥60	2	63/34	48.5	0.164	−0.534	−0.973 to −0.094	0.017
	< 60	4	131/127	27.3	0.248	−0.297	−0.544 to −0.051	0.018
Union time	≥60	0	0/0	NA	NA	NA	NA	NA
	< 60	4	166/143	0	0.556	−0.156	−0.382 to 0.069	0.174
Rate of infection	≥60	4	108/75	0	0.503	1.057	0.317 to 3.523	0.928
	< 60	3	85/81	0	0.429	0.955	0.366 to 2.492	0.925
Rate of fixation failure	≥60	5	126/88	0	0.416	0.130	0.042 to 0.401	0.000
	< 60	3	106/102	0	0.645	0.957	0.245 to 3.743	0.950
Rate of refracture	≥60	2	61/28	0	0.780	3.213	0.390 to 26.465	0.278
	< 60	2	49/47	0	0.796	3.899	0.457 to 33.228	0.213
Rate of reoperation	≥60	4	108/75	0	0.571	0.202	0.084 to 0.484	0.000
	< 60	2	49/47	0	0.610	2.901	0.480 to 17.522	0.246
Rate of nonunion	≥60	3	67/61	0	0.490	0.223	0.058 to 0.859	0.029
	< 60	2	84/63	0	0.704	1.442	0.263 to 7.899	0.673
Rate of excellent and good results	≥60	0	0	NA	NA	NA	NA	NA
	< 60	4	133/131	0	0.555	1.138	1.045 to 1.240	0.003

IF: intramedullary fixation group; EF: extramedullary fixation group.

quality of systematic reviews) Guidelines. No primary personal data will be collected; therefore no additional ethical approval needs to be obtained.

2.1. Search strategy

The electronic databases of PubMed, Embase, Cochrane library, CNKI and Wanfang database were searched from the inception of the database to December 2018, without language restriction. Two independent researchers conducted literature searches using the search strategy of ("femoral subtrochanteric fracture" or "hip fracture") and ("intramedullary fixation") and ("extramedullary fixation"). In addition, the reference lists of previously published randomized trials, review articles, and meta-analyses were manually searched for additional eligible studies. Related articles and reference lists were searched to avoid original miss.

2.2. Inclusion and exclusion criteria

We identified literature that met the following inclusion criteria: (1) randomized and/or non-randomized controlled clinical studies; (2) skeletally mature patients (older than 18 years); (3) comparison of the outcomes of intramedullary fixation and extramedullary fixation in the treatment of femoral subtrochanteric fracture. The exclusion criteria were: (1) abstracts, case reports, letters, editorials, conference articles; (2) repeated studies and data.

2.3. Selection of literature

We used the PRISMA flow diagram to select the included studies. The results of literature search were imported into the software Endnote X7. Two authors independently assessed the potentially eligible studies. Firstly, the titles and abstracts were screened to exclude the duplicated and apparently irrelevant ones or those that do not meet our inclusion criteria. After then, the remaining potential studies were full-text downloaded and reviewed. Any disagreement between two above authors was sent and discussed with the third independent author.

2.4. Data extraction

Two reviewers independently extracted data, and the third reviewer checked the consistency between them. A standard form was used; the extracted items included the following: (1) the general study information, for example, the authors, publishing date, study design, case number, age, gender, intervention method and follow-up term. (2) clinical outcomes, including operation time, intraoperative blood loss, length of incision, length of stay, union time, rate of infection, rate of fixation failure, rate of refracture, rate of reoperation, rate of nonunion and rate of excellent and good results. For continuous outcomes, we extracted the mean and standard deviation (SD) and participant number will be extracted. For dichotomous outcomes, we extracted the total numbers and the numbers of events of both groups. The data in other forms was recalculated when possible to enable pooled analysis. Disagreements between two researchers were resolved by discussion. Whenever necessary, we contacted the authors of the studies for the missing data and additional information.

2.5. Quality assessment of included studies

Two authors independently performed methodological quality and risk of bias assessment of the included RCTs using Cochrane collaboration's tool [13]. The Cochrane tool assesses following items: randomization, allocation concealment, blinding of participants, blinding of outcome assessment, incomplete outcome data, selective outcome reporting and other bias, for each individual item, classifies studies into low, unclear, and high risk of bias. The methodological quality of included cohort studies was assessed according to the Newcastle–Ottawa Scale (NOS) [14]. The NOS uses a star system ranges from zero to nine stars. We determined studies that received the score more than 6 stars to be high-quality.

2.6. Statistical analysis

The data was collected and input into the STATA software (version 12.0; StataCorp, College Station, TX) for meta-analysis. A random-effects model was applied when heterogeneity was detected or the

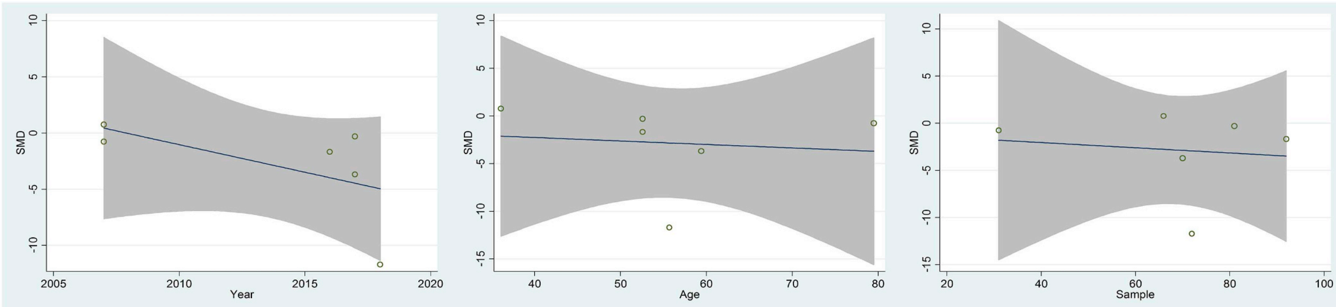

Fig. 4. Meta-regression analysis of intraoperative blood loss for publication year, age of patients and sample size.

statistical heterogeneity was high ($P < 0.05$ or $I^2 > 50\%$) and then further subgroup study and meta-regression analysis were performed to detect the origin of heterogeneity. Otherwise, a fixed-effects model was used ($P \geq 0.05$ or $I^2 \leq 50\%$). To test the strength and stability of the pooled results, we performed a sensitivity analysis by omitting the individual studies one by one. Moreover, the effect of publication bias was investigated by Begg's test and Egger's test. Relative risk (RR) was calculated for dichotomous outcomes, standard mean difference (SMD) was calculated for continuous outcomes.

3. Results

3.1. Included studies

A total 273 potentially relevant articles were identified from the databases. After removal of duplicates, 85 articles were screened for relevance on the basis of the title and abstract. Of the 16 articles that were possibly eligible for inclusion, 5 were excluded for reasons of “the papers were review or without available data” and some other reasons

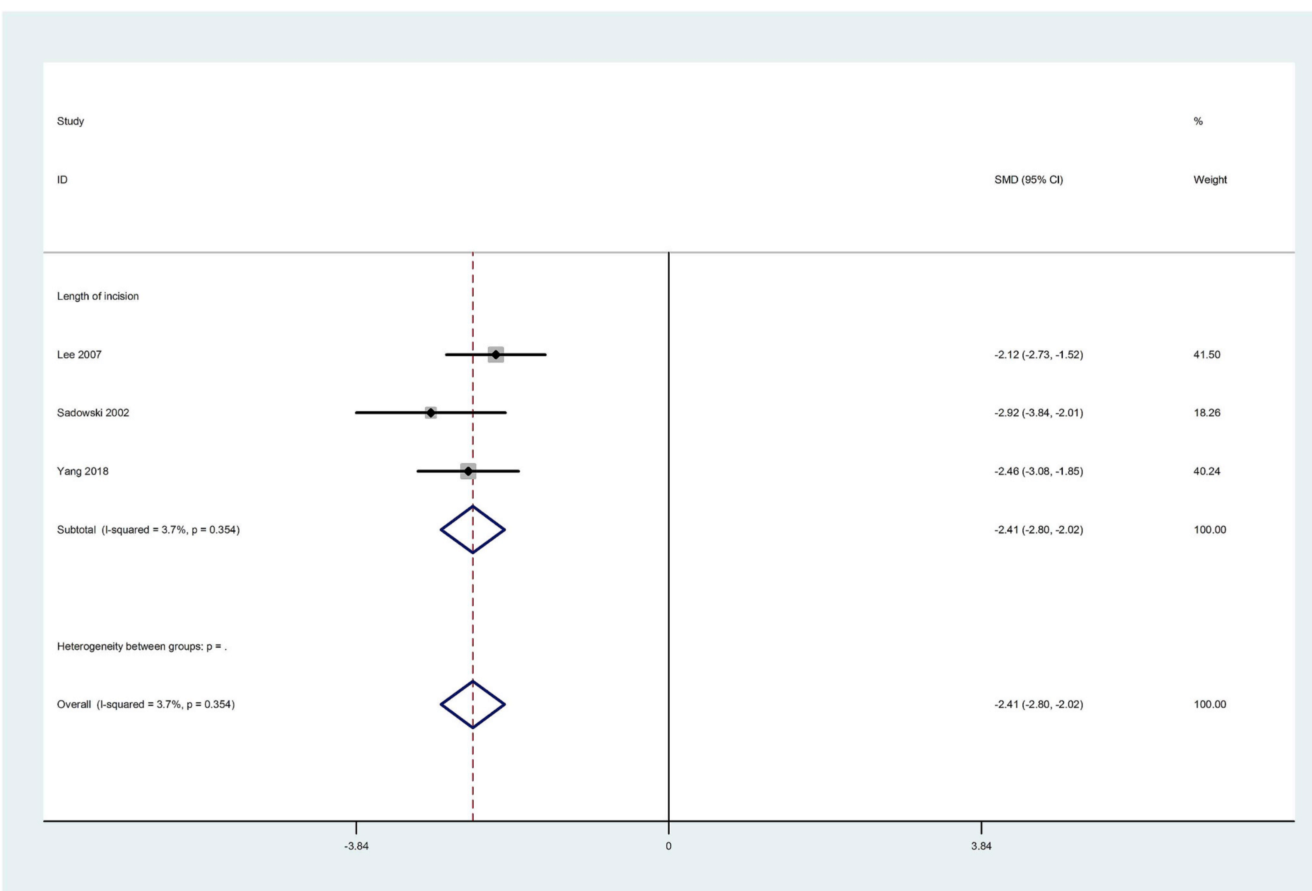

Fig. 5. Forest plot showing length of incision.

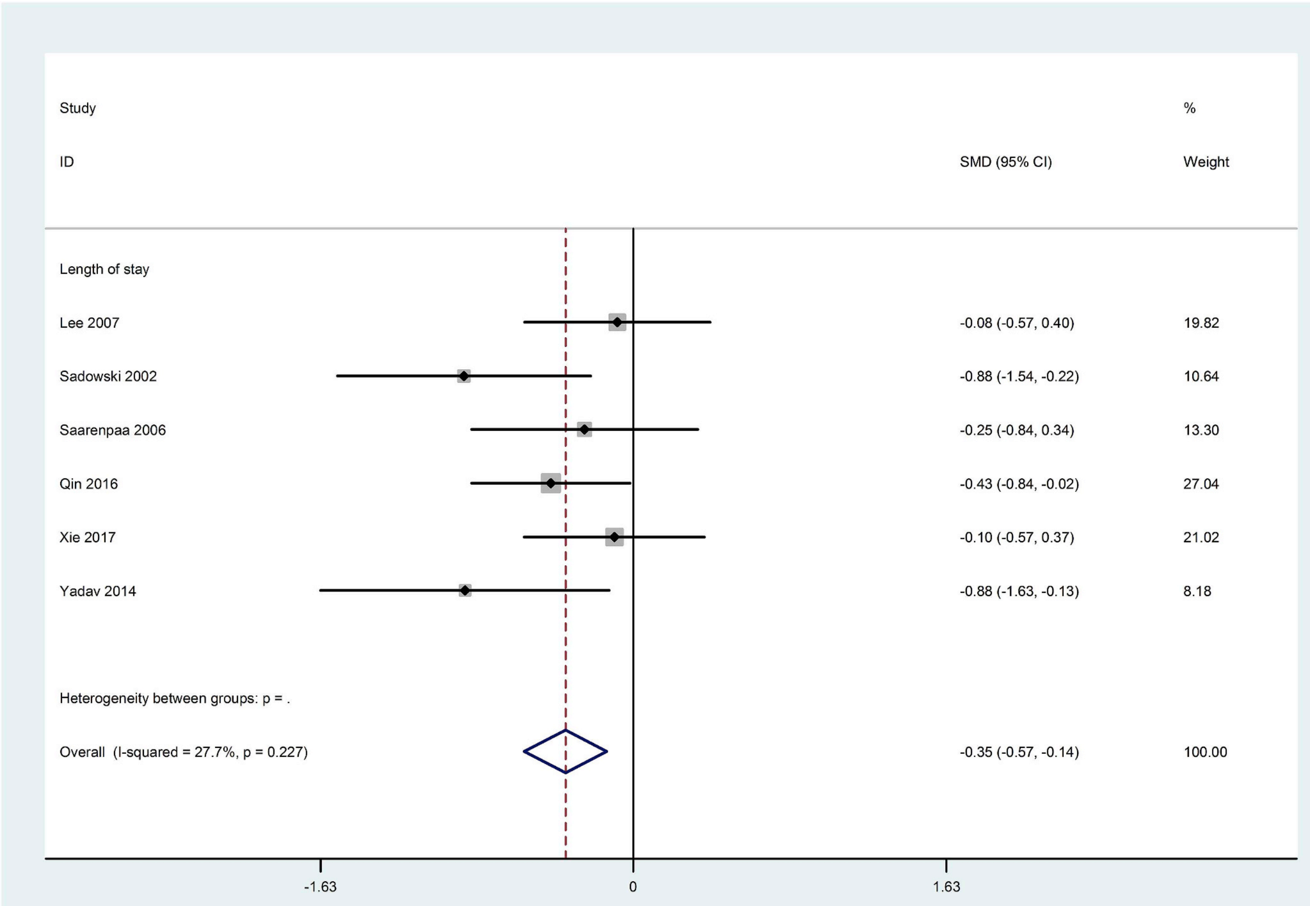

Fig. 6. Forest plot showing length of stay.

(details were showed in Fig. 1). The remaining 11 studies (8 RCTs [5,15–21] and 3 cohort studies [22–24]) were included in this meta-analysis.

3.2. Characteristics and quality assessment of the eligible studies

The characteristics of all the 11 included studies were summarized and shown in Table 1. All of them were published between 2010 and 2017. A total of 343 participants in intramedullary fixation (IF) group and 282 in extramedullary fixation (EF) group were included in this meta-analysis. Risk of bias assessment of RCTs was presented in Table 2. The methodological quality of cohort studies assessed with the NOS are illustrated in Table 3. Two studies scored 8 stars whereas one study scored 7 stars, indicating that all the three included cohort studies were of high quality.

3.3. Clinical outcomes

3.3.1. Operation time

Five studies reported operation time [16,18,21,22,24]. No significant heterogeneity was found in the pooled outcomes, so a fixed-effects model was utilized in our study ($\chi^2 = 5.41$, df = 4, $I^2 = 26.1\%$, $P = 0.25$). As shown in Fig. 2, the pooled results showed that operation time in IF group was significantly shorter than that in EF group (SMD = −1.46; 95% CI = −1.72 to −1.19; P = 0.000). The results of subgroup analysis of patient age (Table 5) showed that operation time in IF group was significantly shorter than that in EF group in both old group (age ≥60) and young group (age < 60).

3.3.2. Intraoperative blood loss

Six studies stated intraoperative blood loss [15,16,18,19,22,23]. Based on the six studies providing available data, the pooled results showed that significant heterogeneity was found ($\chi^2 = 222.09$, df = 5, $I^2 = 97.7\%$, $P = 0.000$), and therefore, a random-effects model was used. The available data demonstrated that intraoperative blood loss in IF group was significantly less compared with that in EF group (SMD = −0.95; 95% CI = −1.20 to −0.71; P = 0.000, Fig. 3). The causes of heterogeneity in the results were explored by subgroup analysis and meta-regression. Subgroup analyses stratifed by age, study type, country and follow-up term were conducted to investigate the difference between IF and EF group (Table 4). The subgroup analysis of age showed that intraoperative blood loss in IF group was significantly less than that in EF group in either low age group (< 55, SMD = −0.65; 95% CI = −0.92 to −0.37; P = 0.000) or high age group (≥55, SMD = −2.16; 95% CI = −2.70 to −1.62; P = 0.000). Meanwhile, the subgroup analysis of study type indicated that IF group

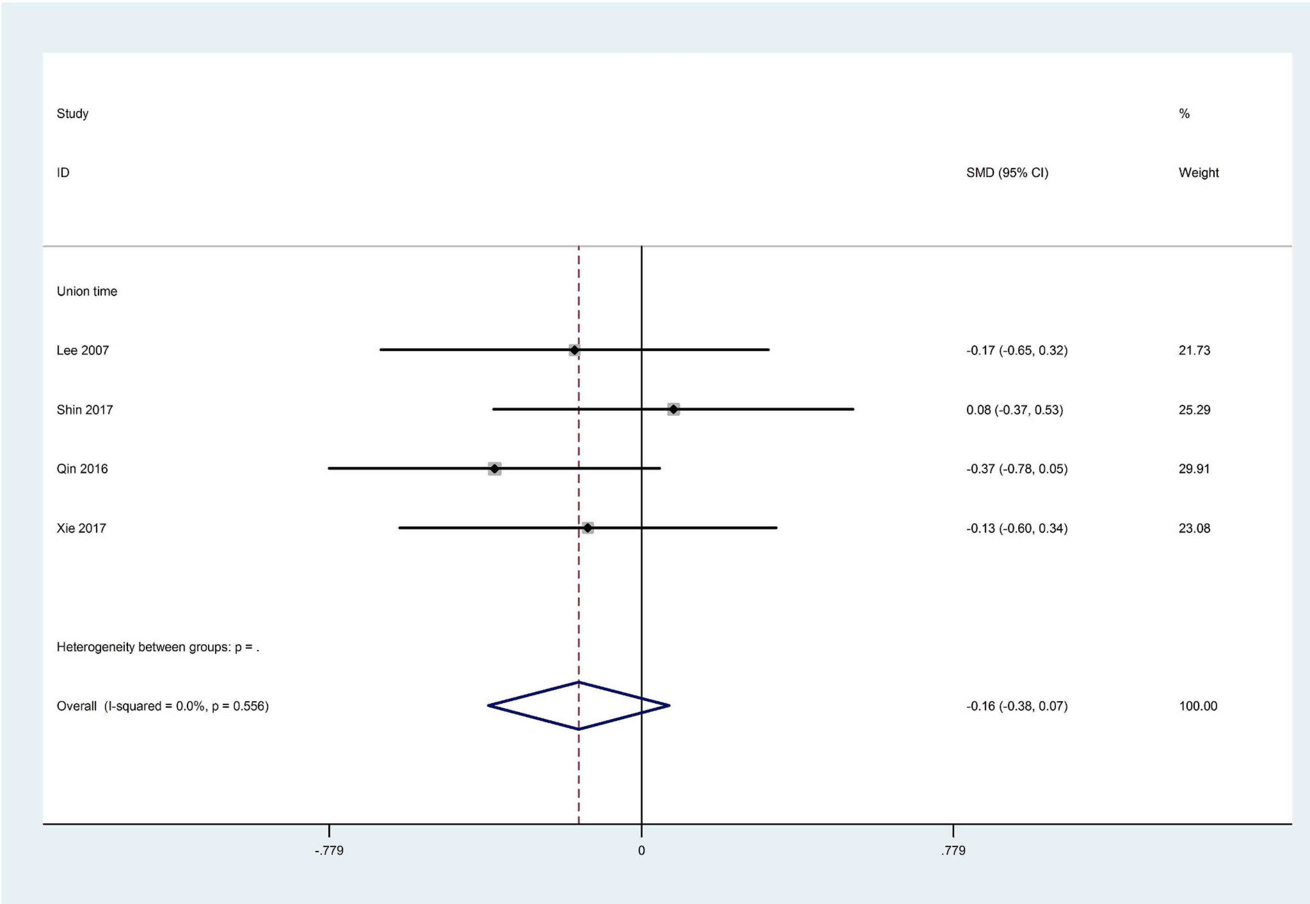

Fig. 7. Forest plot showing union time.

had significantly less intraoperative blood loss in either RCT group (SMD = −0.83; 95% CI = −1.14 to −0.52; P = 0.000) or cohort study group (SMD = −1.15; 95% CI = −1.54 to −0.76; P = 0.000). As for country subgroup, intraoperative blood loss was obviously less in IF group than that in EF group in China group (SMD = −2.61; 95% CI = −3.01 to −2.21; P = 0.000). However, there was no statistically significant difference between the two groups in non-China group (SMD = 0.02.; 95% CI = −0.29 to 0.32; P = 0.91). Besides, the subgroup analysis of follow-up term showed that no significant difference was found in long follow-up term group (SMD = 0.18; 95% CI = −0.16 to 0.51; P = 0.30). Whereas, IF group had evidently less intraoperative blood loss in short follow-up term group (SMD = −2.20; 95% CI = −2.55 to −1.84; P = 0.000). In addition, the meta-regression analysis for publication year, age of patients and sample size were performed to analyse the potential sources of inter-study heterogeneity (Fig. 4). Overall, the publication year (β = −0.49; P = 0.24; R^2 = 15.7%) age of patients (β = −0.037; P = 0.83; R^2 = −25.1%) and sample size (β = −0.028; P = 0.81; R^2 = −24.8%) were not the major sources of heterogeneity for intraoperative blood loss.

3.3.3. Length of incision

There were three studies reporting length of incision [15,19,21]. A fixed-effects model was applied because no significant heterogeneity was found between the studies (χ^2 = 2.08, df = 2, I^2 = 3.7%, P = 0.35). The results indicated that IF group showed significantly shorter length of incision than EF group (SMD = −2.41; 95% CI = −2.80 to −2.02; P = 0.000, Fig. 5). The results of subgroup analysis of patient age (Table 5) showed that length of incision in IF group was significantly shorter than that in EF group in both old group (age ≥60) and young group (age < 60).

3.3.4. Length of stay

Six studies [16,17,19,21,22,24] described length of stay. The pooled results showed no significant heterogeneity (χ^2 = 6.91, df = 5, I^2 = 27.7%, P = 0.23), and therefore, a fixed-effects model was used. The available data demonstrated that length of stay was significantly shorter in IF group in contrast with EF group (SMD = −0.35; 95% CI = −0.57 to −0.14; P = 0.001, Fig. 6). The results of subgroup analysis of patient age (Table 5) revealed that length of stay in IF group was significantly shorter than that in EF group in both old group (age ≥60) and young group (age < 60).

3.3.5. Union time

The results of a pooled statistical analysis of four studies [16,19,22,23] are shown in Fig. 7 and indicate that there was no statistically significantly heterogeneity (χ^2 = 2.08, df = 3, I^2 = 0%,

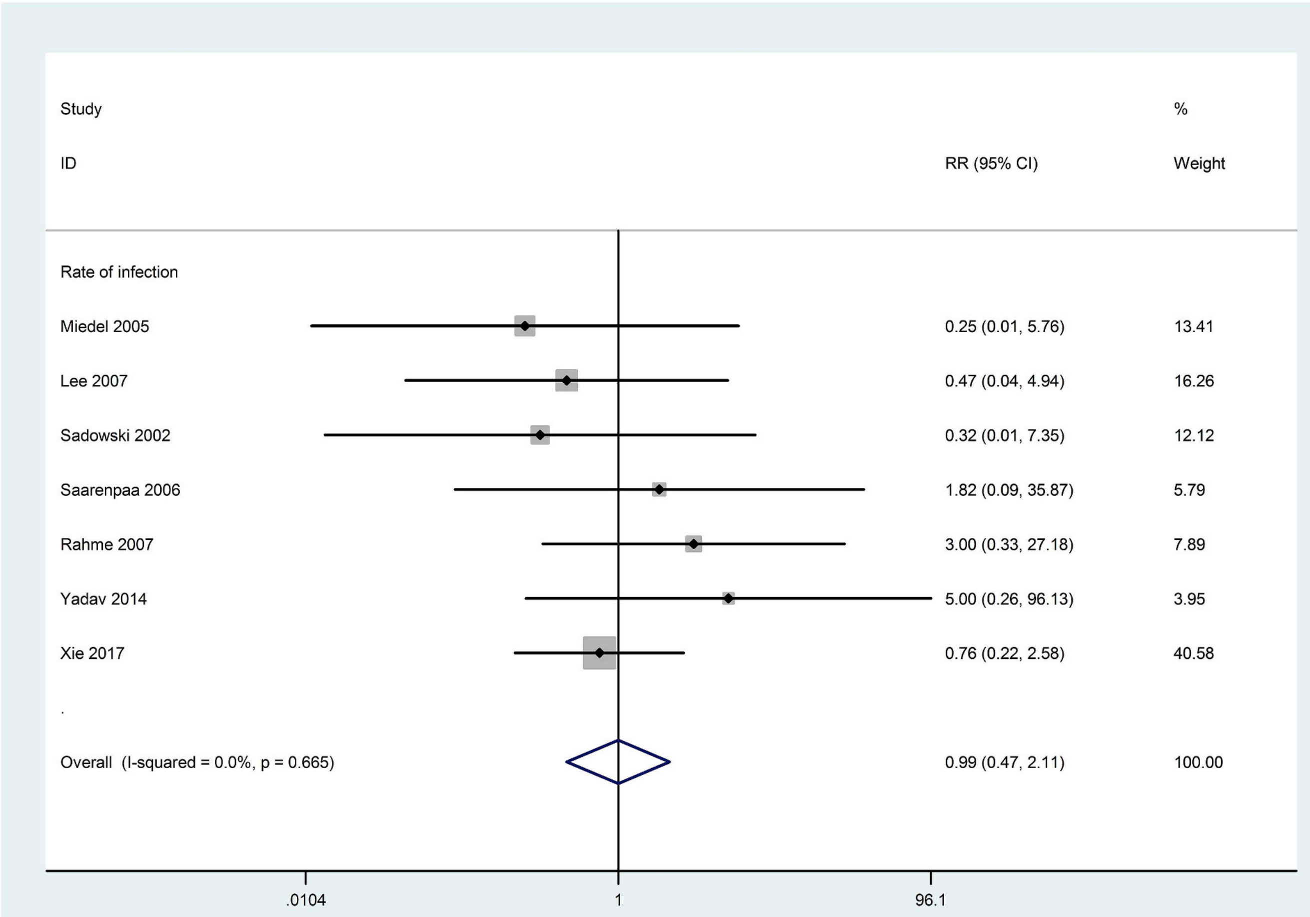

Fig. 8. Forest plot showing rate of infection.

P = 0.56). The results revealed that union time was not significantly different between the two groups (SMD = −0.16; 95% CI = −0.38 to 0.07; P = 0.17, Fig. 7).

3.3.6. *Rate of infection*

Seven studies reported rate of infection [5,17,19–22,24]. No significant heterogeneity was found in the pooled outcomes, so a fixed-effects model was utilized in our study (χ^2 = 4.09, df = 6, I^2 = 0%, P = 0.67). As shown in Fig. 8, the pooled results showed that rate of infection was not significantly different between the two groups (RR = 1.00; 95% CI = 0.47 to 2.11; P = 0.99). The results of subgroup analysis of patient age (Table 5) revealed that no significant difference was found regarding rate of infection between the two groups in both old group (age ≥60) and young group (age < 60).

3.3.7. *Rate of fixation failure*

There were eight studies reporting rate of fixation failure [5,15,18–22,24]. A fixed-effects model was applied because no significant heterogeneity was found between the studies (χ^2 = 8.78, df = 7, I^2 = 20.3%, P = 0.27). We found that IF group revealed significantly lower rate of fixation failure compared to EF group (RR = 0.26; 95% CI = 0.12 to 0.56; P = 0.001, Fig. 9). However, the results of subgroup analysis of patient age (Table 5) indicated that no significant difference was found regarding rate of fixation failure between the two groups in young group.

3.3.8. *Rate of refracture*

Four studies [17–19,24] described rate of refracture. The meta-analysis showed that there was no significant difference between the two groups (RR = 3.5, 95% CI = 0.78 to 15.80, P = 0.10, Fig. 10). While, the heterogeneity among studies was very low (χ^2 = 0.17, df = 3, I^2 = 0%, P = 0.98). The results of subgroup analysis of patient age (Table 5) revealed that no significant difference was detected regarding rate of refracture between the two groups in both old group (age ≥60) and young group (age < 60).

3.3.9. *Rate of reoperation*

Six articles [5,17,19–21,24] provided the relevant data. The summarized estimate of effect size showed rate of reoperation in IF group was significantly lower than EF group (RR = 0.36, 95% CI = 0.18 to 0.71, P = 0.003, Fig. 11). At the same time, no significant statistical heterogeneity was present (χ^2 = 7.24, df = 5, I^2 = 30.9%, P = 0.20). Whereas, the results of subgroup analysis of patient age (Table 5) showed that no significant difference was found regarding rate of

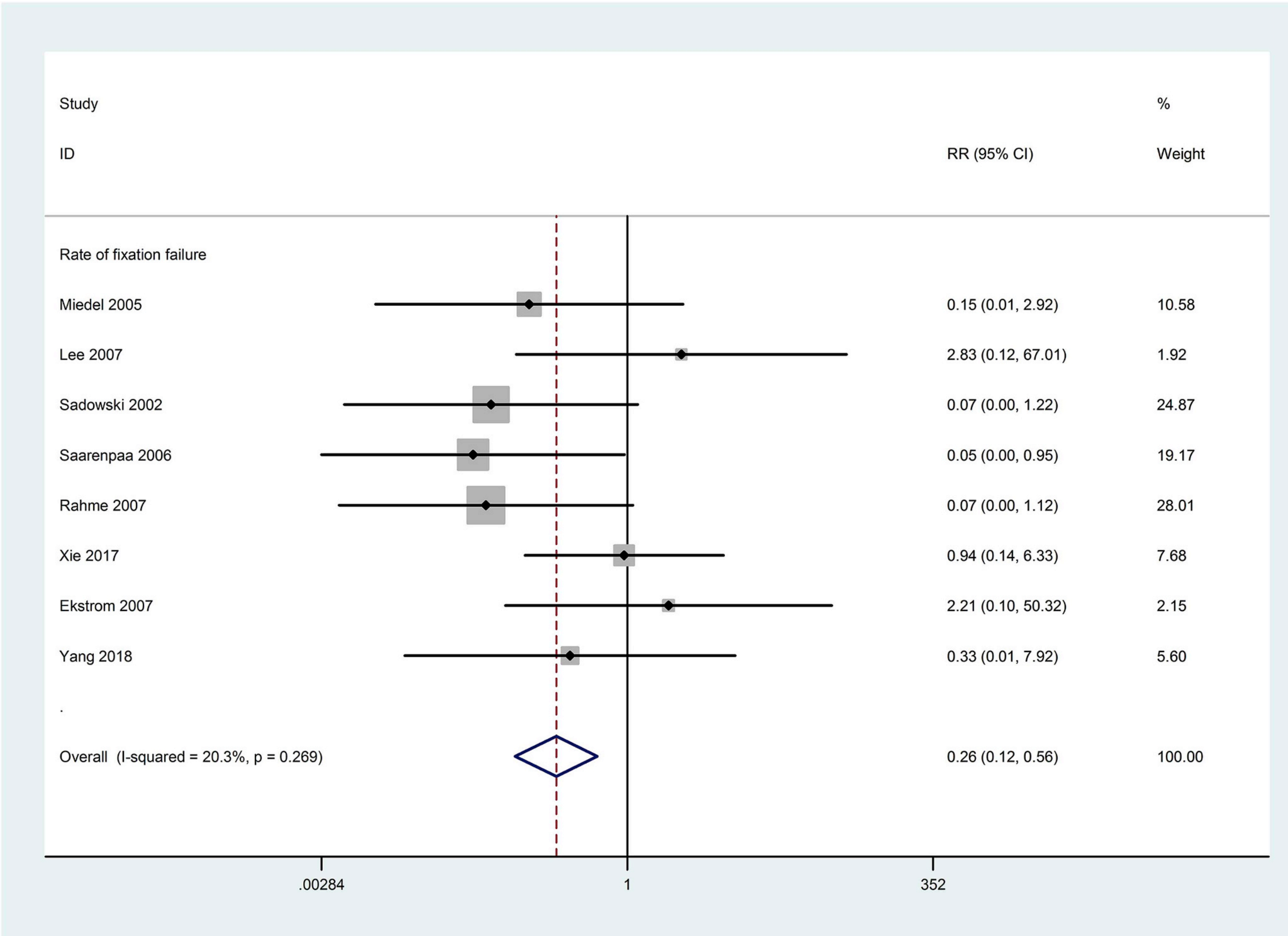

Fig. 9. Forest plot showing rate of fixation failure.

reoperation between the two groups in young group.

3.3.10. Rate of nonunion

Data extracted from five studies [5,18,19,21,23] substantiated that no statistically significant difference was found between the two groups (RR = 0.44, 95% CI = 0.17 to 1.14 P = 0.09, Fig. 12), with an absence of statistical heterogeneity (χ^2 = 3.88, df = 4, I^2 = 0%, P = 0.42). Nevertheless, the results of subgroup analysis of patient age (Table 5) showed that IF group had significantly lower rate of nonunion than EF group in old group.

3.3.11. Rate of excellent and good results

Four studies [15–17,22] provided data regarding rate of excellent and good results. The pooled estimate of information showed that IF group exhibited significantly higher rate of excellent and good results in contrast with EF group (RR = 1.14, 95% CI = 1.05 to 1.24, P = 0.003, Fig. 13), and statistical heterogeneity was not present (χ^2 = 2.09, df = 3, I^2 = 0%, P = 0.56).

3.4. Publication bias and sensitivity analysis

Begg's funnel plot and Egger's test (Fig. 14) were used to assess the potential publication bias of the rate of infection, rate of fixation failure, rate of nonunion studies included in this meta-analysis. The symmetrical shape of the funnel plots and the P values from Begg's and Egger's tests indicated that there was no signifcant publication bias for rate of infection, rate of fixation failure, rate of nonunion (P = 0.76 and P = 0.46, P = 0.17 and P = 0.83, P = 0.81 and P = 0.97, respectively).

To determine the influence of each study on the pooled RRs for rate of infection, rate of fixation failure, rate of nonunion and to verify the robustness of our results, sensitivity analysis was performed by omitting one study at a time and calculating the pooled RRs for the remaining studies. The results of the sensitivity analysis indicated that no signifcant effect on pooled RRs was observed after excluding any single study, suggesting that the results of this meta-analysis were relatively robust (Fig. 15).

4. Discussion

Subtrochanteric fractures are relatively rare, accounting for 10–34% of all hip fractures [24]. The intense concentration of deforming force and decreased vascularity in this region are associated with high incidence of fracture nonunion and implant failure [25]. Treatment of these fractures constitutes a considerable challenge for orthopedic

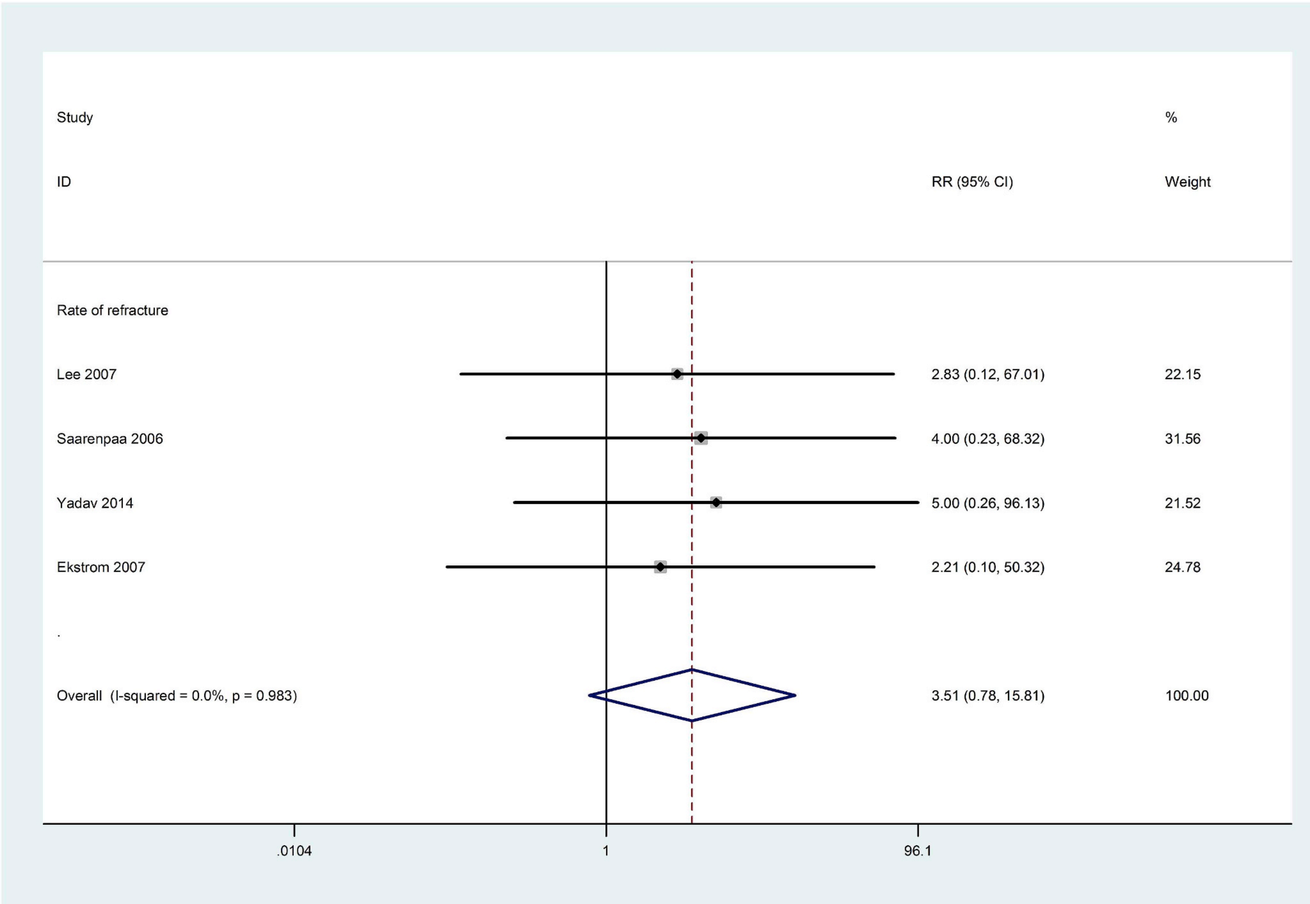

Fig. 10. Forest plot showing rate of refracture.

surgeons. Nowadays, the high incidence of delayed union, malunion and nonunion of such fractures has tilted the balance in favor of operative management. Both intramedullary fixation and extramedullary fixation have been accepted as surgical techniques for the treatment of subtrochanteric fractures. To our knowledge, no high-quality meta-analysis has been reported to analyse the high level clinical evidence in intramedullary fixation versus extramedullary fixation for subtrochanteric fractures. The present study summed up high-quality studies after strict screening in order to find more reliable outcomes. In this meta-analysis, we found that intramedullary fixation could achieve significantly shorter operation time, less intraoperative blood loss, shorter length of incision and length of stay with evidently lower rate of fixation failure, reoperation and higher rate of excellent and good functional results than extramedullary fixation for subtrochanteric fractures.

In the 1970s and 1980s, open anatomic reduction and internal fixation with plates was recommended for subtrochanteric fractures [26,27]. However, Extramedullary fixation with plating has the potential disadvantages of extensive surgical dissection, significant soft tissue damage and blood loss. This leads to problems of fracture nonunion and implant failure. Also, non-concentric plating is prone to fatigue failure and breakage due to the mechanical load-sharing effect. Currently, intramedullary nailing was widely accepted as the treatment of choice for subtrochanteric fractures [5,10]. Intramedullary nailing to incorporate fixation of the femoral neck and head has advantages, namely shorter operating time and less blood loss, as well as lower rates of infection, nonunion and implant failure. Paul et al. [10] reviewed three level I and nine level IV studies to determine if there was any difference in outcome measures between extramedullary and intramedullary implants for the fixation of subtrochanteric facture. In their study, it was shown that operative time and fixation failure were reduced with the use of intramedullary implants for subtrochanteric fractures. Besides, Saarenpää et al. [24] reported that Gamma nail group showed obviously shorter operating time, hospital stay and less fixation failure than dynamic hip screw group in the treatment of subtrochanteric fractures. Meanwhile, Yadav et al. [17] found that intramedullary group could achieve significantly better functional outcomes with shorter duration of surgery, hospital stay and less blood loss than extramedullary group for treatment of subtrochanteric femoral fractures at tertiary level center. Consistent with these results, our meta-analysis demonstrated that intramedullary fixation could acquire much better functional results with significantly shorter operation time, less intraoperative blood loss, shorter length of incision, length of stay, lower rate of fixation failure and reoperation than extramedullary fixation for subtrochanteric fractures. On the other hand, a previous meta-analysis [28] has reported that operative time, intraoperative blood loss and length of hospital stay were not significantly different between intramedullary fixation and extramedullary fixation group,

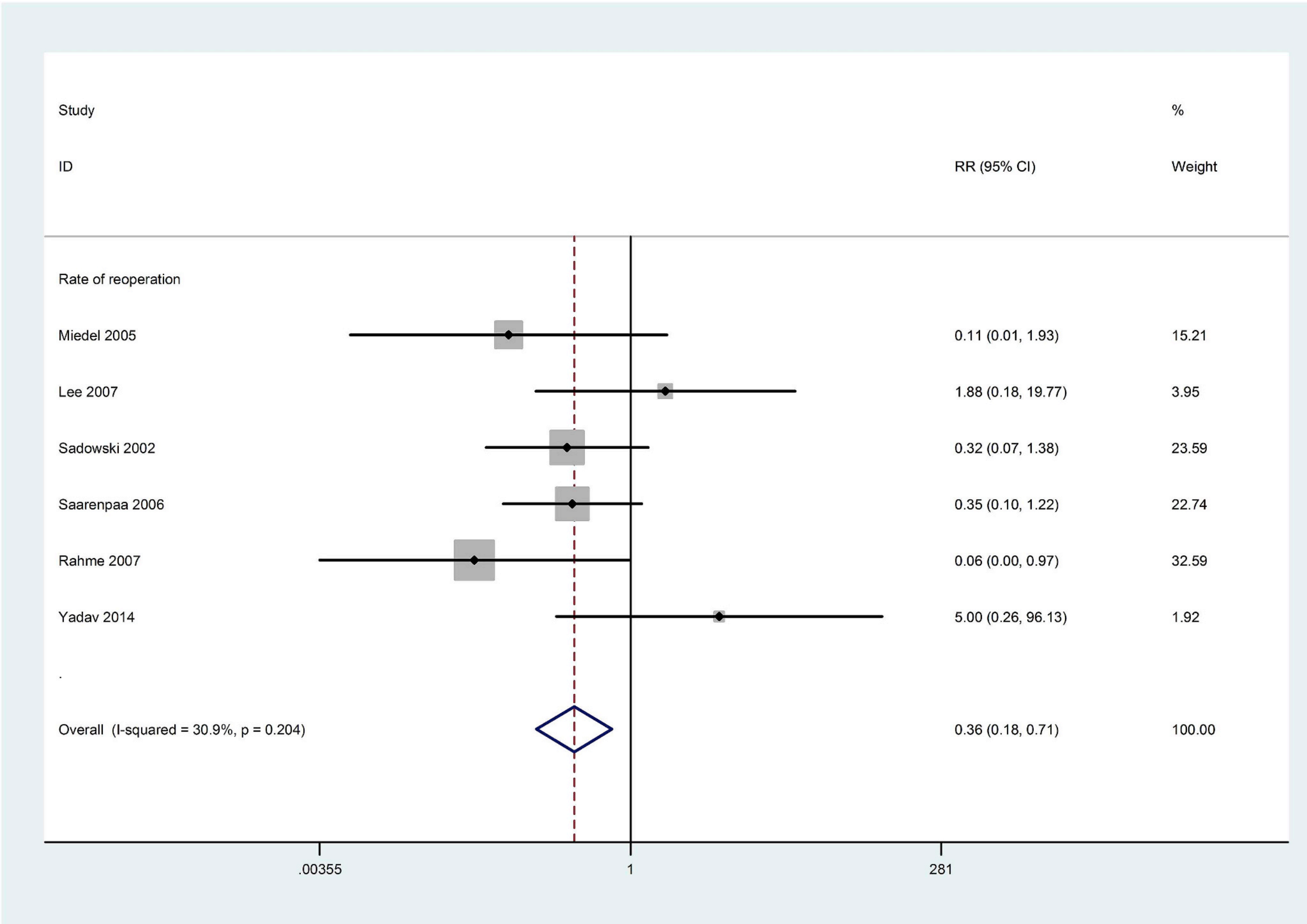

Fig. 11. Forest plot showing rate of reoperation.

which was conflicting with our results. We speculated that the reason lies in the fact that we included more studies and large number patients in our meta-analysis, however, in the previous meta-analysis only included four studies with small number patients. This may be the major cause of the inconsistency. Besides, the rate of nonunion was significantly lower in the intramedullary group compared to the extramedullary group in the previous meta-analysis, which was also different from our results. We surmised that contradiction may attribute to the age of included patients. Six of our included studies were young patients (age < 60), however, only one study was young patients in the previous meta-analysis. The bone quality of young patients was much better than old patients and they can achieve high rate of fracture union. This may account for the difference. Lee et al. [19] compared the surgical outcomes of biologic plating using dynamic condylar screw (DCS) and intramedullary nailing using the Russell-Taylor reconstruction nail to treat 66 comminuted subtrochanteric fractures. In their study, the DCS group achieved better outcomes than the intramedullary nailing group with respect to fluoroscopy time, incision length, blood loss, transfusion and pain score of the hip after surgery. Based on these results, they concluded that biologic plating using DCS may be a feasible fixation device for comminuted subtrochanteric fractures in young patients. These results were inconsistent with our meta-analysis, we speculated that the contradiction may be associated to the number and the age of included patients and the fracture type.

Complications arose regardless of which fixation method was used. The main complications reported in the included studies including superficial infection, fixation failure, refracture, reoperation and nonunion. Our meta-analysis showed that rate of superficial infection, refracture and nonunion was not significantly different between the two groups. However, intramedullary group revealed markedly lower rate of fixation failure and reoperation than extramedullary group, which indicated that intramedullary fixation was much stabler and had earlier time to full weight bearing than extramedullary fixation.

The strengths of this meta-analysis include the clear definition of the research question to reduce bias in the selection of the studies, adherence to an explicit research protocol that was developed prior to the analysis, the comprehensive literature search, consensus between the two reviewers with the entry data elements, and a quality control review of all results. Most of our included studies in this meta-analysis were RCTs, which therefore overcomes the shortcomings of recall or selection bias in non-randomized studies. The methodological quality of included cohort studies was high (a total of 2 studies scored 8 stars whereas 1 study scored 7 stars) according to the NOS. No publication bias was found in our meta-analysis and sensitivity analysis indicated that the results of this meta-analysis were relatively robust.

Nonetheless, some limitations in the present meta-analysis should

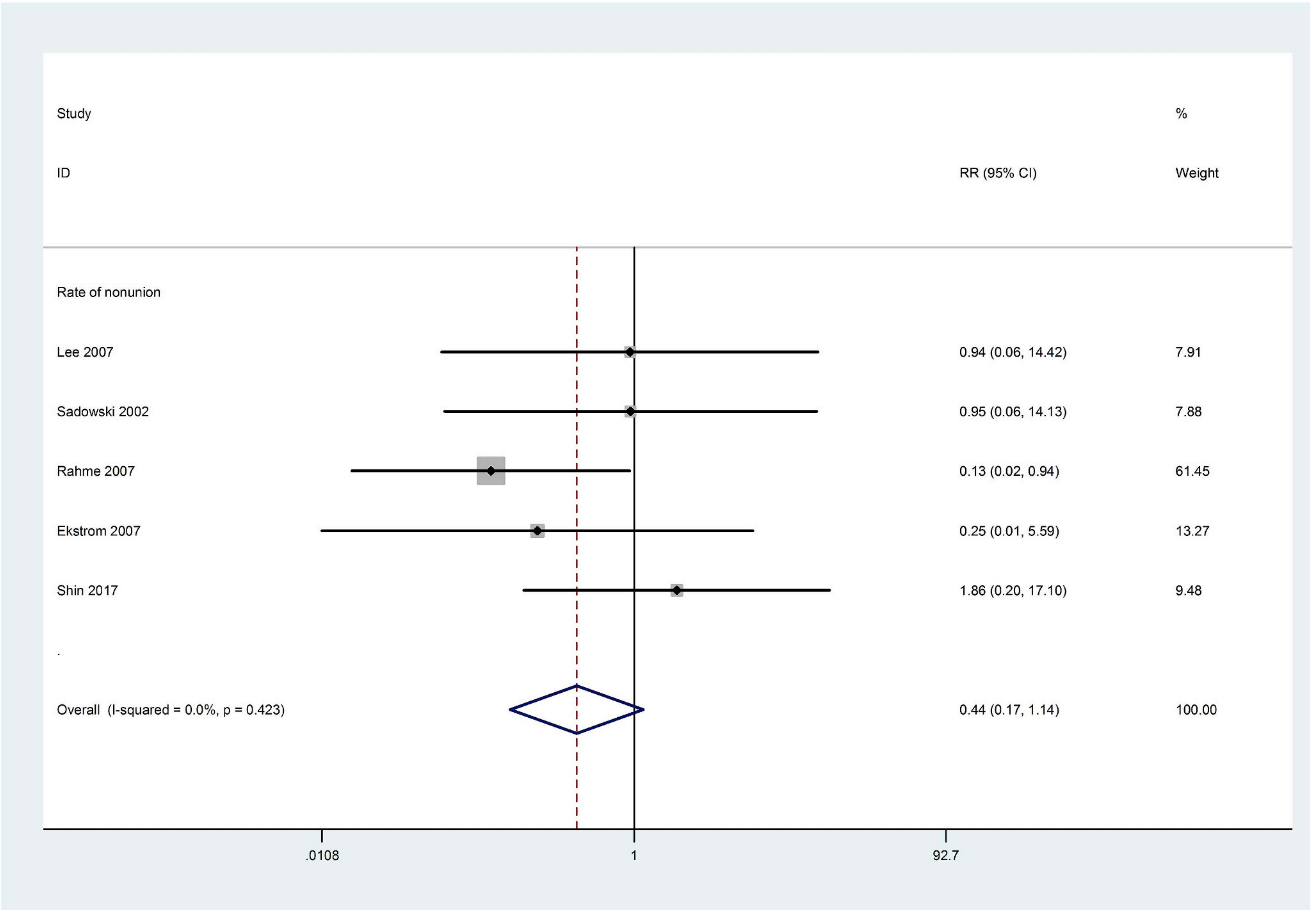

Fig. 12. Forest plot showing rate of nonunion.

be recognized. (1) Only 11 articles with small sample size were included in the study, three included studies were cohort studies, which might lower the evidence level. (2) The duration of the follow-up of the included studies was variable. (3) There are multiple choices for intramedullary and extramedullary devices, which may be the sources of heterogeneity. Therefore, we suggest that larger sample sizes and multicentric high-quality randomized controlled trials could be carried out to evaluate the outcomes of intramedullary fixation versus extramedullary fixation for subtrochanteric fracture in the future. Despite these limitations, this meta-analysis provides evidence that intramedullary fixation could achieve much better functional results with significantly shorter operation time, less intraoperative blood loss, shorter length of incision, length of stay, lower rate of fixation failure and reoperation in the treatment of subtrochanteric fracture.

5. Conclusion

In conclusion, intramedullary fixation for subtrochanteric fracture might be superior to extramedullary fixation in term of shorter operation time, less intraoperative blood loss, shorter length of incision, length of stay and better functional outcomes. Meanwhile, intramedullary fixation had lower rate of fixation failure and reoperation. Therefore, we recommend intramedullary fixation as the treatment of subtrochanteric fracture. However, taking the heterogeneity and small sample size into consideration, more large multi-center and high-quality RCTs are required to go a step further in demonstrating the benefits of intramedullary fixation in treatment of subtrochanteric fracture.

Ethical approval

All analyses were based on previous published studies; thus, no ethical approval is required.

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Author contribution

Wenhao Zheng designed the study and Linzhen Xie wrote this manuscript. Linzhen Xie and Jinwu Wang searched database and reviewed studies. Wenhao Zheng and Chunhui Chen collected and analyzed data. All of the authors have read and approved the final manuscript.

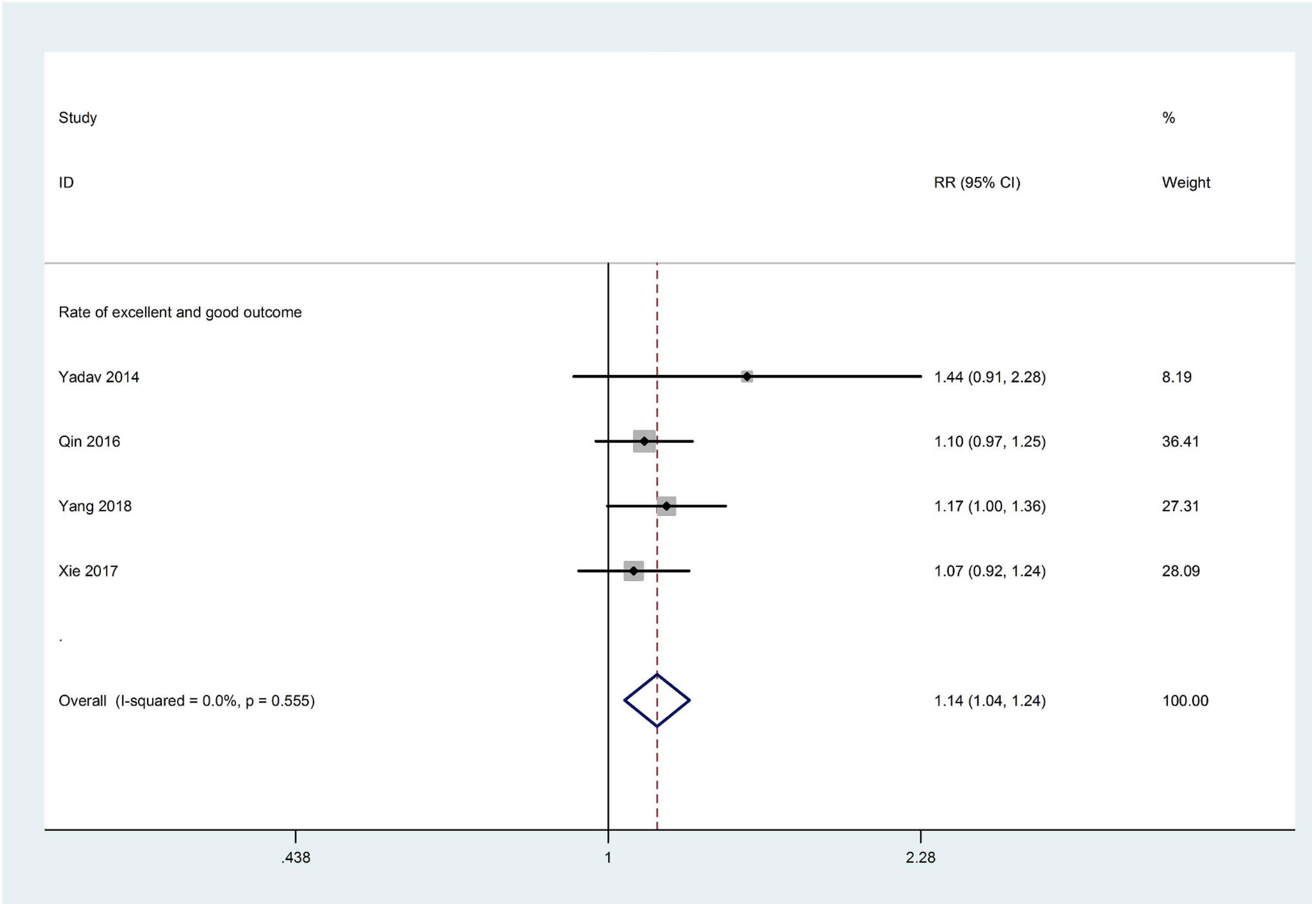

Fig. 13. Forest plot showing rate of excellent and good results.

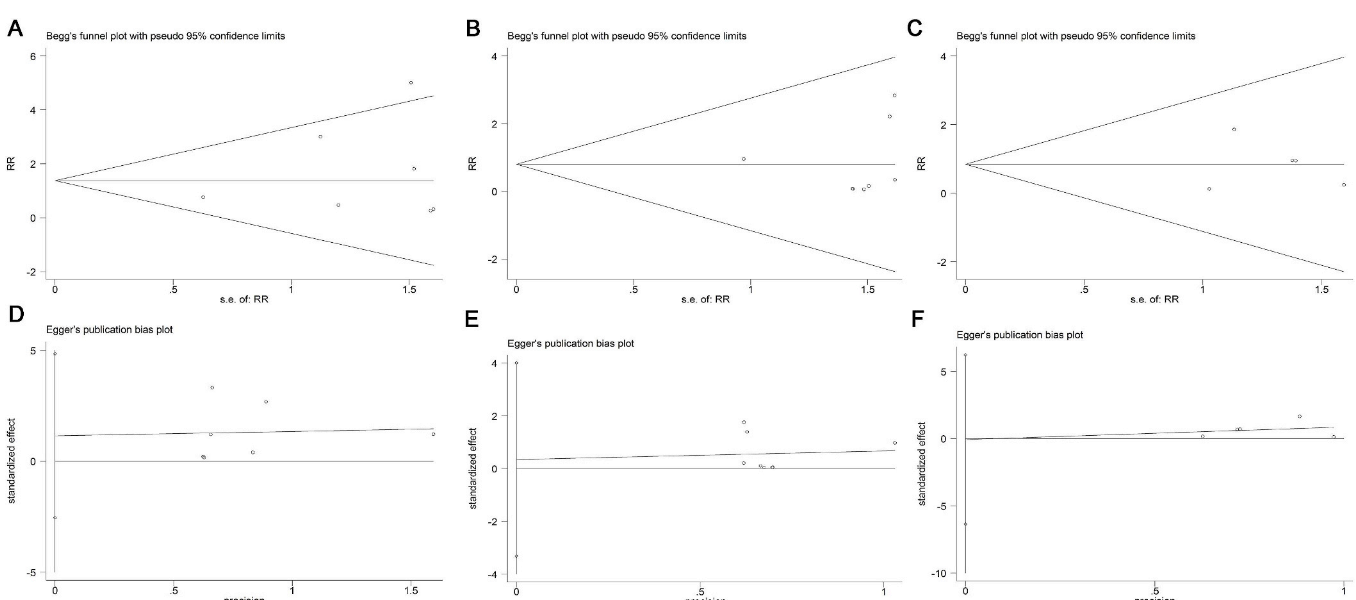

Fig. 14. Begg's funnel plot (A–C) and Egger's test (D–F) of rate of infection, rate of fixation failure and rate of nonunion.

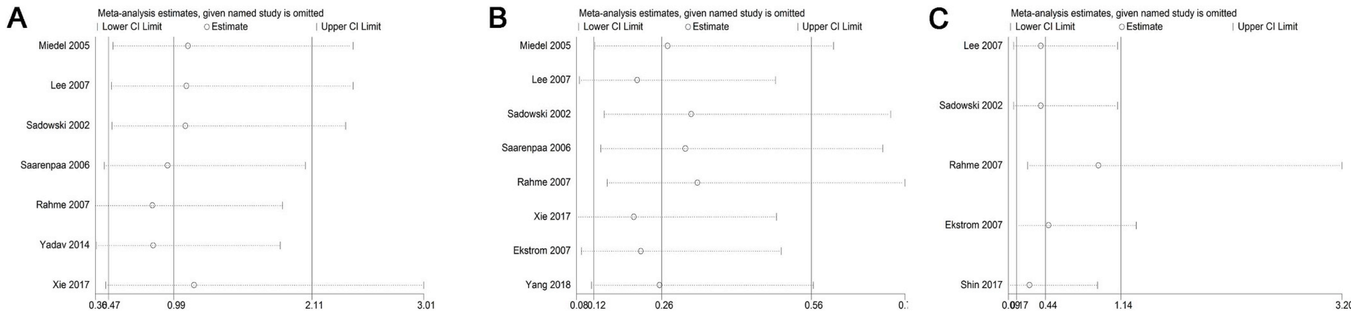

Fig. 15. Sensitivity analysis for rate of infection (A), rate of fixation failure (B) and rate of nonunion(C).

Conflicts of interest

None.

Research registration unique identifying number (UIN)

The Unique Identifying Number (UIN) from the Research Registry of the study is reviewregistry645.

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Not commissioned, externally peer-reviewed.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijsu.2019.01.021.

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