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RESEARCH

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Comparison of the clinical efficacy of patellar lateral retraction and patellar eversion in total knee arthroplasty: a systematic review and meta-analysis

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Abstract

Background According to the mobilization technique of the intraoperative patella, total knee arthroplasty (TKA) can be categorized into patellar eversion (PE) and patellar lateral retraction (PLR). Comparisons between the two procedures are inconclusive; therefore, the study purpose was to assess the postoperative clinical efficacy to identify the most suitable procedure.

Methods Electronic databases were searched, including Web of Science, ScienceDirect, PubMed, Embase, OVID, the Cochrane Library, CINAHL, CNKI, and WANFANG, to identify clinical trials of PLR versus PE from inception to May 2023. The statistical software Stata 15.0 and Review Manager 5.4 were applied to the data analysis.

Results Fifteen studies evaluating a total of 1349 patients and 1409 knees were ultimately included. Statistically significant differences emerged between the PLR and PE groups with respect to blood loss ($P=0.02$), incision length ($P<0.001$), operation time ($P=0.01$), straight leg raise ($P<0.001$), knee range of motion (ROM; $P<0.05$), the Knee Society Score (KSS) functional score ($P=0.0003$), the visual analogue scale (VAS) score (1 and 3 months, both $P<0.05$), and operative complications ($P=0.02$). Furthermore, the PLR and PE groups had similar clinical efficacy in terms of quadriceps strength, VAS score (1 week and 1 year), Hospital for Special Surgery score, KSS pain score, Insall–Salvati ratio, and the occurrence of patella baja (all $P\geq0.05$).

Conclusions The PLR procedure is superior to PE in terms of blood loss, incision length, straight leg raise, knee ROM, VAS score (1 and 3 months), KSS functional score, and operative complications, although PE could decrease the operation time. PLR could achieve better postoperative clinical outcomes than could PE. Therefore, it is recommended that experienced surgeons prioritize PLR in TKA.

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Registration This study was registered in the PROSPERO international registry (Registration ID: CRD42023440722).
Keywords Patellar lateral retraction, Patellar eversion, Total knee arthroplasty, Meta-analysis

Background

The total knee arthroplasty (TKA) is widely regarded as the most effective treatment for advanced knee osteoarthritis (KOA), which can effectively relieve the symptoms of knee pain and limit movement [1]. In conventional TKA, patellar eversion (PE) is often used to expose the knee joint space to facilitate release, osteotomy, and prosthesis installation [2]. With advances in medical technology and the increasing focus on minimally invasive techniques recently, conventional TKA has gradually failed to meet the needs of patients for faster recovery and has evolved towards minimally invasive total knee arthroplasty (MIS TKA) [3, 4]. Compared with conventional TKA, the MIS TKA procedure is generally accepted to be more conservative, with patellar lateral retraction (PLR) instead of PE, resulting in a shorter surgical incision, less soft tissue injury, avoidance of dislocation of the femoral-tibial joint, protection of the extensor mechanism, etc [5]. Several studies have demonstrated that MIS TKA has significant advantages in terms of early postoperative recovery, pain relief, increased early knee range of motion, and improved patient satisfaction [6–8]. However, there are some controversies regarding the effect of PLR on knee function after TKA. Some scholars believe that PLR is beneficial for recovering the muscle strength of the quadriceps femoris and reducing postoperative knee pain in patients [9, 10], and it can also reduce the incidence of patella baja [11]. In contrast, other scholars believe that both PLR and PE during TKA can achieve satisfactory clinical outcomes and that PLR is not conducive to the exposure of the surgical field, which undoubtedly increases the difficulty of surgery so that PLR is not necessary [12, 13]. Currently, comparisons between the PLR and PE procedures in TKA are inconclusive.

To systematically evaluate the distinct benefits associated with two surgical procedures, verify whether the mobilization technique of the intraoperative patella affects the recovery of knee function after TKA, and establish a more evidence-based foundation for the intervention protocols of KOA, the study compared the postoperative recovery of knee function after the two surgical procedures in TKA. It was hypothesized that the postoperative functional recovery of knees in the PLR group outperformed the PE group.

Methods

This study was conducted in accordance with the guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [14].

Search strategy

Following the Cochrane Collaboration's recommendations, we conducted searches in several comprehensive databases for studies, including Web of Science, ScienceDirect, PubMed, Embase, OVID, the Cochrane Library, CNKI, CINAHL, and WANFANG, spanning from inception to May 2023. All relevant studies were systematically identified without imposing any language constraints and professionally translated when needed. The systematic search was performed using the keywords "total knee arthroplasty", "TKA", "MIS TKA", "conventional TKA", "patella(r)", "eversion", and "lateral retraction". The search strategy was performed by using all fields, i.e., "((conventional total knee arthroplasty) OR (patellar turnover) OR (patellar eversion)) AND ((MIS TKA) OR (minimally invasive total knee arthroplasty) OR (patellar lateral retraction) OR (patellar lateral displacement))". The relevant studies and abstracts were identified through manual searching, subsequent to an initial search, in order to find those meeting the criteria.

Study selection

According to the initial retrieval of the studies' abstracts, independent reviews were conducted by two members of our team, who selected appropriate studies for a comprehensive analysis. If the corresponding information was not contained in the abstract, we reviewed the study's full text.

This study's inclusion criteria included the following aspects: (1) individuals diagnosed with degenerative knee disease (unilateral or bilateral involvement) of any sex, race, or age; (2) studies that focused on comparing PLR versus PE; (3) studies that focused mainly on the recovery of knee function after surgery; (4) retrospective controlled studies and prospective controlled studies, and (5) studies that provided detailedly subject counts in the PLR and PE groups, along with the means, standard deviations, or odds ratios of the parameters. The exclusion criteria were (1) duplicate publications; (2) commentaries, case reports, expert opinions, editorials, cadaveric studies, reviews, and letters; (3) studies that reported insufficient or incomplete outcomes; (4) no studies meeting the inclusion criteria with respect to study interventions; (5) patients diagnosed with rheumatoid arthritis, traumatic arthritis, or arthritis caused by tumours, haemophilia, etc.; and (6) original studies not designed accurately.

Data extraction and quality assessment

Two investigators used the preestablished data extraction form to gather information from the studies included, and settled any differences by referring to a third investigator.

The data collected encompassed (1) the studies' basic characteristics, i.e., journal title, publication date, country, the authors, and article title; (2) the demographic information, i.e., age, sex, race, BMI, disease course and severity; (3) the methodological aspects, i.e., controlled, randomized, and blinded; and (4) surgical approach, sample size, outcomes, and follow-up time. If key details were incomplete or unclear, preventing further analysis, we communicated with the corresponding authors for additional information. The quality of methodology in these included randomized controlled trials (RCTs) was reviewed by the risk of bias assessment tool provided by the Cochrane Handbook [15]. For the included non-RCTs, the Methodological Index for Non-Randomized Studies (MINORS) score was performed to evaluate study quality [16].

Outcome measures

The outcomes encompassed the operation-related parameters (operation time (OT), blood loss (BL), and incision length (IL)), knee function parameters (number of days until postoperative active straight leg raising (SLR), postoperative quadriceps strength (QS; 6 weeks, 3 months, and 6 months), and postoperative knee range of motion (ROM; 1 week, 1 month, 3 months, and 1 year)), knee scores (postoperative visual analogue scale (VAS) score (1 week, 1 month, 3 months, and 1 year), Hospital for Special Surgery (HSS) score, and Knee Society Score (KSS) functional and pain scores), and other parameters (postoperative Insall−Salvati (IS) ratio, occurrence of patella baja (PB), and occurrence of operative complications (OC)).

Statistical analysis

We represented continuous outcomes by weighted mean difference (WMD) or standard mean deviation (SMD), while dichotomous outcomes were presented using odds ratios (ORs), all presented with 95% confidence intervals (CIs). The synthetic data of the IL, the VAS score, and the IS ratio was expressed using the WMD. The OT, BL, SLR, QS, ROM, and KSS and HSS scores were expressed using the SMD because different testing methods were used or the means were too large. The OR was used to express the occurrence of PB and OC. Heterogeneity was identified through an evaluation of discrepancies among studies, with these inconsistencies attributed to actual study differences rather than random errors or chance occurrences [17]. In this study, heterogeneity was assessed through I^2 and chi-square tests. A random effects model was selected if heterogeneity was statistically significant ($I^2 > 50\%$), whereas a fixed effects model was employed when no significant heterogeneity ($I^2 \leq 50\%$) was found [18]. When heterogeneity was detected, sensitivity analysis was conducted by removing study that contributed to it. Besides, we conducted meta-regression analysis to explore potential factors influencing the results and identified the source of heterogeneity, and publication bias was assessed using Egger's test. We ultimately analysed the data when heterogeneity was not detected. Except for heterogeneity test, difference was deemed to be statistically significant while $P<0.05$. The results analyses were conducted using statistical software Stata 15.0 and Review Manager 5.4 supplied by the Stata Corp and Nordic Cochrane Centre, respectively.

Results

Search and selection

A total of 315 articles were initially identified through both our online and manual searches. After removing 234 duplicated studies, eighty-one studies were retained. Of these, after examining the abstracts, fifty-two studies were eliminated as they were not applicable to the purpose. After reviewing the entire texts, fourteen were eliminated due to incomplete relevant data or the absence of a comparison between PLR and PE. Ultimately, this meta-analysis included fifteen studies (ten in English and five in Chinese) containing 1349 patients and 1409 knees [6, 9, 11, 12, 19–29]. The flow diagram adhering to the PRISMA 2020 framework is illustrated in Fig. 1. A prospective comparison was conducted across thirteen studies based on the measured parameters [6, 9, 11, 12, 21–29], whereas the remaining two studies [19, 20] compared parameters retrospectively. Nine studies [6, 12, 19, 21–26] compared groups according to operation-related parameters; thirteen [6, 9, 12, 19–23, 25–29] compared knee function parameters; twelve [6, 9, 11, 12, 19–23, 26, 27, 29] compared knee scores; and fourteen [6, 9, 11, 12, 19–28] compared other parameters. The general characteristics of fifteen studies are summarized in Table 1.

The meta-analysis encompassed fifteen studies, employing I^2 and chi-square tests to assess heterogeneity across these study outcomes. Thirteen of the studies were RCTs [6, 9, 11, 12, 21–29], and the Fig. 2 shows the risk of bias summary and graph. The remaining two studies were retrospective controlled studies [19, 20], and their MINORS scores are shown in Table 2. The methodological quality was overall good, characterized by a low risk of bias.

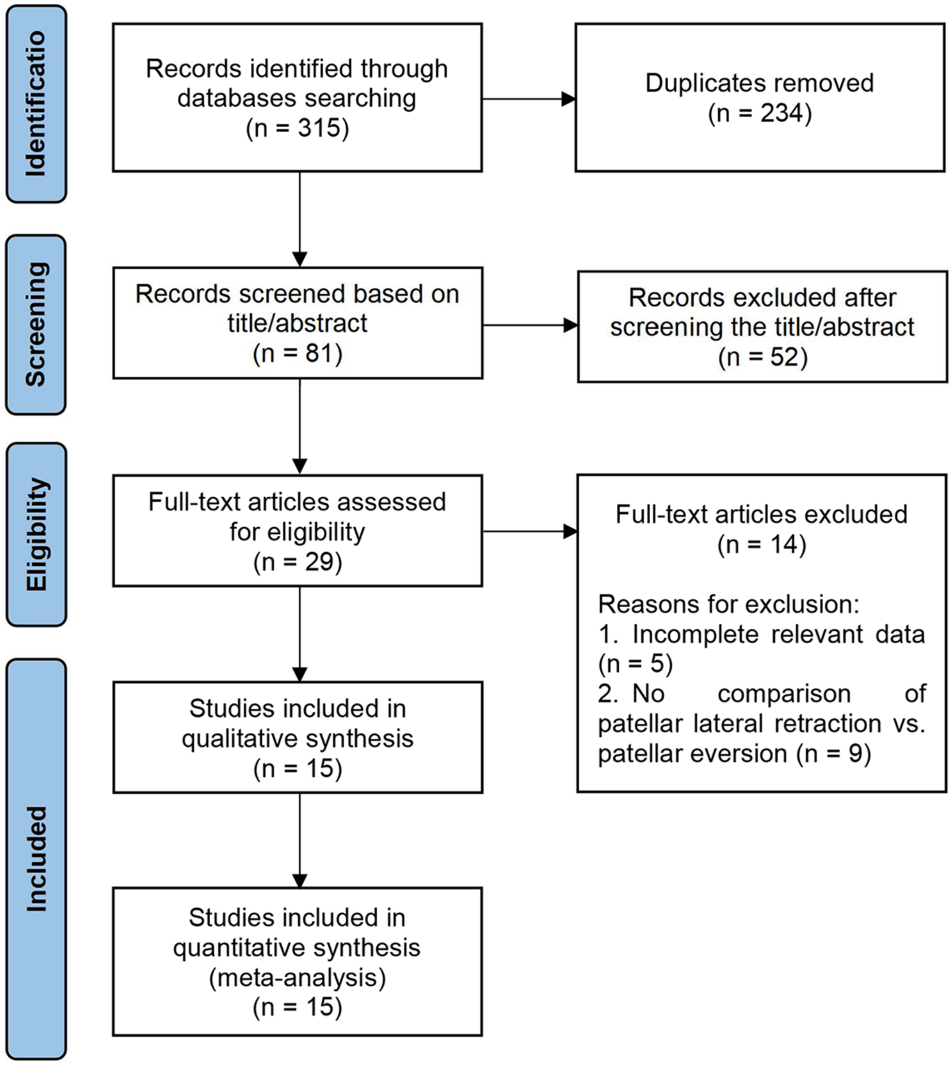

Fig. 1 The flow diagram of searching studies

Operation-related parameters

Among the fifteen studies, operation-related parameters, including OT, BL, and IL, were compared between the PLR and PE groups in nine studies involving 991 knees (501 in the PLR group and 490 in the PE group). Nine of these studies compared OT between the PLR ($n = 501$) and PE ($n = 490$) groups. The PLR group showed a statistically significant increase in OT compared to the PE group, with a standard mean difference of 0.28 (I^2 = 64%, $P = 0.01$, 95% CI: 0.07 to 0.50, Fig. 3a). Five studies compared the BL between the PLR ($n = 315$) and PE ($n = 307$) groups. The PE group showed a statistically significant increase in BL compared to the PLR group, with a standard mean difference of -0.29 (I^2 = 57%, $P = 0.02$, 95% CI: -0.54 to -0.04, Fig. 3b). Three studies compared the IL between the PLR ($n = 152$) and PE ($n = 152$) groups. The PE group showed a statistically significant increase in IL compared to the PLR group, with a weighted mean difference of -0.83 cm (I^2 = 26%, $P < 0.001$, 95% CI: -1.07 to -0.59, Fig. 3c). Significant differences were found between the original analysis and the sensitivity analysis with regard to the OT and BL (Table 3).

Knee function parameters

This study focused on the SLR, QS, and ROM in terms of knee function parameters. The SLR between the PLR ($n = 481$) and PE ($n = 489$) groups was compared in thirteen studies. The PE group showed a statistically significant increase in SLR compared to the PLR group, with a standard mean difference of -0.63 (I^2 = 38%, $P < 0.001$, 95% CI: -0.76 to -0.50, Fig. 4a). QS was divided into three subgroups according to the follow-up time: 6 weeks, 3 months and 6 months. The standard mean differences in QS in the three subgroups were all favouring the PLR group, but the differences were not statistically significant. (all $P \geq 0.05$, Fig. 4b). The ROM was divided into

Table 1 Details of the included studies

First author	Year	Study type	Mean age (years)		Sample size (M/F)		BMI (kg/m^2)		Approach	Follow-up (months)	Outcomes	Patellar of replacement
			PLR	PE	PLR	PE	PLR	PE				
Arnout et al. [12]	2009	RCT	64	67	30(8/22)	30(12/18)	31	28.2	Medial parapatellar	12	OT, IL, VAS, ROM, KSS, OC	Yes
Chowdhury et al. [9]	2021	RCT	NA	NA	41(10/31)	41(10/31)	NA	NA	Medial parapatellar	12	SLR, QS, VAS, KSS, PB	No
Dalury et al. [29]	2009	RCT	65.7	65.7	37(15/22)	37(15/22)	31.6	31.6	Medial parapatellar	6	QS, ROM, KSS	NA
Guo et al. [19]	2021	RCS	72.73	71.86	53(22/31)	45(20/25)	28.69	29.27	Medial parapatellar	6	OT, BL, SLR, IS, VAS, ROM, KSS, PB, OC	No
Huang et al. [20]	2016	RCS	62.46	63.13	40(14/26)	45(17/28)	23.97	24.78	Medial parapatellar	Mean 13	SLR, IS, VAS, ROM, KSS, PB, OC	No
Jenkins et al. [24]	2014	RCT	60	60	60(25/35)	57(19/38)	32.4	31.3	Medial parapatellar	12	OT, IS, PB, OC	Yes
Majima et al. [23]	2011	RCT	71.8	69.2	100(21/79)	100(18/82)	NA	NA	Subvastus	Mean 66	OT, BL, SLR, ROM, HSS, OC	Yes
Reid et al. [27]	2014	RCT	70	68	30(12/18)	36(16/20)	NA	NA	Medial parapatellar	12	IS, VAS, ROM, PB, OC	No
Su et al. [11]	2020	RCT	64.28	64.35	25(2/23)	25(3/22)	24.16	24.42	Medial parapatellar	12	IS, HSS, PB	No
Sun et al. [21]	2016	RCT	73.5	72.8	40(24/16)	40(22/18)	NA	NA	Medial parapatellar	12	OT, BL, SLR, VAS, ROM, OC	No
Tang et al. [22]	2021	RCT	72.63	73.21	86(36/50)	86(46/40)	23.58	24.00	Medial parapatellar	Mean 15.8	OT, BL, SLR, IL, IS, VAS, ROM	No
Umrani et al. [25]	2013	RCT	64.3	66.7	36(0/36)	36(0/36)	28.78	27.63	Midvastus	12	OT, BL, QS, IL, OC	Yes
Walter et al. [28]	2007	RCT	71.5	75.7	25(6/19)	36(10/26)	31.8	31.3	Midvastus	At least 3	SLR, OC	Yes
Yuan et al. [6]	2020	RCT	67.2	65.9	52(20/32)	52(22/30)	26.8	26.5	Medial parapatellar	At least 12	OT, SLR, VAS, ROM, HSS, PB, OC	No
Zan et al. [26]	2016	RCT	NA	NA	44(18/26)	44(26/18)	NA	NA	Medial parapatellar	12	OT, SLR, VAS, ROM, PB, OC	No

PLR, patellar lateral retraction; PE, patellar eversion; RCT, randomized controlled trial; RCS, retrospective comparative study; M, male; F, female; OT, operation time (min); BL, blood loss (ml); IL, incision length (cm); SLR, days taken until postoperative active straight leg raising (d); QS, quadriceps strength (N); ROM, knee range of motion (°); VAS, visual analogue scale score; KSS, Knee Society Score; HSS, Hospital for Special Surgery score; IS, Insall-Salvati ratio; PB, occurrence of patella baja; OC, occurrence of operative complication; NA, not available

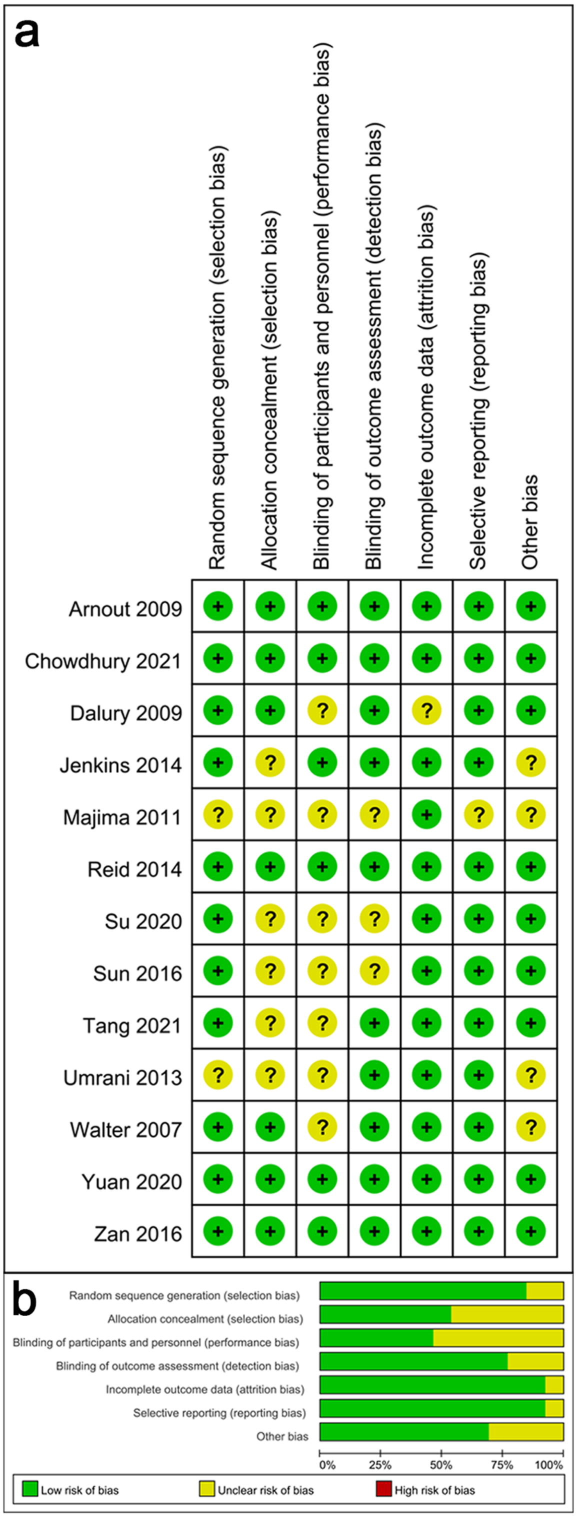

Fig. 2 (**a**) Risk of bias summary of the included studies. (**b**) Risk of bias graph

Table 2 Methodological Index for Non-Randomized Studies scores for included non-randomized controlled trials

MINORS checklist	Guo et al. [19]	Huang et al. [20]
A clearly stated aim	2	2
Inclusion of consecutive patients	2	2
Prospective collection of data	2	2
Endpoints appropriate to the aim of the study	2	2
Unbiased assessment of the study endpoint	1	1
Follow-up period appropriate to the aim of the study	2	2
Loss to follow up less than 5%	2	2
Prospective calculation of the study size	0	0
An adequate control group	2	2
Contemporary groups	2	2
Baseline equivalence of groups	2	2
Adequate statistical analyses	2	2
Total	**21**	**21**

0–16: poor research quality; 17–20: fair research quality; 21–24: high research quality

four subgroups according to the follow-up time: 1 week, 1 month, 3 months, and 1 year. The pooled results revealed that the PLR group achieved a greater ROM than did the PE group in any subgroup (all $P < 0.05$, Fig. 5). No significant difference was found between the original analysis and the sensitivity analysis regarding the knee function parameters (Table 3).

Knee scores

Within the studies included, twelve compared the knee scores between the PLR ($n = 578$) and PE ($n = 581$) groups, which focused mainly on the VAS, KSS, and HSS scores. The VAS score was divided into four subgroups according to the follow-up time: 1 week, 1 month, 3 months, and 1 year. The pooled results demonstrated that the PLR group achieved a lower VAS score than did the PE group at 1 month and 3 months (both $P < 0.05$, Fig. 6), whereas the scores of the two groups were not significantly different (both $P \geq 0.05$) at 1 week and 1 year. The KSS was separated into two components: the KSS function score and the KSS pain score. The pooled results revealed that the PLR group had higher KSS function scores compared to the PE group (I^2 = 43%, $P = 0.0003$, SMD = 0.37, 95% CI: 0.17 to 0.57, Fig. 7a), whereas the KSS pain scores of the two groups did not significantly differ (I^2 = 48%, $P = 0.41$, SMD = 0.11, 95% CI: -0.15 to 0.38). The results revealed that the PLR group had a higher HSS score compared to the PE group, yet this difference did not achieve statistical significance (I^2 = 87%, $P = 0.09$, SMD = 0.58, 95% CI: -0.08 to 1.25, Fig. 7b). Significant differences were found between the original analysis and the sensitivity analysis regarding the knee score parameters (Table 3).

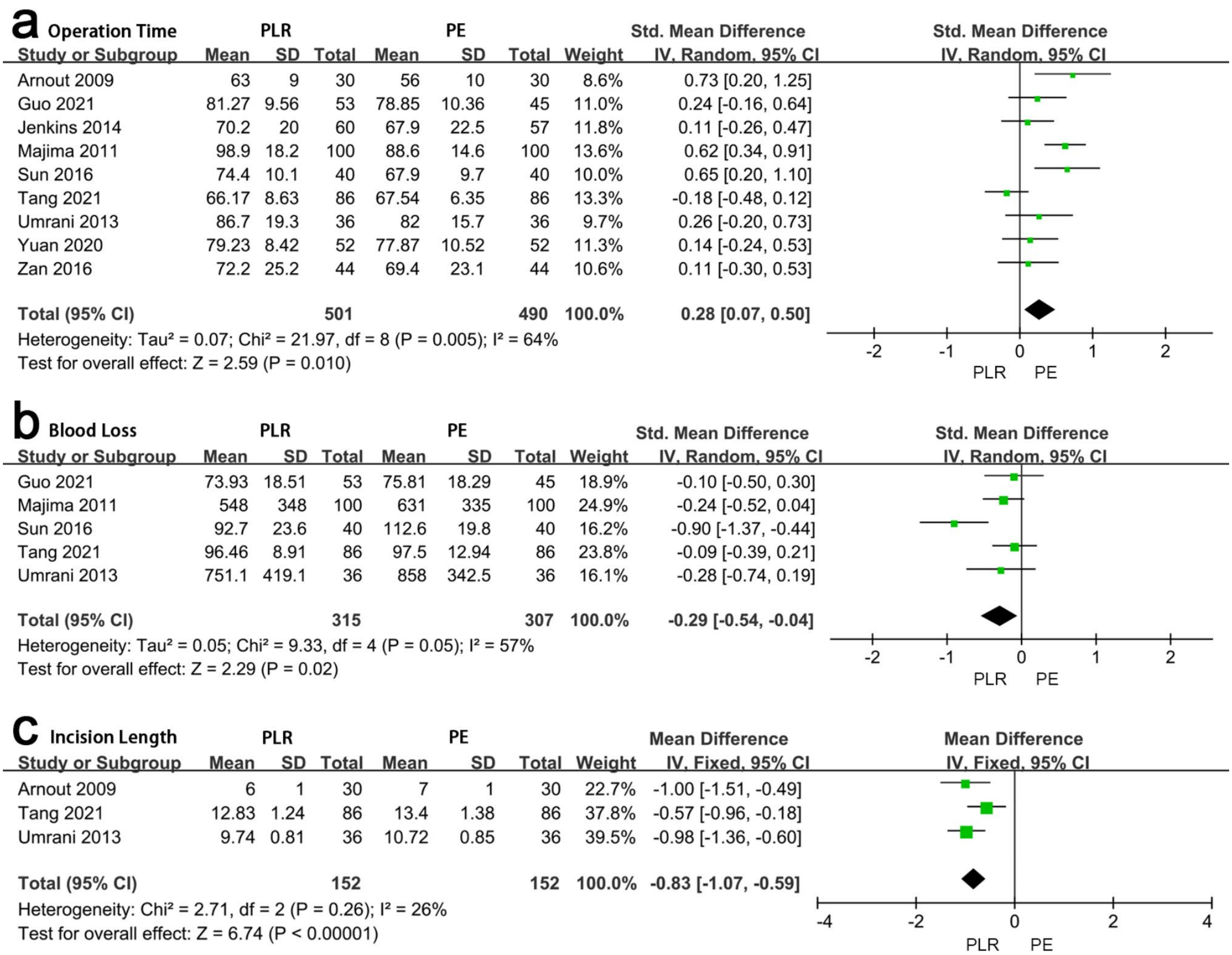

Fig. 3 Forest plot of operation related parameters in the two groups. (**a**) the operation time; (**b**) the blood loss; (**c**) the incision length

Other parameters

In addition, this study focused on the IS ratio and the occurrence of PB and OC in terms of other parameters. Six studies compared the IS ratios between the PLR ($n=290$) and PE ($n=290$) groups. The weighted mean difference in the IS ratio was 0.05 for the PLR group between the two groups, but no significant difference was found (I^2 = 91%, $P=0.13$, 95% CI: -0.01 to 0.11, Fig. 8a). The occurrence of PB was compared between the PLR ($n=341$) and PE ($n=341$) groups in eight studies. The odds ratio for PB between the two groups was 0.48 for the PE group, but no significant difference was found (I^2 = 0%, $P=0.11$, 95% CI: -0.19 to 1.20, Fig. 8b). Eleven studies compared the occurrence of OC between the PLR ($n=510$) and PE ($n=521$) groups. The odds ratio for OC between the two groups was 0.57 for the PE group, which had a statistically significant impact (I^2 = 0%, $P=0.02$, 95% CI: 0.36 to 0.92, Fig. 8c). No significant difference was found between the original analysis and the sensitivity analysis regarding the other parameters (Table 3).

Meta-regression analysis

Table 4 presents the findings from the meta-regression analysis of the ROM-3 M and IS ratios between the PLR and PE groups with regard to study type, publication year, country, and sex. These variables had no significant effect on the mean difference in the ROM-3 M or IS ratio between the two groups, according to the results (all $P\geq 0.05$).

Publication bias analysis

As indicated in Table 5, the findings from the publication bias analysis are displayed. Egger's test was performed to evaluate publication bias in ROM-3 M and the IS ratio. The findings demonstrated that publication bias was negligible and had no significant effect on the ROM-3M ($P=0.493$) or IS ratio ($P=0.310$) between the two groups.

Discussion

Our results found that the knee functional recovery in the PLR group was better than or similar to that in the PE group except for the operation time, which supported

Table 3 Sensitivity analysis

Study	Parameter	Before exclusion	After exclusion	Statistical significance
Tang et al. [22]	OT	SMD = 0.28, 95% CI = 0.07 to 0.50, I^2 = 64%	SMD = 0.35, 95% CI = 0.17 to 0.53, I^2 = 40%	Difference
Sun et al. [21]	BL	SMD = -0.29, 95% CI = -0.54 to -0.04, I^2 = 57%	SMD = -0.17, 95% CI = -0.34 to 0.00, I^2 = 0%	Difference
Guo et al. [19]	IS ratio	WMD = 0.05, 95% CI = -0.01 to 0.11, I^2 = 91%	I^2 > 50%	No difference
Huang et al. [20]				
Jenkins et al. [24]				
Reid et al. [27]				
Su et al. [11]				
Tang et al. [22]				
Tang et al. [22]	VAS-1 M	WMD = -0.58, 95% CI = -1.13 to -0.02, I^2 = 96%	WMD = -0.29, 95% CI = -0.42 to -0.16, I^2 = 0%	Difference
Reid et al. [27]	VAS-3 M	WMD = -0.36, 95% CI = -0.64 to -0.08, I^2 = 83%	WMD = -0.20, 95% CI = -0.32 to -0.08, I^2 = 0%	Difference
Zan et al. [26]	VAS-1Y	WMD = -0.07, 95% CI = -0.21 to 0.06, I^2 = 66%	WMD = -0.13, 95% CI = -0.23 to -0.03, I^2 = 26%	Difference
Dalury et al. [29]	ROM-3 M	SMD = 0.48, 95% CI = -0.00 to 0.96, I^2 = 85%	I^2 > 50%	No difference
Guo et al. [19]				
Huang et al. [20]				
Reid et al. [27]				
Sun et al. [21]				
Zan et al. [26]				
Su et al. [11]	HSS	SMD = 0.58, 95% CI = -0.08 to 1.25, I^2 = 87%	SMD = 0.20, 95% CI = -0.03 to 0.42, I^2 = 0%	Difference

SMD, standard mean difference; WMD, weighted mean difference; CI, confidence interval; OT, operation time (min); BL, blood loss (ml); ROM, knee range of motion (°); VAS, visual analogue scale score; HSS, Hospital for Special Surgery score; IS, Insall-Salvati ratio

the previous hypothesis that the postoperative functional recovery of patients' knees in the PLR group outperformed that in the PE group.

As a standard surgical procedure for severe KOA, TKA effectively alleviates knee pain, corrects deformities, enhances knee function, and significantly improves patients' quality of life, with positive clinical efficacy [1, 30]. During TKA, the patella must be mobilized to achieve clear surgical exposure for optimal visualization [8]. Theoretically, the PLR procedure can reduce the pressure on the extensor mechanism and the related soft tissue injury, which promotes better recovery of extensor function [31]. Bonutti et al. [5] reported that when no PE occurred during the operation, the pressure on the quadriceps tendon decreased by 8% and 16%. The disadvantage of PLR is that the joint space is not fully exposed, which makes it difficult to place the prosthesis and may lead to the occurrence of prosthesis dislocation [32]. In contrast, PE can increase the exposure of the joint space, which is more conducive to placing a prosthesis, but it increases the pressure on the extensor mechanism, which may cause quadriceps injury and damage the patellar tendon, leading to scarring, shortening, and even the occurrence of patella baja [5, 32]. Some prospective studies have compared PLR with PE, but the results and conclusions are not the same or similar [9, 10, 12]. It is still uncertain whether PLR is weaker or stronger than PE regarding the knee function recovery.

A systematic review of six RCTs conducted by Zan et al. [33] revealed that PE could shorten the operation time, but the skin incision was longer, which was consistent with our results. One study concluded that the disadvantage of PLR was the inadequate exposure of the surgical field, which made intraoperative manoeuvres such as osteotomies and fitting of prostheses difficult, and this was the main reason for the increase in the operative time of the MIS TKA group [12]. Both Majima et al. [23] and Umrani et al. [25] found that the amount of intraoperative blood loss associated with PLR was less than that associated with PE, but the results were not significantly different. According to our results, the amount of intraoperative blood loss associated with PE was greater than that associated with PLR. One possible explanation for the above difference is the sample size, which also reflects the advantages and necessity of this meta-analysis.

The SLR embodies the functional recovery of the knee extensor mechanism, especially the quadriceps strength, and is the main index for evaluating the knee early after surgery. Some studies have shown that the PE group reached the SLR significantly later than the PLR group did [26, 28]. Dalury et al. [29] compared the proportion of SLR between the two groups on Days 1, 2, 3, and 10 postoperatively, but the comparison revealed no significant differences. In our study, the results found that patients undergoing PLR reached the SLR more quickly, and we believe that this is beneficial for the early recovery of knee function after surgery; this may be because PLR can better protect the blood supply around and inside the patella. Some studies reported no significant differences in quadriceps strength between the two groups at 6 months or 1 year postoperatively [12, 24], which was consistent with our results. Based on these results, we speculate that the difference in surgical procedures does not affect quadriceps strength at 6 weeks postoperatively.

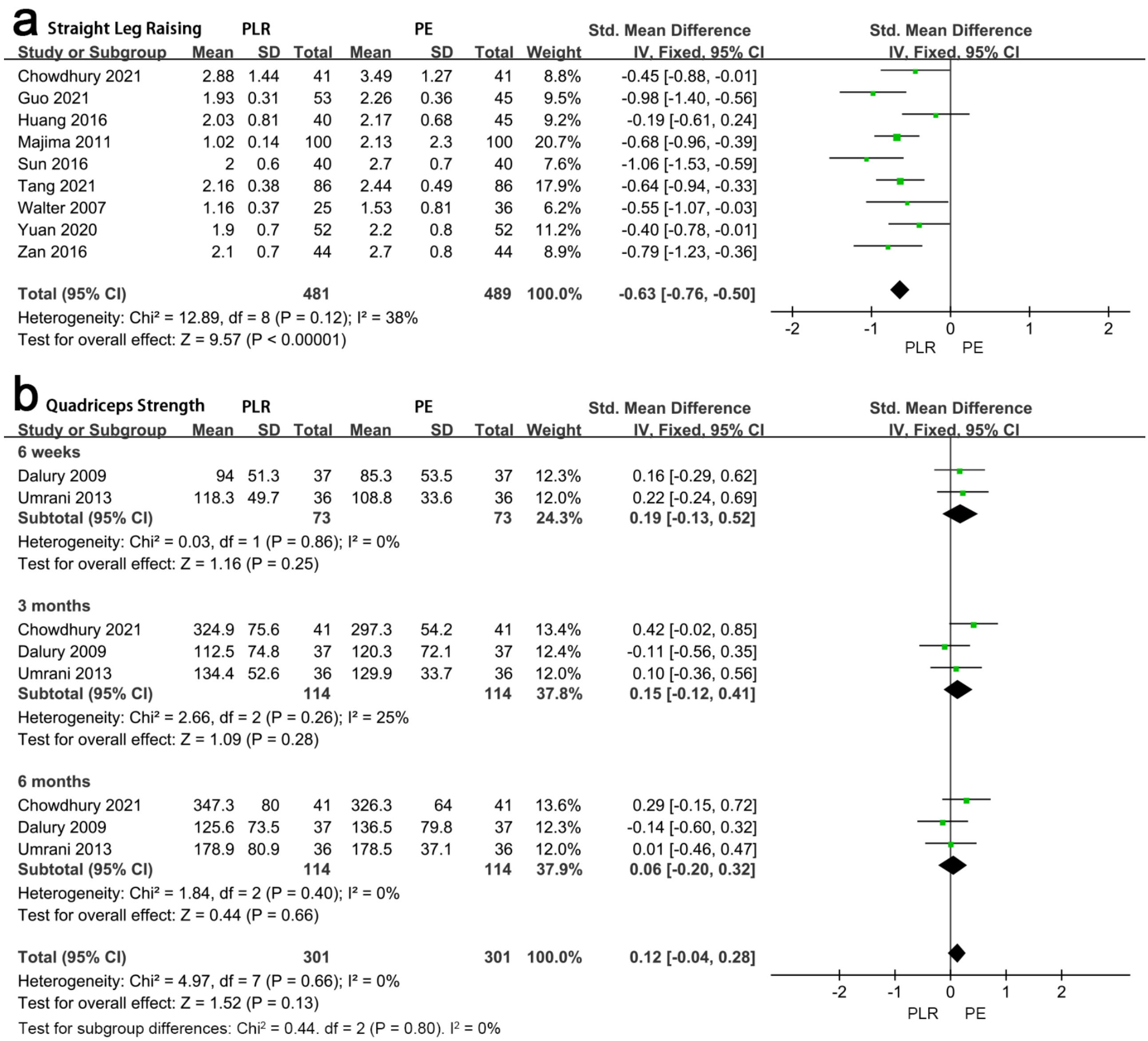

Fig. 4 Forest plot of the days taken until straight leg raising (**a**) and quadriceps strength (**b**) in the two groups

Both Arnout et al. [12] and Zan et al. [26] demonstrated that the PLR group was significantly superior to the PE group in terms of active and passive ROM, with a statistically significant difference, which was similar to our results. We noticed that patients who underwent PLR were superior to those who underwent PE in terms of knee ROM at 1 week, 1 month, 3 months and 1 year postoperatively. This may be because PE overstretches the extensor mechanism, leading to microtrauma, which in turn causes fibrosis of the patellar tendon, thus adversely affecting the knee ROM after surgery.

The VAS score, HSS score, KSS pain score, and KSS function score are the main indices used to reflect the long-term recovery of knee function and efficacy after TKA. In this study, we reported that the PLR group was better than the PE group in terms of the above four scores, but no statistically significant differences were found in the VAS-1 W, VAS-1Y, KSS pain, or HSS scores. Some studies compared the VAS scores of the two groups during rest and activity and reported that the VAS score significantly improved both at rest and after activity, with the minimum score occurring 1 year postoperatively [24]. One possible explanation for the above phenomenon is that the incision has not healed at one week postoperatively, and at one year after the operation or until the final follow-up, the knee function or proprioception has basically recovered. In addition, the VAS, HSS, KSS pain, and KSS function scores are subjective perception scores of patients, which may introduce some biases to the results.

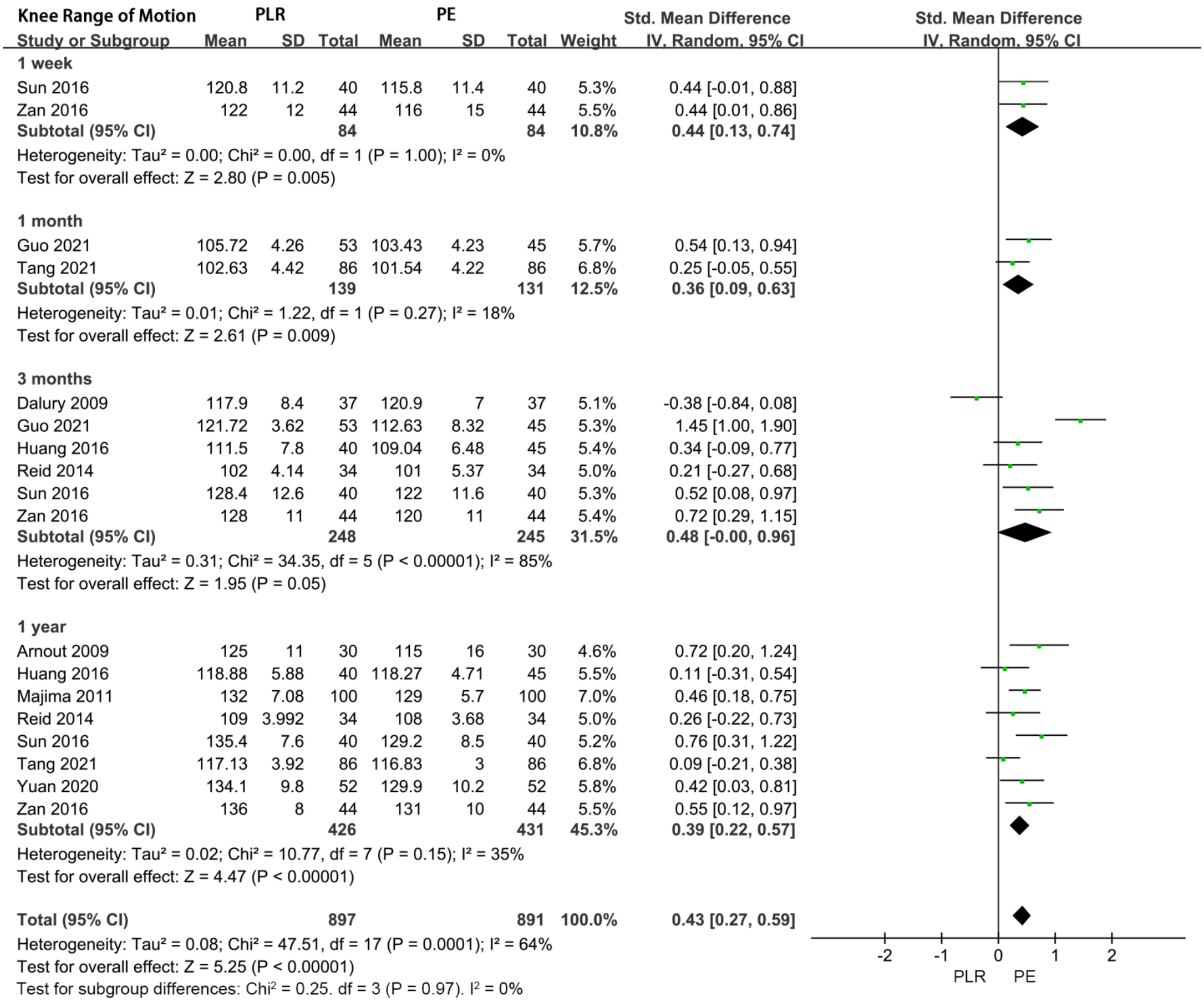

Fig. 5 Forest plot of the knee range of motion in the two groups

The Insall–Salvati ratio is a measure of patellar height. Usually, when the IS ratio is less than 0.8, patella baja occurs [24, 27]. A study compared the IS ratio between the two groups at 1 year after surgery and reported that the IS ratio in the PE group was inferior to that in the PLR group, and it was believed that the PE group was more likely to have a low patella [12]. In this study, no difference was found between the PLR and PE groups with regard to the IS ratio, which is consistent with the results of Sharma et al. [34]. Interestingly, the occurrence of patella baja was similar to that of the IS ratio in the two groups. In addition, our findings revealed that the PE group had more operative complications than did the PLR group. Patellofemoral problems are common postoperative complications and can be caused by many factors. Some studies have revealed the sensitivity of the patellar blood supply to knee flexion and the PLR, and especially to PE [10]. The patellar blood supply could be related to functional recovery of the knee and complications, which are associated with the mobilization of the patella [33, 35]. These factors must be further confirmed with larger sample sizes.

Although some new discoveries have been made, this study has certain limitations that ought to be noted. First, this study was a meta-analysis and included a relatively small number of studies, so its results and conclusions are biased. Second, three different surgical approaches were used in the present study, which may reduce the accuracy of the conclusions. Third, due to the different materials and types of prostheses used, performance differences cannot be excluded. Fourth, the impact of patellar replacement on the study results cannot be ruled out. Finally, publication bias and meta-regression analyses were conducted for the IS ratio and ROM-3 M, yet no sources of heterogeneity were identified. Therefore, when applying the results to broader contexts, it is important to

Visual Analogue Scale	PLR			PE				Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
1 week								
Chowdhury 2021	6.02	1.04	41	6.54	1.1	41	4.5%	-0.52 [-0.98, -0.06]
Sun 2016	4.4	1.2	40	4.5	1.4	40	3.9%	-0.10 [-0.67, 0.47]
Zan 2016	4.1	1.2	44	4.2	1.1	44	4.4%	-0.10 [-0.58, 0.38]
Subtotal (95% CI)			**125**			**125**	**12.7%**	**-0.26 [-0.55, 0.03]**
Heterogeneity: Tau² = 0.00; Chi² = 1.94, df = 2 (P = 0.38); I² = 0%								
Test for overall effect: Z = 1.78 (P = 0.07)								
1 month								
Chowdhury 2021	4.8	1.08	41	5.32	1.01	41	4.5%	-0.52 [-0.97, -0.07]
Guo 2021	3.11	0.53	53	3.37	0.26	45	6.1%	-0.26 [-0.42, -0.10]
Tang 2021	2.58	0.5	86	3.79	0.59	86	6.1%	-1.21 [-1.37, -1.05]
Zan 2016	1.8	0.6	44	2.1	0.7	44	5.6%	-0.30 [-0.57, -0.03]
Subtotal (95% CI)			**224**			**216**	**22.2%**	**-0.58 [-1.13, -0.02]**
Heterogeneity: Tau² = 0.30; Chi² = 74.09, df = 3 (P < 0.00001); I² = 96%								
Test for overall effect: Z = 2.03 (P = 0.04)								
3 months								
Chowdhury 2021	2.34	1.02	41	2.661	1.02	41	4.6%	-0.32 [-0.76, 0.12]
Guo 2021	1.73	0.37	53	1.91	0.42	45	6.1%	-0.18 [-0.34, -0.02]
Huang 2016	1.59	0.68	40	1.82	0.62	45	5.5%	-0.23 [-0.51, 0.05]
Reid 2014	1.08	0.44	34	1.93	0.54	34	5.7%	-0.85 [-1.08, -0.62]
Sun 2016	1.8	0.7	40	2	0.6	40	5.5%	-0.20 [-0.49, 0.09]
Subtotal (95% CI)			**208**			**205**	**27.4%**	**-0.36 [-0.64, -0.08]**
Heterogeneity: Tau² = 0.08; Chi² = 23.69, df = 4 (P < 0.0001); I² = 83%								
Test for overall effect: Z = 2.51 (P = 0.01)								
1 year								
Arnout 2009	1.3	1.6	30	1.8	1.9	30	2.5%	-0.50 [-1.39, 0.39]
Chowdhury 2021	0.71	0.68	41	0.68	0.72	41	5.4%	0.03 [-0.27, 0.33]
Huang 2016	1.09	0.57	40	1.25	0.57	45	5.7%	-0.16 [-0.40, 0.08]
Reid 2014	0.9	0.38	34	1.1	0.47	34	5.9%	-0.20 [-0.40, 0.00]
Sun 2016	1.5	0.4	40	1.5	0.3	40	6.1%	0.00 [-0.15, 0.15]
Tang 2021	1.08	0.28	86	1.29	0.46	86	6.2%	-0.21 [-0.32, -0.10]
Yuan 2020	0	0	52	0	0	52		Not estimable
Zan 2016	1.4	0.4	44	1.2	0.5	44	6.0%	0.20 [0.01, 0.39]
Subtotal (95% CI)			**367**			**372**	**37.7%**	**-0.07 [-0.21, 0.06]**
Heterogeneity: Tau² = 0.02; Chi² = 17.45, df = 6 (P = 0.008); I² = 66%								
Test for overall effect: Z = 1.04 (P = 0.30)								
Total (95% CI)			**924**			**918**	**100.0%**	**-0.29 [-0.47, -0.11]**
Heterogeneity: Tau² = 0.13; Chi² = 196.67, df = 18 (P < 0.00001); I² = 91%								
Test for overall effect: Z = 3.20 (P = 0.001)								
Test for subgroup differences: Chi² = 6.15. df = 3 (P = 0.10). I² = 51.2%								

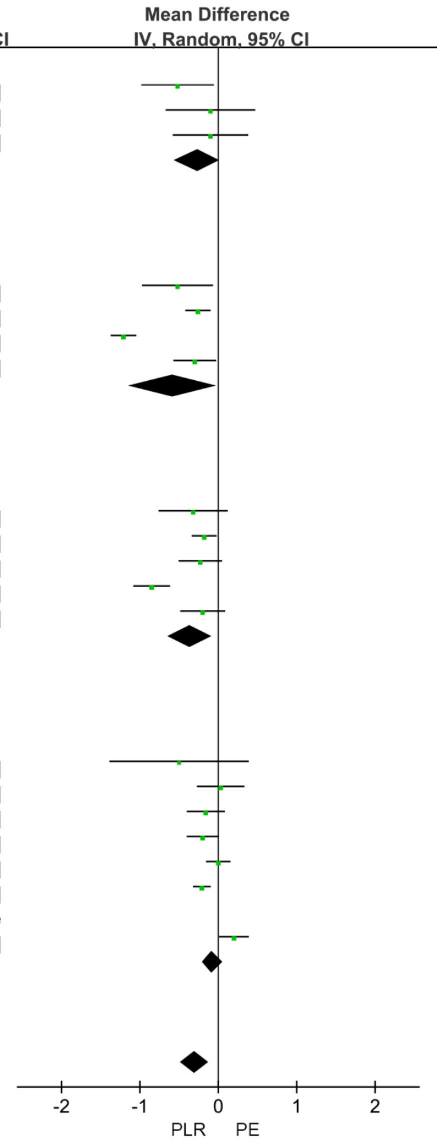

Fig. 6 Forest plot of the visual analogue scale score in the two groups

account for the above limitations. As more high-quality studies emerge, these discoveries need to be confirmed in future studies.

Conclusions

As the most current systematic review and meta-analysis encompassing the maximum number of patients and studies, our findings indicated that PLR is superior to PE in terms of BL, IL, SLR, ROM, the VAS-1 M, VAS-3 M, and KSS functional scores, and the occurrence of OC; PE could decrease the operation time; and no significant differences were found for other outcome measures. The PLR procedure could achieve better postoperative clinical outcomes. However, as more high-quality studies emerge, the results require further validation in future study.

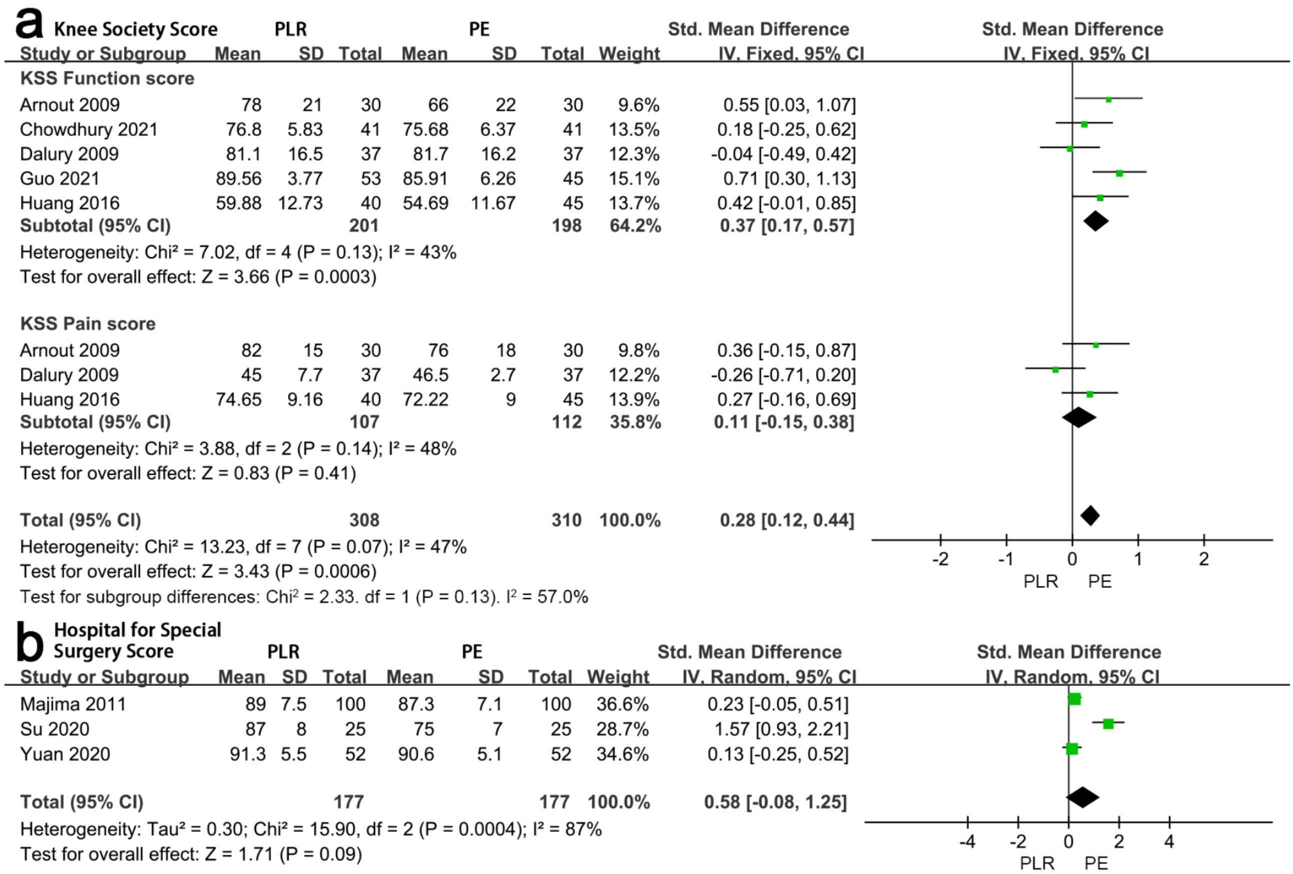

Fig. 7 Forest plot of the Knee Society Score (**a**) and Hospital for Special Surgery score (**b**) in the two groups

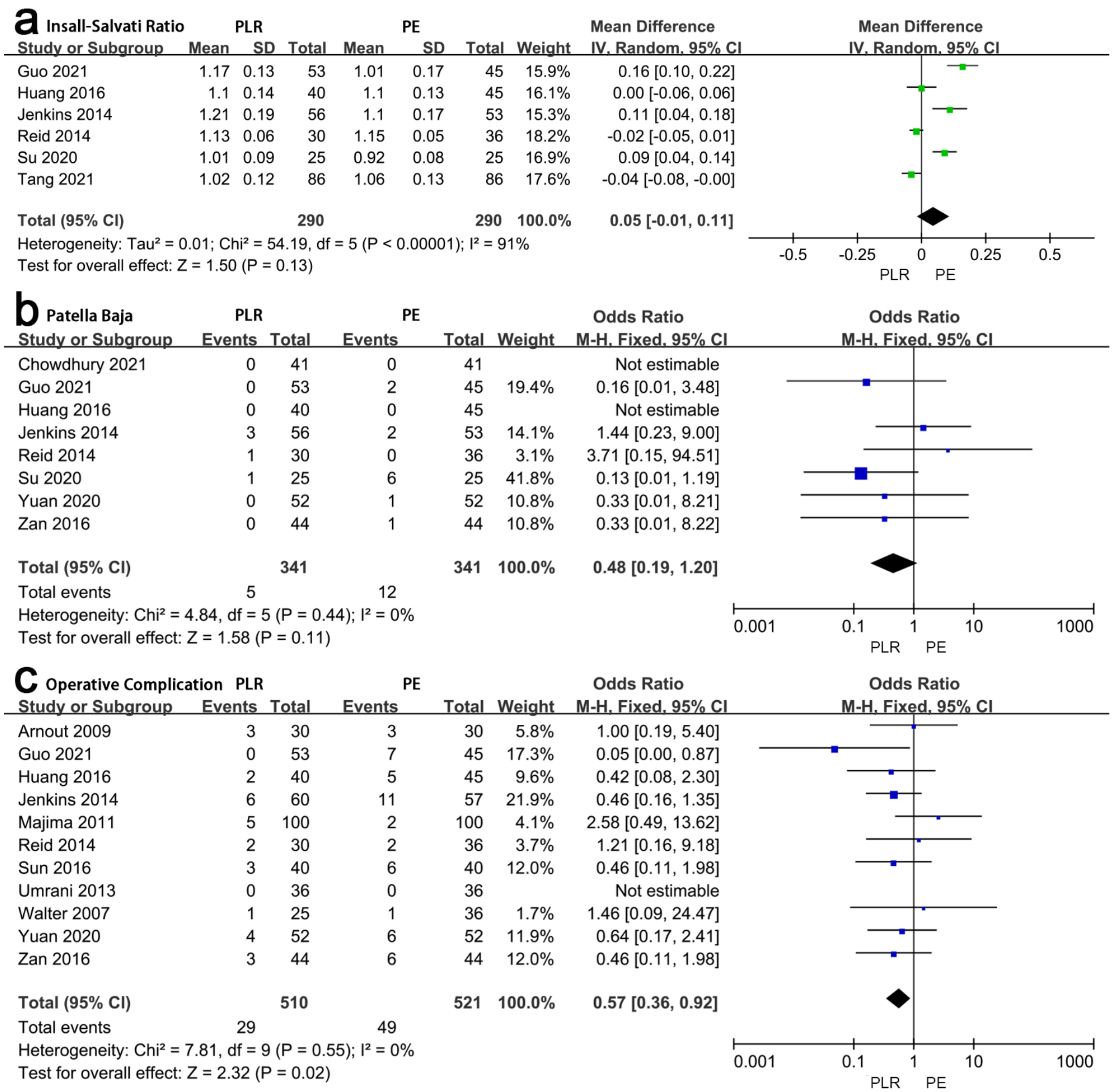

Fig. 8 Forest plot of other parameters in the two groups. (**a**) the Insall-Salvati ratio; (**b**) the occurrence of patella baja; (**c**) the occurrence of operative complications

Table 4 Meta-regression analysis in the knee range of motion (3 months) and Insall-Salvati ratio between two groups

Parameters	Variable	Coefficient	Standard error	*P* value	95% confidence interval
ROM-3 M	Year	0.194	0.056	0.179	-0.517 to 0.904
	Type	0.590	0.636	0.524	-7.491 to 8.672
	Country	-0.144	0.231	0.645	-3.080 to 2.792
	Sex	-0.675	0.944	0.605	-12.675 to 11.325
	Constant	-389.837	112.827	0.179	-1823.436 to 1043.763
IS ratio	Year	0.099	0.231	0.742	-2.832 to 3.030
	Type	0.452	1.077	0.747	-13.237 to 14.141
	Country	0.230	1.086	0.529	-13.564 to 14.023
	Sex	-1.662	1.819	0.867	-24.777 to 21.454
	Constant	-199.084	466.973	0.743	-6132.539 to 5734.371

ROM, knee range of motion (°); IS, Insall-Salvati ratio

Table 5 Publication bias analysis (Egger's test) in the knee range of motion (3 months) and Insall-Salvati ratio between two groups

Parameters	Standard effect	Coefficient	Standard error	*P* value	95% confidence interval
ROM-3 M	slope	5.934	7.215	0.457	-14.099 to 25.966
	bias	-23.829	31.587	0.493	-111.528 to 63.870
IS ratio	slope	-1.148	1.205	0.394	-4.493 to 2.196
	bias	6.716	5.775	0.310	-9.319 to 22.751

ROM, knee range of motion (°); IS, Insall-Salvati ratio

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Author contributions
YF and QJ conceived the study. MD and XS wrote the first draft of the manuscript. YUG and PS collected the clinical studies included. MD and YJG independently extracted the data. WR analyzed the results information. YW and HF revised the manuscript. All authors contributed to the article and approved the submitted version.

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Data Availability
All data generated or analysed during this study are included in this published article.

Declarations

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Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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