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REVIEW

Does intraoperative patellar eversion affect clinical and functional outcomes in patients undergoing primary total knee arthroplasty? An evidence-based meta-analysis

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Abstract

Purpose This meta-analysis aims to compare the early postoperative recovery, complications encountered, length of hospital stay, and initial functional scores between patellar eversion and non-eversion manoeuvres in patients undergoing during primary total knee arthroplasty (TKA) based on clinical studies available in the literature.

Methods A systematic literature search was conducted using PubMed, Embase, Web of Science, and the Cochrane Library databases between January 1, 2000 and August 12, 2022. Prospective trials comparing clinical, radiological, and functional outcomes in patients undergoing TKA with and without patellar eversion manoeuvre were included. The meta-analysis was performed using Rev-Man version 5.41 (Cochrane Collaboration). Pooled-odds ratios (for categorical data) and mean differences with 95% confidence intervals (for continuous data) were calculated ($p < 0.05$ was regarded as statistically significant).

Results Ten (out of the 298 publications identified in this subject) were included for the meta-analysis. The patellar eversion group (PEG) had a significantly shorter tourniquet time [mean difference (MD) − 8.91 min; $p = 0.002$], although the overall intraoperative blood loss was higher (IOBL; MD 93.02 ml; $p = 0.0003$). The patellar retraction group (PRG), on the other hand, revealed statistically better early clinical outcomes in terms of shorter time necessary to perform active straight leg raising (MD 0.66, $p = 0.0001$), shorter time to achieve 90° knee-flexion (MD 0.29, $p = 0.03$), higher degree of knee flexion achieved at 90 days (MD − 1.90, $p = 0.03$), and reduced length of hospital stay (MD 0.65, $p = 0.03$). There was no statistically significant difference in the early complication rates, 36-item short-form health survey (1 year), visual analogue scores (1 year), and Insall-Salvati index at follow-up between the groups.

Conclusion The implications from the evaluated studies suggest that in comparison with patellar eversion, patellar retraction manoeuvre during surgery provides significantly faster recovery of quadriceps function, earlier attainment of functional knee range of motion (ROM), and shorter length of hospital stay in patients undergoing TKA.

Keywords Total knee arthroplasty · Outcome analysis · Patellar eversion · Patellar retraction · Knee exposure

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Introduction

Total knee arthroplasty (TKA) has emerged as a highly effective surgical strategy and has shown tremendous ability to ameliorate the pain, function, disability, and activities of daily living (ADL) of patients with symptomatic end-stage arthritic knee disease [1]. One of the key steps during surgery involves mobilisation of the patella to allow better visualisation of knee anatomy in order to enable appropriate placement of prosthetic components[2]. Although the traditional approach for patellar mobilisation has involved patellar eversion, more recently, proponents of minimally invasive TKA have recommended non-eversion techniques such as patellar retraction or subluxation to improve outcomes [1–4].

During eversion, patella is twisted along the longitudinal axis of quadriceps mechanism and retracted laterally [1, 5, 6]. Despite providing an excellent exposure during TKA, this manoeuvre has been criticised in the past for imparting significant insult to the entire extensor mechanism. This can lead to ischemia, fibrosis, and compromised strength of the quadriceps mechanism, which may in turn result in a suboptimal patellar position [1].

To date, four meta-analyses and one review of overlapping meta-analysis have compared the outcome following patellar eversion and non-eversion manoeuvres in TKA [1–3, 7, 8]. While there is a consensus among all the published studies that the two approaches do not differ much in terms of long-term clinical, radiological, or functional outcomes, there has been considerable ambiguity about their individual effects on early clinical and functional outcomes (including pain severity and length of hospital stay) [1–8].

As global healthcare costs have risen,, bundled payment model (model of re-imbursement where a single, comprehensive payment is made for a single event of healthcare delivery) has become progressively more prevalent for TJA [9]. In addition, innovative quality improvement models utilising enhanced recovery programs [such as “enhanced recovery after surgery” (ERAS)] have been encouraged after TKA in order to meliorate patient experience, minimise in-hospital stay, facilitate faster rehabilitation, and mitigate hospital-related expenditures [9]. With this background, the current meta-analysis was planned to evaluate the recent prospective trials and analyse the overall impact of the two patellar mobilisation techniques on the early postoperative recovery of patients following TKA.

Material and methods

We performed a meta-analysis following the guidelines put forth by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [10].

Protocol registration

The protocol for this systematic review has been registered in PROSPERO (registration number: CRD42022363341, title: “Patellar eversion versus patellar retraction for total knee arthroplasty: a systematic review and meta-analysis”).

Search strategy

A systematic search of the PubMed, Scopus, Web of Science, and Cochrane Library databases was performed with overall search strategy ((Total knee replacement) OR (Total knee arthroplasty)) AND ((patella* eversion) OR (patella* retraction)).

The reference lists of articles were also screened. The references were then fed into EndNote web so as to check for duplication, compilation, and final manual selection. The last date of search was August 20, 2022. Authors were not contacted for any additional information. The search strategy is shown in Table 1.

Data extraction

Two authors (MKP and VK) performed the searches individually, screened the titles and abstracts, and assessed them for inclusion. The full texts of potentially eligible studies were independently considered. Any disagreement was resolved by discussion with the senior author (VJ). For RCTs, two authors (MKP and VK) individually assessed the risk of bias in the included studies by considering random sequence generation, allocation concealment, blinding of participant, personnel, and outcome assessment, incomplete outcome data, selective reporting, and other bias as per the Cochrane Handbook for systemic reviews of interventions. Each of these criteria was judged using: A = yes (low risk of bias), B = no (high risk of bias), and C = unclear (either lack of information or uncertainty over the potential for bias). Any disagreement was similarly resolved. The Risk Of Bias In Non-randomized Studies—of Interventions (ROBINS-I) was used for non-randomised studies using the RobVis tool available online.

Inclusion criteria

The PICOS (Population; Intervention; Comparator; Outcomes and Study) criteria employed to include studies into our meta-analysis were:

Population: patients with end-stage knee arthritis.

Intervention: primary TKAs.

Table 1 Search strategy

S no	Search	Terms
1	#1	Total knee replacement) OR (Total knee arthroplasty
2	#2	(patella* eversion) OR (patella* retraction)
3	#1 AND #2	

("arthroplasty, replacement, knee "[MeSH Terms] OR ("arthroplasty"[All Fields] AND "replacement"[All Fields] AND "knee"[All Fields]) OR "knee replacement arthroplasty"[All Fields] OR ("total"[All Fields] AND "knee"[All Fields] AND "replacement"[All Fields]) OR "total knee replacement"[All Fields] OR ("arthroplasty, replacement, knee"[MeSH Terms] OR ("arthroplasty"[All Fields] AND "replacement"[All Fields] AND "knee"[All Fields]) OR "knee replacement arthroplasty"[All Fields] OR ("total"[All Fields] AND "knee"[All Fields] AND "arthroplasty"[All Fields]) OR "total knee arthroplasty"[All Fields])) AND (("patella*"[All Fields] AND ("eversion"[All Fields] OR "eversions"[All Fields])) OR ("patella*"[All Fields] AND ("retract"[All Fields] OR "retractable"[All Fields] OR "retracted"[All Fields] OR "retracting"[All Fields] OR "retraction"[All Fields] OR "retractions"[All Fields] OR "retracts"[All Fields])))

("patella*"[All Fields] AND ("eversion"[All Fields] OR "eversions"[All Fields])) OR ("patella*"[All Fields] AND ("retract"[All Fields] OR "retractable"[All Fields] OR "retracted"[All Fields] OR "retracting"[All Fields] OR "retraction"[All Fields] OR "retractions"[All Fields] OR "retracts"[All Fields]))

"arthroplasty, replacement, knee"[MeSH Terms] OR ("arthroplasty"[All Fields] AND "replacement"[All Fields] AND "knee"[All Fields]) OR "knee replacement arthroplasty"[All Fields] OR ("total"[All Fields] AND "knee"[All Fields] AND "replacement"[All Fields]) OR "total knee replacement"[All Fields] OR ("arthroplasty, replacement, knee"[MeSH Terms] OR ("arthroplasty"[All Fields] AND "replacement"[All Fields] AND "knee"[All Fields]) OR "knee replacement arthroplasty"[All Fields] OR ("total"[All Fields] AND "knee"[All Fields] AND "arthroplasty"[All Fields]) OR "total knee arthroplasty"[All Fields])

Comparator: eversion versus non-eversion techniques of patellar mobilisation.

Outcomes: intraoperative blood loss (IOBL), operative or tourniquet time, length of incision, visual analogue score (VAS) for pain, SF-36 [physical component score (PCS) and mental component score (MCS) components], complications or adverse events reported {like patellar tendon injury, lateral condyle fracture, anterior knee/ retropatellar pain, incisional fat liquefaction, knee haematoma, delayed healing, superficial or deep infections or other wound complications, deep venous thrombosis (DVT), pulmonary embolism (PE), stroke [cerebrovascular accident (CVA)], peroneal nerve palsy, and scar-related issues (including patella baja or knee stiffness)}, length of hospital stay, time taken to straight leg raising (SLR), time to 90° knee flexion, knee range of motion (ROM), functional outcome scores (WOMAC/KSS/Oxford knee score) for knee, and radiological parameters including Insall-Salvati index

Study design: prospective comparative studies (PCS)/randomised controlled trials (RCTs)

Exclusion criteria

Studies were excluded based on the following criteria:

1. In-vitro biomechanical (cadaveric or finite-element) or animal model studies.
2. Observational or non-comparative or non-prospective interventional studies.
3. Review articles on TKA.
4. Unpublished articles or proceedings of meetings.

Statistical analysis

A narrative synthesis of the findings of the finally included prospective studies was performed in a tabular format. Mean (standard deviation) was used to describe the data for continuous variables (as reported), and number (frequency/percentage) was used for categorical variables. Pre-designed forms were used for data extraction. Details including author names, journal, year of publication, study period, study type, uni- or bilaterality of TKAs, demographic variables (including weight, height, and BMI), aetiology of knee arthritis, preoperative knee range of motion and alignment variables, and pre- and postoperative outcome variables (as previously mentioned along with special remarks or qualitative summarisation as deemed necessary by the authors) were recorded. Relative risks, odds ratios (for categorical variables), and mean difference/standardised mean difference (for continuous variables) were considered for statistical pooling using appropriate statistical techniques.

The heterogeneity between studies in relevant effect measures was assessed using chi square and I^2 statistics. Statistically pooling was performed using fixed-effect or random-effects meta-analysis (Der Simonian and Laird methods), as deemed appropriate (fixed-effect model was applied if $I^2 < 50\%$ and random-effects model if I^2 was $> 50\%$) [11]. Appropriate forest plots were generated. Subgroup analysis was conducted for studies with and without patella resurfacing. RevMan version 5.41 (Cochrane collaboration) was used for all meta-analyses. Pooled odds ratios (for categorical data) and mean differences with 95% confidence intervals (for continuous data) were depicted. Additionally, funnel plot analysis was used for depicting publication bias. A two-sided p-value < 0.05 was regarded as statistically significant.

Results

Results of literature search

The PRISMA flowchart is presented in Fig. 1. Our search yielded 91, 101, and 86 manuscripts on PubMed, Scopus, and Web of Science, respectively. No additional articles were found on the Cochrane Library (all texts). After screening for duplicates and excluding unrelated articles on the basis of title, 20 manuscripts were considered for assessment of full texts. Finally, 11 articles, which were published between 2005 and 2021, were included for the current systematic review and qualitative summarisation. Among them, 10 articles reporting the relevant variables were included for meta-analysis.

Characteristics of the studies

A summary of the studies included in the review is presented in Table 2. Nine studies were RCTs (level 1 evidence) and 2 were single-blinded, prospective, comparative studies (level 2) [4–6, 12–19]. One of the RCTs [16] was not included in our meta-analysis, since this study did not report variables relevant to our meta-analysis.

A total of 971 patients (493 with patellar eversion and 478 with non-eversion/patellar retraction/subluxation manipulations) were analysed. Overall, three of the included manuscripts were published in the *Journal of Arthroplasty*, two in *JBJS(Am)*; and the remaining articles were published in *CORR*, *KSSTA*, *JCOT*, *Orthopaedic Surgery*, and *Arthritis* journals. Mid-vastus approach was used in three studies [15, 18, 19], and medial parapatellar approach was employed in the remaining studies. In one of the studies, minimally invasive and conventional TKA approaches were employed for the patella-retraction (PRG) and patella-eversion groups (PEG), respectively [17]. Two studies were published from the USA, two emanated from China, and one article each was published from India, Japan, Belgium, Australia, Korea, and Italy.

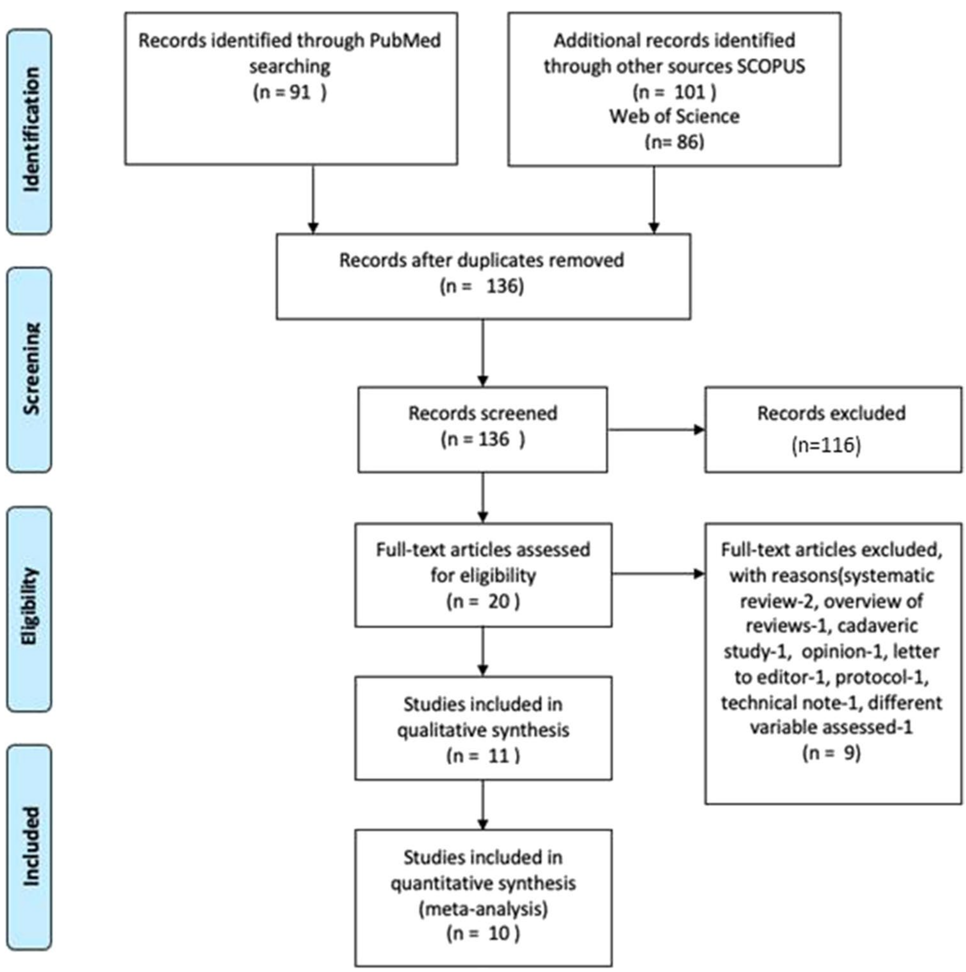


Fig. 1 PRISMA flow diagram

Table 2 Characteristics of included studies ($n = 10$)

Sl no	Author	Year	Country	Journal	Study design	Cases	Controls	Uni-/bilateral	Diagnosis	Age (years) Case: Ctrl [mean (SD)]	Male case: Ctrl
1	Boerger	2005	UK	*CORR*	RCT	60	60	UL	Degenerative	68 (5): 69 (6)	15:14
2	Walter	2007	USA	*J Arthroplasty*	RCT	36	86	UL	NR	75.5 (9.5):67 (10.2)	10:23
3	Arnout	2009	Belgium	*Knee Surg Sports TraumatolArthrosc*	RCT	31	30	NR	Degenerative	67 (8):64 (8)	13:22
4	Majima	2011	Japan	*Arthritis*	PCS	100	100	Both UL and BL	Degenerative	69.2 (8.1):71.8 (7.7)	18:21
5	Umrani	2013	Korea	*J Arthroplasty*	RCT	36	36	NR	Degenerative	66.7 (6.6):64.3(6.9)	0:0
6	Reid	2014	Australia	*JBJS*	RCT	36	30	NR	NR	68:70	16:12
7	Jenkins	2014	USA	*JBJS*	RCT	60	60	UL	Degenerative	60:60	NR
8	Zan	2015	China	*J Arthroplasty*	RCT	44	44	BL	Degenerative	NR	18:18
9	Yuan	2020	China	*OrthopSurg*	RCT	52	52	UL	Degenerative	65.9 (7.4):67.2 (8.1)	22:20
10	Chawdhary	2021	India	*JCOT*	PCS	41	41	BL	Degenerative	63.2:63.2	10:10

RCT, randomised controlled trial; *PCS*, prospective comparative study (non-randomised); *SD*, standard deviation; *USA*, United States of America; *UL*, unilateral; *BL*, bilateral; *Ctrl*, controls; *NR*, not reported

Results of the meta-analysis

Intraoperative variables

A majority of the studies comparing the two types of patellar manipulation manoeuvres reported on three intraoperative variables, namely, surgical duration, tourniquet time, and IOBL.

Surgical duration and tourniquet time: based on the meta-analysis of three studies reporting on surgical duration, we did not observe any statistically significant difference with regard to the surgical time between the two groups [mean difference (MD) − 4.71 min, 95% CI − 12.28 min; test of overall effect: $z = 1.22$, $p = 0.22$]. There was a considerable heterogeneity among the included studies (chi square = 26.74, $p < 0.001$, $I^2 = 93\%$), indicating a random-effects model (Fig. 2). Analysis of subgroups revealed no statistically significant difference with regard to the surgical time between the two groups for two studies without patella resurfacing [mean difference (MD) − 0.75 min, 95% CI − 3.01 min, 1.52 min; $z = 0.65$, $p = 0.52$]. However, the operative time was significantly lower in the PEG as compared to PRG (84 ± 7 min vs 94 ± 8 min, mean difference (MD) − 10 min; 95% CI 12.69 min, 7.31 min; z = 7.29, $p < 0.001$) in the studies involving patella resurfacing. The test for subgroup differences was significant (with chi square = 26.58, $I^2 = 96.2\%$, $p < 0.001$).

Five studies compared the tourniquet time between the two approaches. Patella resurfacing was performed in all these studies. Based on the meta-analysis of the pooled data from these studies, the tourniquet time was significantly shorter in the PEG as compared to the retraction group (MD − 8.91 min; 95% CI − 14.47 min, − 3.35 min; test of overall effect: $z = 3.14$, $p = 0.002$). There was substantial heterogeneity among the included studies (chi square = 22.96, $I^2 = 83\%$, $p = 0.0001$), indicating a random-effects model (Fig. 3).

IOBL: the meta-analysis of data on IOBL from two studies (both involving patella resurfacing) indicated significantly higher blood loss in the PEG (MD 93.02 ml; 95% CI 43.78 ml, 146.26 ml; test of overall effect: $z = 3.63$, $p = 0.0003$). There was no significant heterogeneity (chi square = 0.09, $I^2 = 0\%$, $p = 0.77$); therefore, fixed-effects model was used (Fig. 4).

Early postoperative outcomes

Two categories of parameters were employed to describe the early postoperative outcome in the included studies, namely, variables discussing early patient recovery and early complication rates.

Early patient recovery variables: a majority of the included studies discussed the following variables to compare the early postoperative recovery in patients:

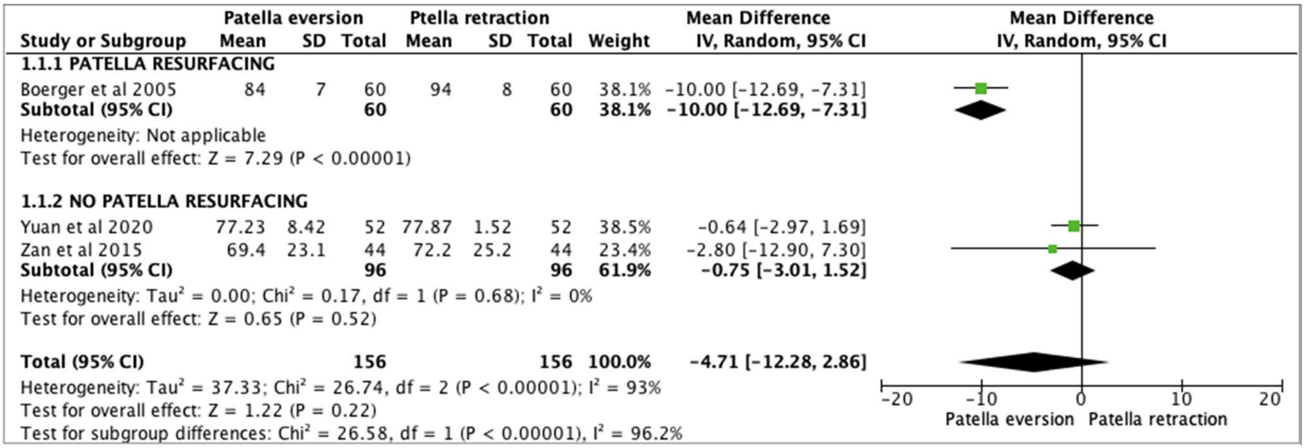


Fig. 2 Operative time

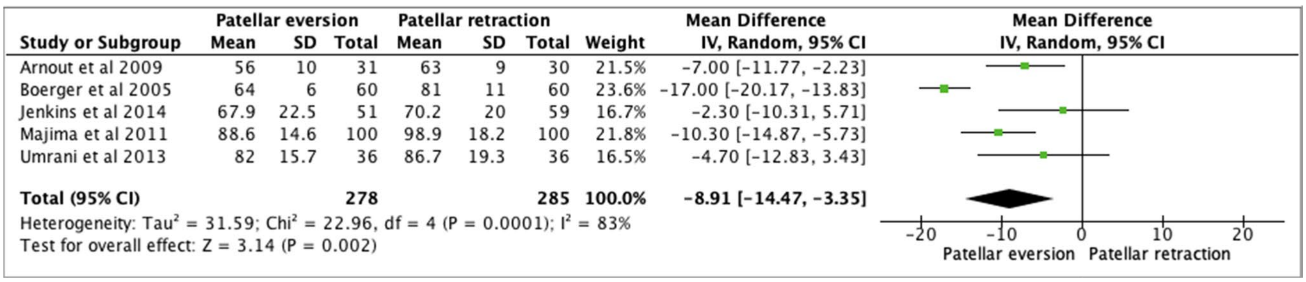


Fig. 3 Tourniquet time

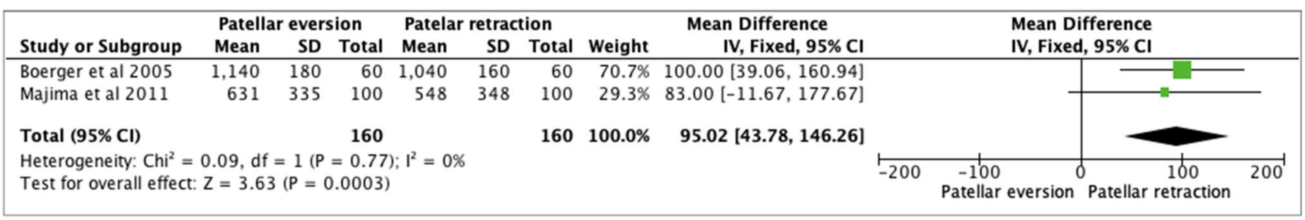


Fig. 4 Blood loss

a. Time to perform active straight leg raising (SLR; as a surrogate to describe the recovery of quadriceps function)
b. Time to achieve 90° knee-flexion and degree of knee flexion at 90 days [to assess the recovery of knee range of motion (ROM)]; and
c. Length of stay in the hospital.

Time to perform active SLR: the meta-analysis of five studies demonstrated that PRG required significantly shorter time to perform active SLR postoperatively as compared to PEG (MD 0.66; 95% CI 0.32, 0.99; test of overall effect: $z=3.87$, $p=0.0001$). There was significant heterogeneity among the included studies (chi square = 12.37, $I^2=68\%$, $p=0.01$), and so random effects model was utilised. Analysis of subgroups revealed a statistically significant difference with regard to the time taken to achieve active SLR between the two groups for the two studies without patella resurfacing [mean difference (MD) 0.60 days; 95% CI 0.33, 0.88; $z=4.26$, $p<0.0001$]. Similarly, the time taken to achieve active SLR was significantly higher in the PEG as compared to PRG [mean difference (MD) 0.71; 95% CI 0.09; 1.32; $z=2.26$, $p=0.02$] in the studies involving patella resurfacing. Test for subgroup differences was not statistically significant (with chi square = 0.1, $I^2=0\%$, $p=0.76$). These results possibly indicate reduced insult to quadriceps mechanism with the patella approach, resulting in earlier recovery of the quadriceps function with patellar retraction as compared to eversion (Fig. 5).

Time to achieve 90º knee-flexion: the meta-analysis of two studies (both without patella resurfacing) reporting on the required data indicated a significantly shorter time to achieve 90º knee flexion in the PRG (MD 0.29, 95% CI 0.03, 0.55; test of overall effect: $z=2.21$, $p=0.03$). There was no significant heterogeneity among the studies (chi square = 1.52, $I^2=34$); therefore, fixed-effects model was used (Fig. 6).

Degree of knee flexion achieved at 90 days: additionally, significantly greater knee flexion was observed at the 90-day time point in the PRG (based on 2 studies reporting on these data: Reid et al. without patella resurfacing: MD − 1.00; 95% CI − 3.30, 1.30; not statistically significant; Boerger et al. with patella resurfacing: MD − 3.00; 95% CI − 5.53, − 0.47; statistically significant; overall MD − 1.90; 95% CI − 3.60, − 0.20; test of overall effect: $z=2.19$, $p=0.03$). There was no significant heterogeneity among the included studies (chi square = 1.32, $I^2=24\%$, $p=0.25$), and fixed-effects model was utilised (Fig. 7).

Length of stay in the hospital: based on the meta-analysis of five studies presenting data on the length of hospital stay, patients in the PEG had significantly longer days of inpatient stay (MD 0.65; 95% CI 0.05, 1.25; test of overall effect: $z=2.13$, $p=0.03$). There was significant heterogeneity among the studies (*chi square* = 18.08, $I^2=78\%$, $p=0.001$), indicating a random-effects model. Analysis of subgroups revealed no significant difference with regard to the length of stay between the two groups for the three studies with resurfacing of patella [MD 0.35; 95% CI − 0.29, 0.99; $z=1.08$; $p=0.28$]. However, the length of stay was significantly lower in the PEG as compared with PRG (MD 1.09 days; 95% CI 0.26, 1.92; $z=2.56$, $p=0.001$) on analysing the two studies with patella resurfacing. The test for subgroup differences was not significant (chi square = 1.89; $I^2=47.1\%$; $p=0.17$; Fig. 8).

Complication rates: complications including patellar tendon injury, lateral condyle fracture, anterior knee/retropatellar pain, incisional fat liquefaction, knee haematoma, delayed healing, superficial or deep infections or other wound complications, deep venous thrombosis (DVT), pulmonary embolism (PE), stroke [cerebrovascular accident (CVA)], peroneal nerve palsy, and scar-related issues (including patella baja or knee stiffness) were compared. There was no statistically significant difference found in total number of complications between the two groups (based on the 10 studies reporting relevant data: total of 59 complications in 493 patients in PEG, against 43 complications among 478 cases in the PRG) [with a Mantel Haenszel odds ratio (MH-OR) of 1.48; 95% CI 0.96, 2.29; $z=1.77$, $p=0.08$; chi square = 9.44, $p=0.22$; $I^2=26\%$; fixed-effects model was used].

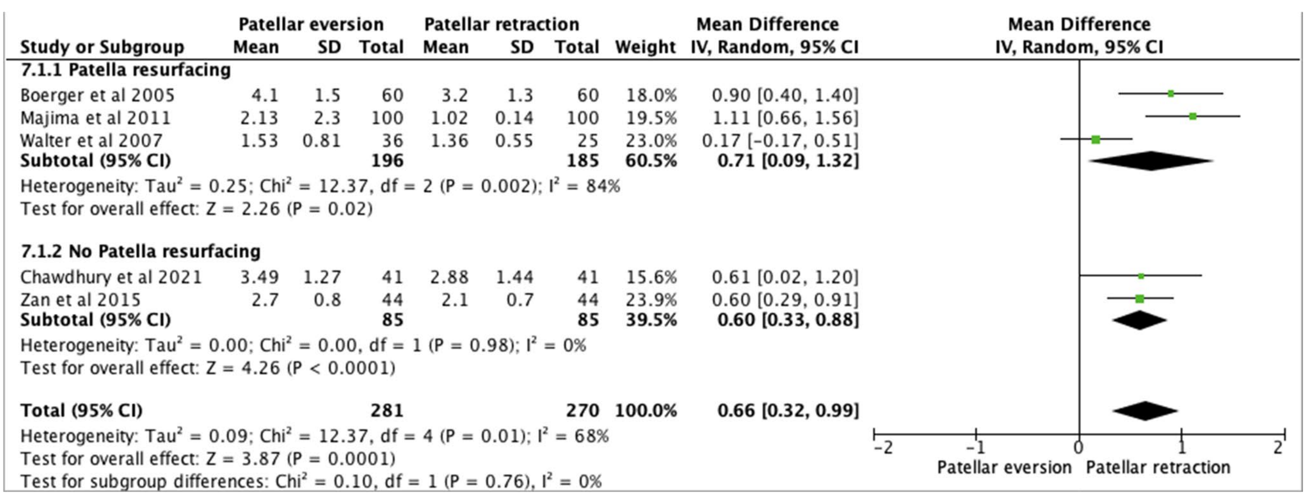


Fig. 5 Time for SLR

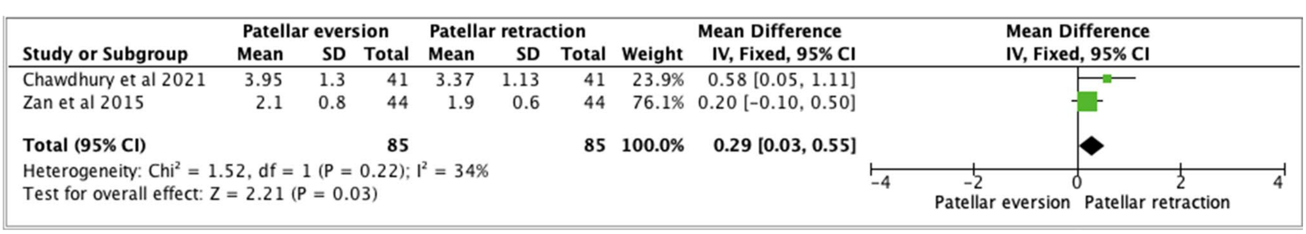


Fig. 6 Time to 90° knee flexion

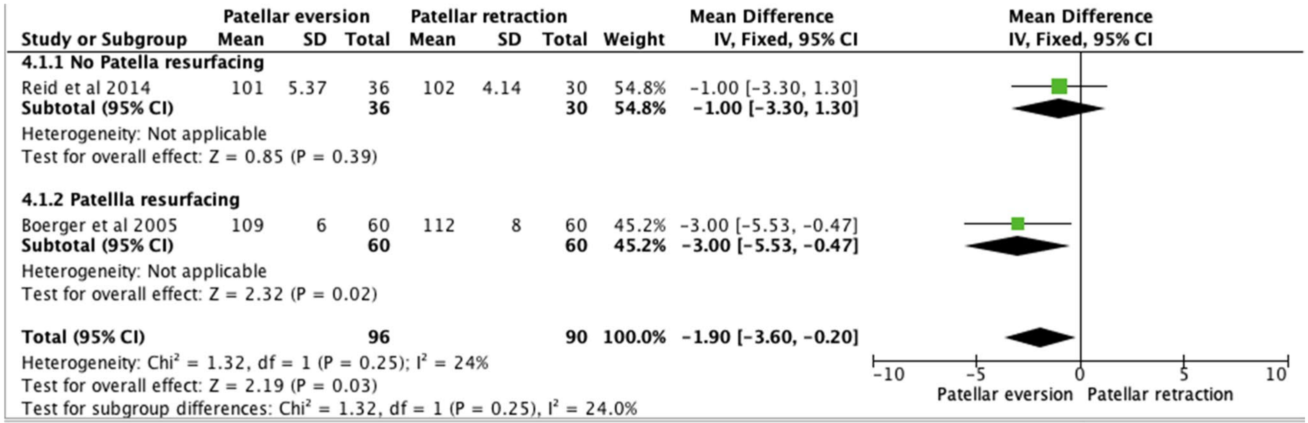


Fig. 7 Knee flexion (at 90 days)

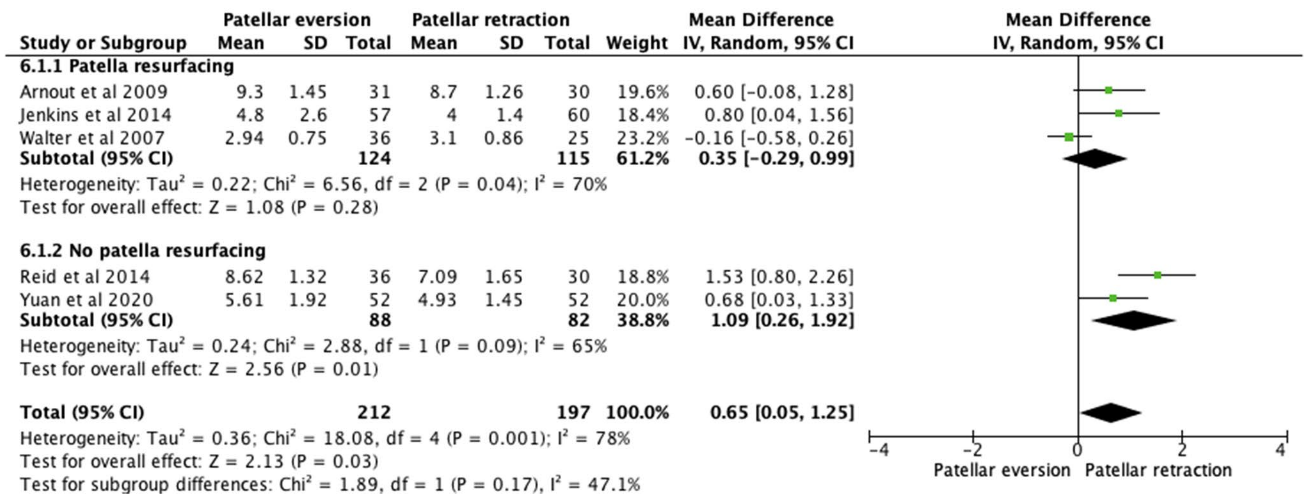


Fig. 8 Length of stay

Analysis of subgroups revealed no significant difference between the two groups with regard to complications [based on 4 studies without patella resurfacing; 15/173 complications in PEG vs 10/167 complications in PRG with a Mantel Haenszel odds ratio (MH-OR) of 1.50; 95% CI 0.65, 3.45; $z = 0.95$; $p = 0.34$]. Similarly, there was no statistically significant difference with regard to complications between the two groups for the five studies involving patella resurfacing [44/320 complications in PEG vs 33/311 complications in PRG with a Mantel Haenszel odds ratio (MH-OR) of 1.48; 95% CI 0.89, 2.45; $z = 1.5$; $p = 0.13$]. The test for subgroup differences was not statistically significant (chi square = 0; $I^2 = 0\%$; $p = 0.98$; Fig. 9A). The funnel plot for the same was asymmetrical, thereby suggesting a likelihood of publication bias (Fig. 9B).

Delayed postoperative outcome

Pain (visual analogue score—VAS) at one year: based on the available data from four studies, there was no statistically significant difference in pain perception (VAS) between the PEG and the PRG (MD 0.02; 95% CI − 0.23, 0.28; test of overall effect: $z = 0.19$, $p = 0.85$). There was considerable heterogeneity among the included studies (chi square = 9.21, $p = 0.03$, $I^2 = 67\%$), indicating a random-effects model. The analysis of subgroups revealed no statistically significant difference in VAS between the 2 groups for the 3 studies without patella resurfacing [MD 0.09; 95% CI − 0.07, 0.24; $z = 1.05$; $p = 0.29$]. Similarly, the VAS score was not significantly different in the PEG and PRG (MD 0.50; 95% CI − 0.38, 1.38; $z = 1.11$; $p = 0.27$) in the studies involving patella resurfacing. The

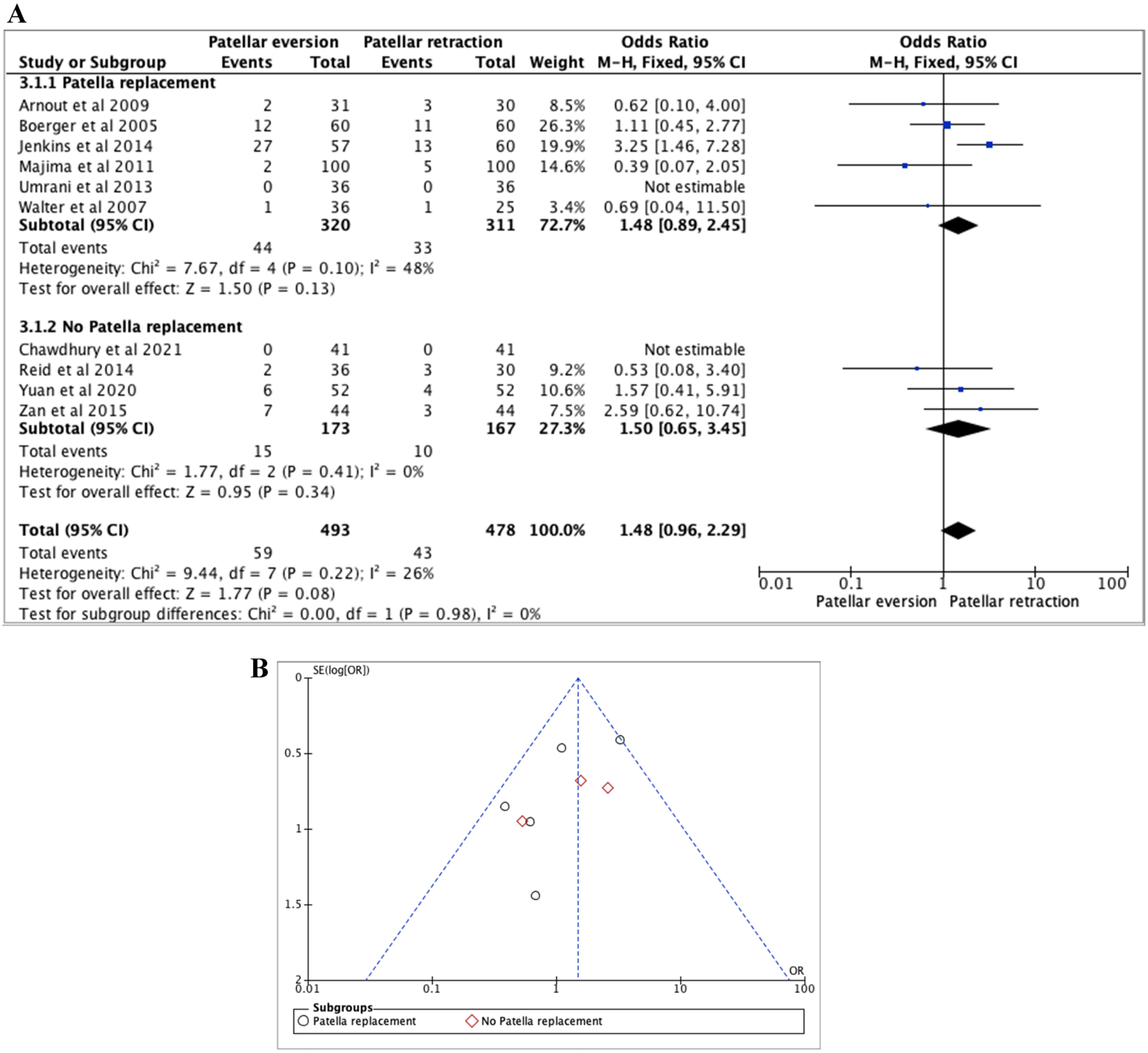


Fig. 9 **A** Forest plot (complications). **B** Funnel plot (complications)

test for subgroup differences was not statistically significant (chi square = 0.83; $I^2 = 0\%$; $p = 0.36$; Fig. 10).

SF-36 at one year [physical component score (PCS) and mental component score (MCS)]: similarly, meta-analysis of the available data from two studies (both without patella resurfacing) yielded no statistically significant difference in the PCS of SF-36 at one year between the two groups (MD 0.25; 95% CI − 1.32, 1.81; test of overall effect: $z = 0.31$, $p = 0.76$). There was no significant heterogeneity among the studies (chi square = 0.21, $p = 0.65$, $I^2 = 0\%$); therefore a fixed-effects model was utilised (Fig. 11).

Additionally, our analysis from two studies (both without patella resurfacing) failed to reveal any significant difference in the MCS of SF-36 at 1-year between the groups (MD − 0.46; 95% CI − 2.06, 1.15; test of overall effect: $z = 0.56$, $p = 0.57$). There was no significant heterogeneity among the studies (chi square = 0.22, $p = 0.64$, $I^2 = 0\%$), necessitating a fixed-effects model (Fig. 12).

Insall-Salvati index at one year: finally, the meta-analysis of data available from two studies (Jenkins et al. with patella resurfacing: MD − 11; 95% CI − 0.17, − 0.05; statistically significant; and Reid et al. without patella resurfacing, MD 0.03; 95% CI 0.00, 0.06; statistically significant); overall analysis yielded no statistically significant difference in Insall-Salvati ratio at one year time point between the groups (MD − 0.04; 95% CI − 0.17, 0.10; test

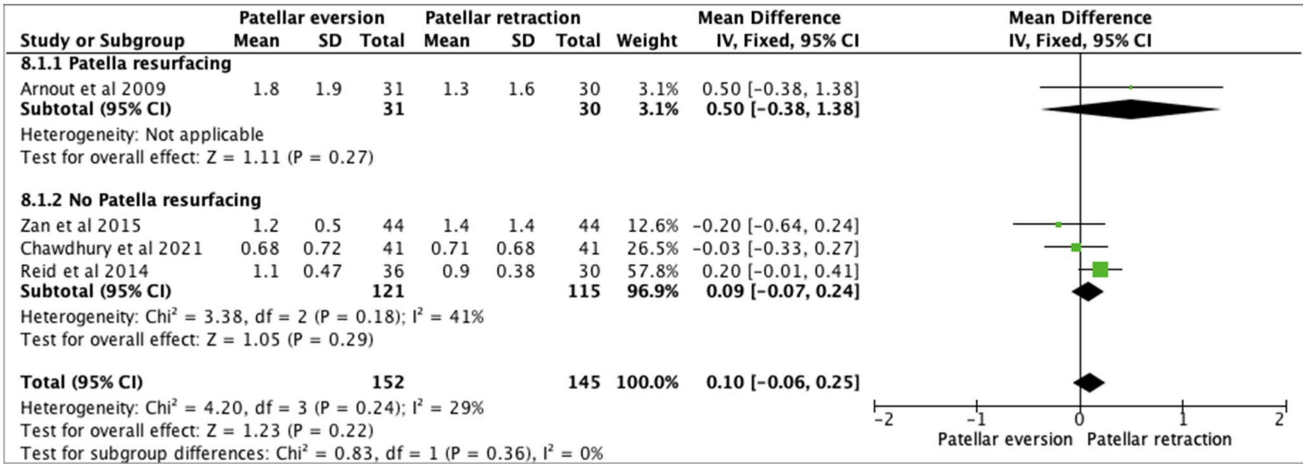


Fig. 10 Pain (VAS) at 1 year

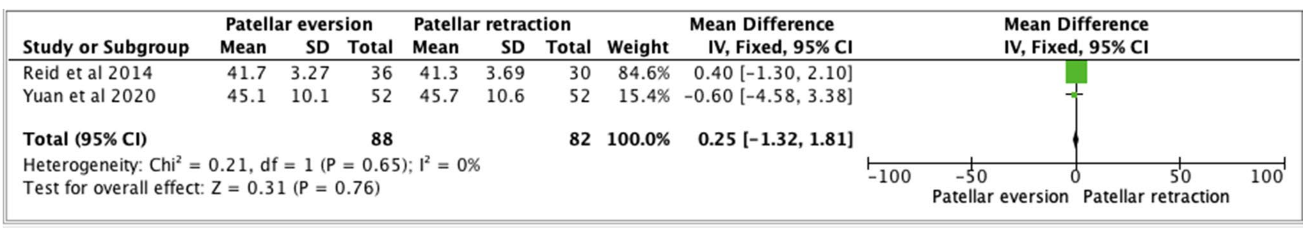


Fig. 11 SF-36PCS (1 year)

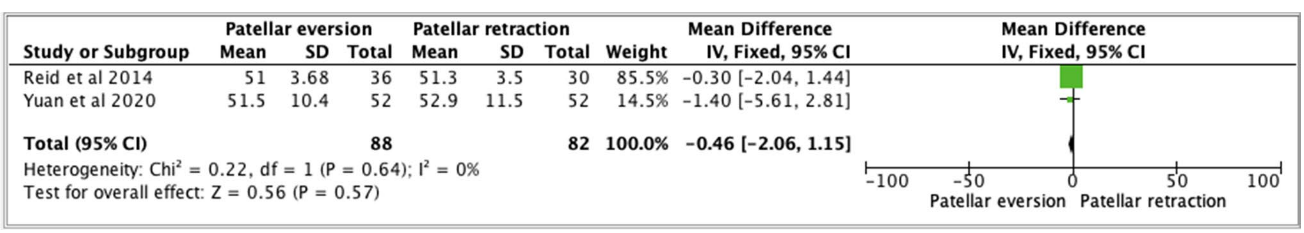


Fig. 12 SF-36 MCS (1 year)

of overall effect: $z = 0.53$, $p = 0.6$). There was significant heterogeneity among the studies (chi square = 15.04, $p = 0.0001$, $I^2 = 93\%$), indicating the need for random-effects model (Fig. 13).

Assessment of risk of bias

The traffic light plots depicting the assessment of risk of bias for the nine RCTs and 2 non-randomised trials have been shown in Figs. 14A, B and 15, respectively.

Discussion

ERAS is a well-recognised acronym, which stands for "enhanced recovery after surgery" [20]. This terminology, initially introduced in 2001, describes the bundle of pre-operative and postoperative multi-modal strategies which can potentially mitigate the surgery-associated stresses and expedite patients' recovery following major surgical procedures[21]. It is characterised by a combination of systems put forth by special surgical societies worldwide under the category of "ERAS elements". Over the past

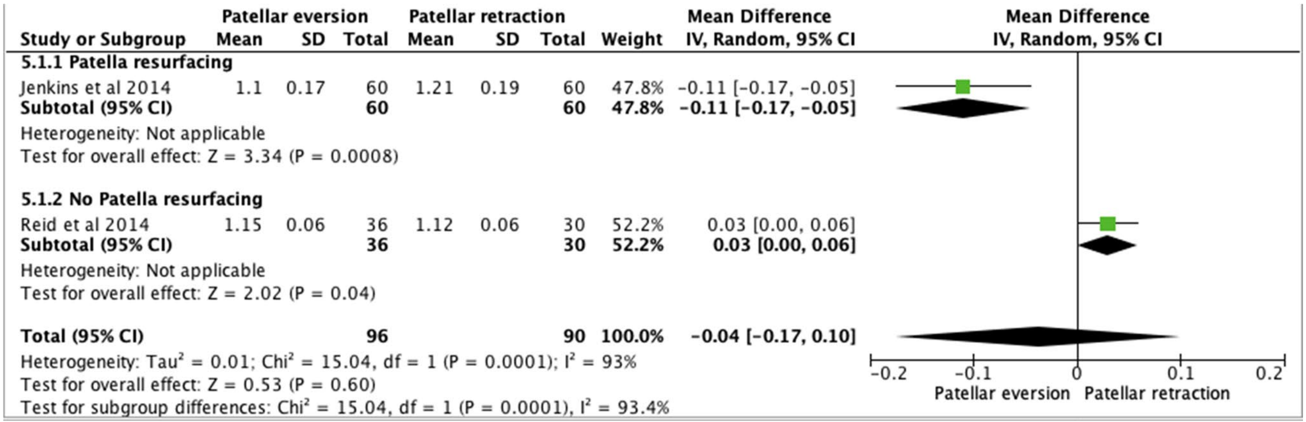


Fig. 13 Insall-Salvati index at 1 year

decade, ERAS has been progressively recognised globally and promoted for its well-acknowledged benefits. Broadly, the ERAS programs are focused upon streamlining and standardising the healthcare programs or strategies [22]. In the context of arthroplasty surgeries, there has been a global paradigm shift in the postoperative care from conventional approach (involving gradual recovery) to ERAS approach (encouraging expedited patient recuperation) [23]. With a progressive rise in the aging population globally, the overall rates of TKA have also been proportionately increasing. In the USA alone, the incidence of TKA is projected to increase to an estimated 3.48 million patients by 2030 [24]. In addition, the rising healthcare expenditure has resulted in a shift in the model from the conventional fee-for-service to a value-based reimbursement, which typically describes a single-time payment for the entire episode of a patient's treatment [25].

Traditionally, the surgical approach during TKA has involved an open, conventional exposure requiring patellar eversion during the entire operative time [6, 8, 12]. However, with growing concerns regarding the mechanical and ischaemic insults to various components of the extensor mechanism, minimally invasive approaches involving alternative techniques of patellar manipulation (involving subluxation or retraction of patella alone) have been developed [1, 3, 4]. With as many as nine RCTs, four meta-analyses, and one review of overlapping meta-analysis published in the last decade comparing the early and delayed outcome following these two patellar manipulation techniques, this has been a well-researched subject in the realm of knee arthroplasty surgeries [1, 3, 4, 7, 8, 12, 16, 18]. Although there has been a consensus in the hitherto published literature that the two patellar manipulation techniques do not differ much in terms of the long-term outcomes; whether the type of manoeuvre used to mobilise patella has a bearing upon the early recovery of patients is still an issue of substantial dubiety [1].

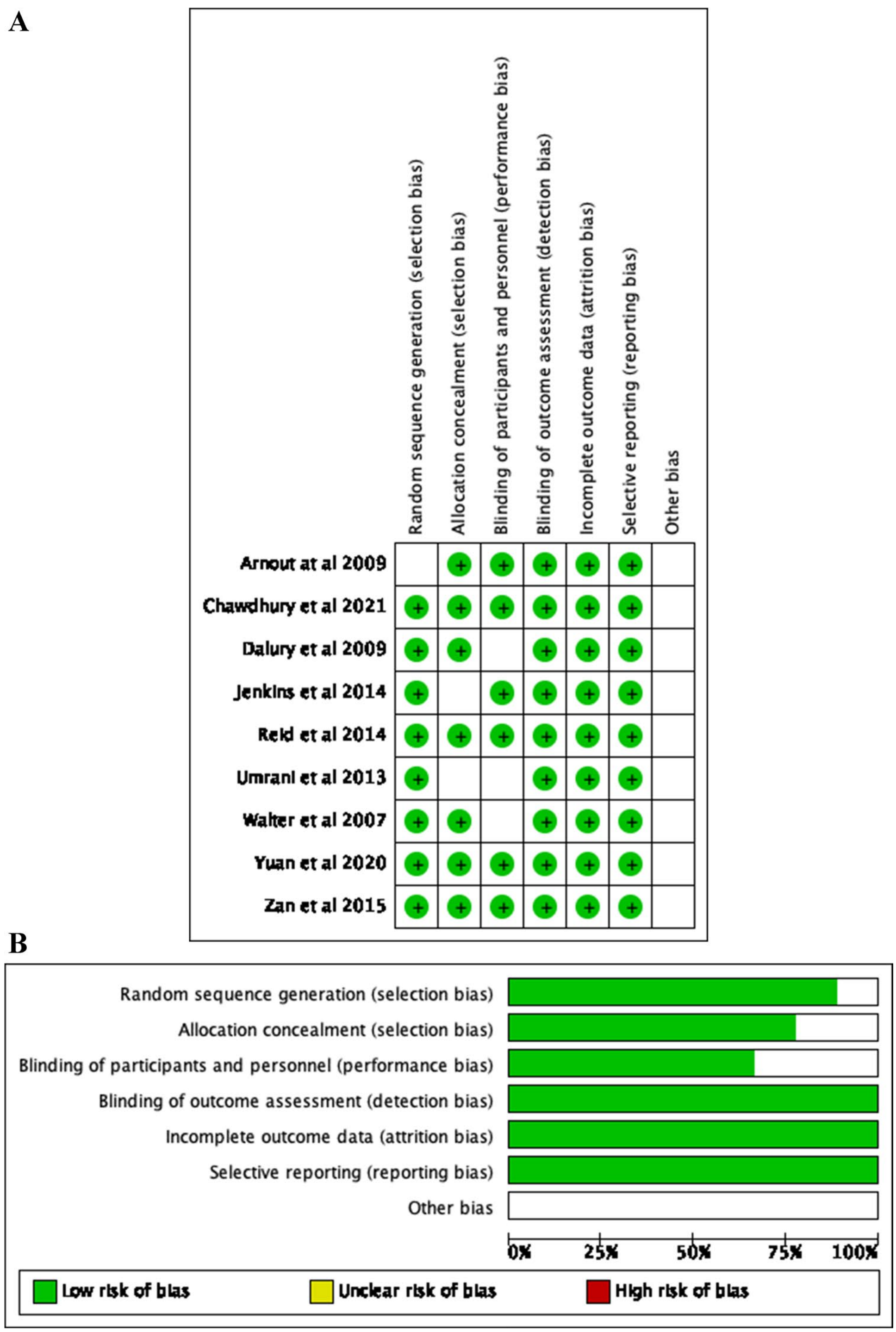
With the ongoing shifts in the reimbursement models and increasing focus on ERAS protocols, the importance of identifying patient-specific parameters affecting the overall cost of care following TKA, cannot be understated [9, 22]. The current study was thus planned to perform a meta-analysis to evaluate the impact of these two patellar manoeuvring strategies on the intraoperative parameters and early postoperative recovery of patients undergoing TKA.

Intraoperative parameters

With regard to the intraoperative parameters, based on our pooled data, we could observe that patellar eversion manoeuvre was associated with a substantially reduced "tourniquet time"; although the "surgical duration" (as mentioned in these studies) was not significantly different between the two techniques [4, 5, 12, 13, 17–19]. There was considerable heterogeneity across the included studies with regard to the reporting of both these parameters. Two of the previously published meta-analyses reported good evidence that the eversion manoeuvre was associated with shorter tourniquet time [4, 7, 8]. The recent meta-analysis by Wang et al. (2022) [1], however, concluded that the surgical duration was not substantially different between the two techniques. The practice of routine use of tourniquet and approach for TKA (open versus minimally invasive; parapatellar versus mid-/sub-vastus) has substantially evolved over the past decade, which has contributed to the heterogeneity in the reporting of this parameter [6]. Nevertheless, based on our analysis, the evidence that the operative time of TKA varies with the type of patellar manipulation is not incontrovertible.

We could also observe that the non-eversion technique was associated with significantly lower blood losses as compared with eversion manoeuvre. A significant contributor to this observation in our meta-analysis was the prospective study by Boerger et al.[18] comparing

Fig. 14 **A** Risk of bias summary. **B** Risk of bias graph



mini-subvastus and conventional para-patellar exposures where the minimal approach was associated with at least 100 ml less blood loss ($p < 0.001$). This finding was not reproduced in the other RCTs or subsequent meta-analysis; therefore, the current evidence shows no clear benefit of one approach over the other.

Early postoperative outcome

Based on our meta-analysis, the avoidance of patellar eversion significantly improves the early recovery of quadriceps strength and knee ROM. In fact, the evidence favouring the non-eversion patellar mobilisation techniques with regard to

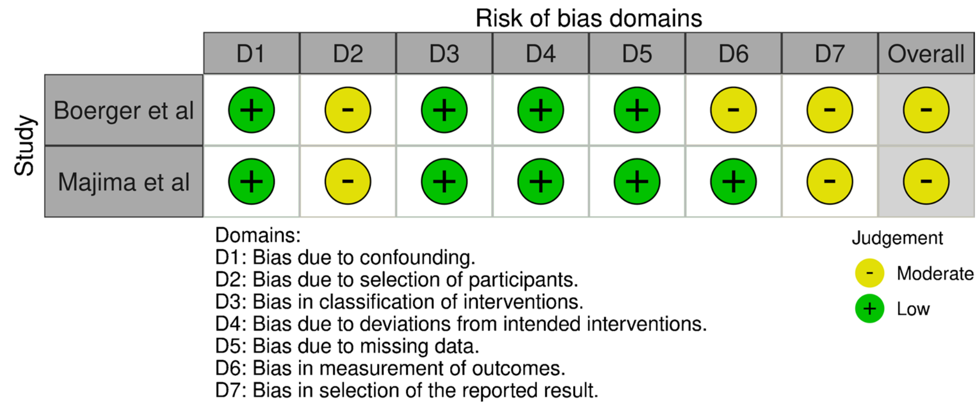


Fig. 15 ROBINS-I

both these early recovery parameters is quite strong. These findings may be attributed to the degree of manipulation and ischemia sustained by the entire quadriceps mechanism during prolonged patellar eversion [1]. The previous meta-analyses have been quite inconsistent with the reporting of these early patient outcome parameters. While the meta-analysis by Wang et al. [1] showed substantially earlier time to SLR in PRG, all the other meta-analyses failed to reveal any significant difference between the two techniques [2–4, 7, 8].

Our analysis demonstrated a significantly shorter in-hospital stay in the PRG. This finding is consistent with the early functional recovery demonstrated in this category of patients. The previous meta-analyses by Wang et al. [1] and Yang et al. [8] revealed significantly lower complication rates in the PRG. However, in our study, the complication rates were not different between the two groups. Overall, minor wound healing issues or superficial infections (20.6% of all complications), DVT (20.6%), patellar tendon or other iatrogenic injuries (10.8%), and retro-patellar pain (8.8%) were the most commonly observed complications in both the groups. In the study by Yuan et al.[6], none of the groups had any pain at 3 weeks, 2 months, 6 months, or 1 year. However, during the early postoperative period (at 24, 48, and 72 h), PEG had significantly higher VAS score than PRG.

As previously mentioned, the previous meta-analysis focused more on longer term outcome as compared to the early results [1–4, 8]. In addition, more recent RCTs have been published in the last five years are included in our analysis. These two factors might explain why the observations made in our meta-analysis were substantially different from the previous meta-analyses with regard to early post-TKA recovery.

Delayed postoperative outcome

One of the important arguments against patellar eversion manoeuvre during TKA in the initial literature has been the concern regarding chronic patellar or extensor mechanism scarring potentially leading to chronic patella-femoral issues or pain, patella baja, and poorer long-term functional or pain outcome. However, all the previous meta-analyses have evaluated these parameters extensively and have failed to demonstrate any substantial impact of the type of patellar manipulation on the long-term prognosis. Even in our analysis, we failed to demonstrate any significant long-term difference in the clinical (VAS at 1 year), functional (SF-36), and radiological outcomes (patellar position) between the two approaches.

Limitations of the study

Although the study has comprehensively compared the intra- and early postoperative outcomes following TKA, there is paucity of data for analysis in the current literature regarding the healthcare costs and economic burden on the system. Additionally, there is significant variation in the functional outcome variables studied during the postoperative period. Apart from the patellar manipulation techniques, additional factors during surgical exposure including use of tourniquet, types of approaches (minimally invasive, sub-vastus, mid-vastus versus open/conventional para-patellar approaches) may also have influenced the outcome. A detailed evaluation of the contributions of each of these individual factors to the overall outcome was beyond the scope of our study.

Conclusion

Based on our analysis, the patellar retraction technique is associated with significantly earlier recovery of quadriceps function, earlier recovery of knee range of motion (ROM), and shorter length of hospital stay in comparison with patellar eversion techniques. Although patellar retraction technique is associated with lower IOBL and longer tourniquet time, the evidence regarding these intraoperative variables is still not incontrovertible. There is clear evidence that no difference exists with regard to the long-term clinical, radiological, and functional outcomes between the two patellar mobilisation techniques.

Author contribution Vibhu Krishnan Viswanathan: methodology, formal analysis and investigation, and writing (original draft preparation). Mohit Kumar Patralekh: conceptualisation, methodology, formal analysis and investigation, and resources. Guna Pratheep Kalanjiyam: methodology and formal analysis and investigation. Karthikeyan P. Iyengar: conceptualisation, methodology, and writing (review and editing). Karthik Vishwanathan: conceptualisation, methodology, and writing (review and editing). Vijay Kumar Jain: conceptualisation, methodology, writing (review and editing), resources, and supervision.

Data availability Available (meta-analysis).

Code availability Not applicable (meta-analysis).

Declarations

Ethical approval Not applicable (meta-analysis).

Consent to participate Not applicable (meta-analysis).

Consent for publication Not applicable (meta-analysis).

Conflict of interest The authors declare no competing interests.

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