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KNEE ARTHROPLASTY

Gap balancing versus measured resection for primary total knee arthroplasty: a meta-analysis study

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Abstract

Introduction To achieve the most desirable post-operative results, operation techniques and procedures for total knee arthroplasty (TKA) are highly standardized. However, debates persist whether patients having undergone a gap balancing technique (GB) perform better than those having undergone measured resection (MR) technique. Therefore, a meta-analysis study was conducted to investigate advantages of GB compared to the MR. The focus of the present study was on clinical and functional scores, radiological measurements and further complications.

Materials and methods The present meta-analysis was conducted according to the PRISMA checklist. In November 2019, literature search was performed. All clinical studies comparing measured resection technique versus gap balancing technique for primary total knee arthroplasty were considered for inclusion. Only articles reporting quantitative data under the outcomes of interest were eligible for inclusion. The methodological quality assessment and statistical analyses were performed through the Review Manager Software version 5.3 (The Cochrane Collaboration, Copenhagen).

Results Data from 25 clinical trials (2971 procedures) were collected. Patient baseline demonstrated a good comparability. No difference among the two cohorts was found in terms of SF-12 Mental and Physical, ROM, KSS, KSS Function, OKS, WOMAC. No difference was found in the alignment of mechanical axis and femoral rotation. During the knee motion, no difference was found between the medial and lateral gaps among the two techniques. The GB showed a significant elevated joint line ($P < 0.0001$), along with a longer duration of the operating time ($P = 0.001$). No differences were found in terms of revision surgery, aseptic loosening or prosthetic infections.

Conclusion GB and MR achieve similar outcomes for TKA. In the GB group, a proximalisation of the joint line and extended operating time was detected. Regarding the additional outcomes of interest, the present analysis showed comparability between both groups, MR and GB.

Keywords Total knee arthroplasty · Measured resection · Gap balancing

Introduction

Total knee arthroplasty (TKA) yields high satisfaction rate among selected patients [1]. TKA restores physiological joint biomechanics and improves patients quality of life [2]. Surgical techniques and procedures for TKA are highly standardized to achieve the best outcome. However, debates persist whether gap balancing (GB) performs better than the measured resection (MR) technique [3]. In the GB technique, an initial soft tissue release followed by bone resection is performed to obtain gap balancing over flexion and extension [4, 5]. Differently, in the MR technique, a direct bony resection following the anatomical landmarks (e.g., anteroposterior and transepicondylar axis) is performed, with subsequent soft tissue release [4, 6]. Several topic-related scientific reviews have been conducted [7–10]. However, whether any technique provides better implant alignment and surgical outcome is subject of current discussion [11–13]. Despite recent publications of clinical studies, consensus is still lacking and debates are ongoing [3,

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14–16]. Therefore, a meta-analysis of current evidence was performed. The purpose of the present study was to update current evidences and investigate possible advantages of GB compared to the MR in terms of clinical scores, radiological measurements and complications.

Materials and methods

Search strategy

The present meta-analysis was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses: the PRISMA checklist [17]. The endpoints of the initial research were:

- P (population): total knee arthroplasty;
- I (intervention): measured resection;
- C (comparison): gap balancing;
- O (outcomes): clinical scores, radiological measurements, complications.

Literature search

Two independent authors (FM, AD) performed the literature search. In November 2019, the main online databases were accessed: Pubmed, Google Scholar, Scopus, Embase. The following keywords were used in combination: *total knee arthroplasty, replacement, prosthesis, measured, resection, gap, balancing, compared, versus, KSS, lateral, medial, component, rotation, axis, condyle, femur, tibia, joint line, radiography, outcomes, scores, KSS, SF-12, ROM, flexion, extension.* The full-text of the articles of interest were accessed. The bibliographies of the included studies were also screened. Disagreements between the authors were mutually debated and solved by a third author (JE).

Eligibility criteria

All clinical studies comparing measured resection versus gap balancing operating techniques for primary total knee arthroplasty were considered for inclusion. According to the authors' language capabilities, only articles in English, Italian, German, Spanish, French were included. According to the Oxford Centre of Evidenced-Based Medicine [18], articles level of evidence I to IV were included in the present work. Only articles published in the last 10 years were included. Reviews, case reports, expert opinions, letters, editorials were excluded. Animal, in vitro, cadaveric and biomechanics studies were also excluded. Articles treating TKA in revision setting were excluded. Both mobile and fixed bearing were included. Only articles reporting quantitative data were considered for inclusion. Missing data under the outcomes of interest warranted the exclusion from the present study.

Outcomes of interest

Two independent authors (FM, AD) performed data extraction. The following data were collected for each study: author and year of publication, type of study, number of TKAs, mean age of the samples, percentage of female study population and mean BMI (kg/m^2). The outcomes of interest were the analysis of the post-operative clinical scores (KSS, KSFS, SF-12 Physical and Mental, ROM, OKS, WOMAC), operating time, radiological measurements of the medial and lateral joint gaps during the knee motion, the mechanical axis, external rotation of femoral component implant. Further complications were collected: infections, aseptic loosening and revision rate.

Methodological quality assessment

The methodological quality assessment was performed through the risk of bias summary of the Review Manager Software version 5.3 (The Cochrane Collaboration, Copenhagen). To evaluate the quality, the following bias were investigated: selection, detection, attrition, reporting and other not-reported sources of possible bias.

Statistical analysis

The statistical analysis was performed by one author (FM). The Review Manager Software version 5.3 was used for the present investigation. Continuous variables were analysed through the inverse variance statistical method with the standardized mean difference (SMD) effect measure. Dichotomic variables were analysed through the Mantel–Haenszel statistical method with the odd ratio (OR) effect measure. Heterogeneity was evaluated through the χ^2 and Higgins I^2 test. If $\chi^2 > 0.5$ and $I^2 > 60\%$ high level of heterogeneity was detected. A fixed effect analysis model was set in all the comparisons. If high data heterogeneity was evidenced, a random effect analysis model was adopted. The confidence interval was set at 95% in all the comparisons. Values of $P < 0.05$ were considered statistically significant.

Results

Search result

The initial literature search resulted in 355 publications of which only 82 compared directly the 2 surgical techniques MR versus GB for TKA. Of them, 23 studies were duplicates, therefore excluded. A further 23 publications did not

match the eligibility criteria, 11 because lack of quantitative data under the outcomes of interest. This last selection process left 25 studies for inclusion: 11 randomized clinical trials, 8 prospective and 6 retrospective cohort studies. The flowchart of the literature search is shown in Fig. 1.

Methodological quality assessment

The Cochrane risk of bias summary tool detected some limitations. There was a moderate risk of selection and detection bias. This was attributable to the reduced number of the studies providing samples randomization (40%) and blinding (45%). The risk of attrition and reporting bias were low. Similar, also the risk of unknown source of bias scored low. Concluding, the quality of the methodological assessment was good. The risk of bias summary if shown in Fig. 2.

Patient demographic

Data from a total of 2971 TKAs were analysed. The mean follow-up was 32.53 ± 28.7 months. The MR group included 1470 samples (64% female). The mean age of this cohort was 69.99 ± 3.6 years, the mean BMI 29.45 2.1 kg/m^2. The GB group included 1501 samples (67% female). The mean age of this cohort was 69.55 ± 4.5 years, the mean BMI 29.64 2.0 kg/m^2. No differences were found among the groups concerning age ($P = 0.4$), gender ($P = 0.3$) and BMI ($P = 0.4$). The demographic generalities of patients included are shown in Table 1.

Outcomes of interest

Any noteworthy differences among the two cohort were found in terms of the analysis of several scores; SF-12 Mental (SMD − 0.05; 95% CI − 0.29, 0.19; Higgins I^2 44%;

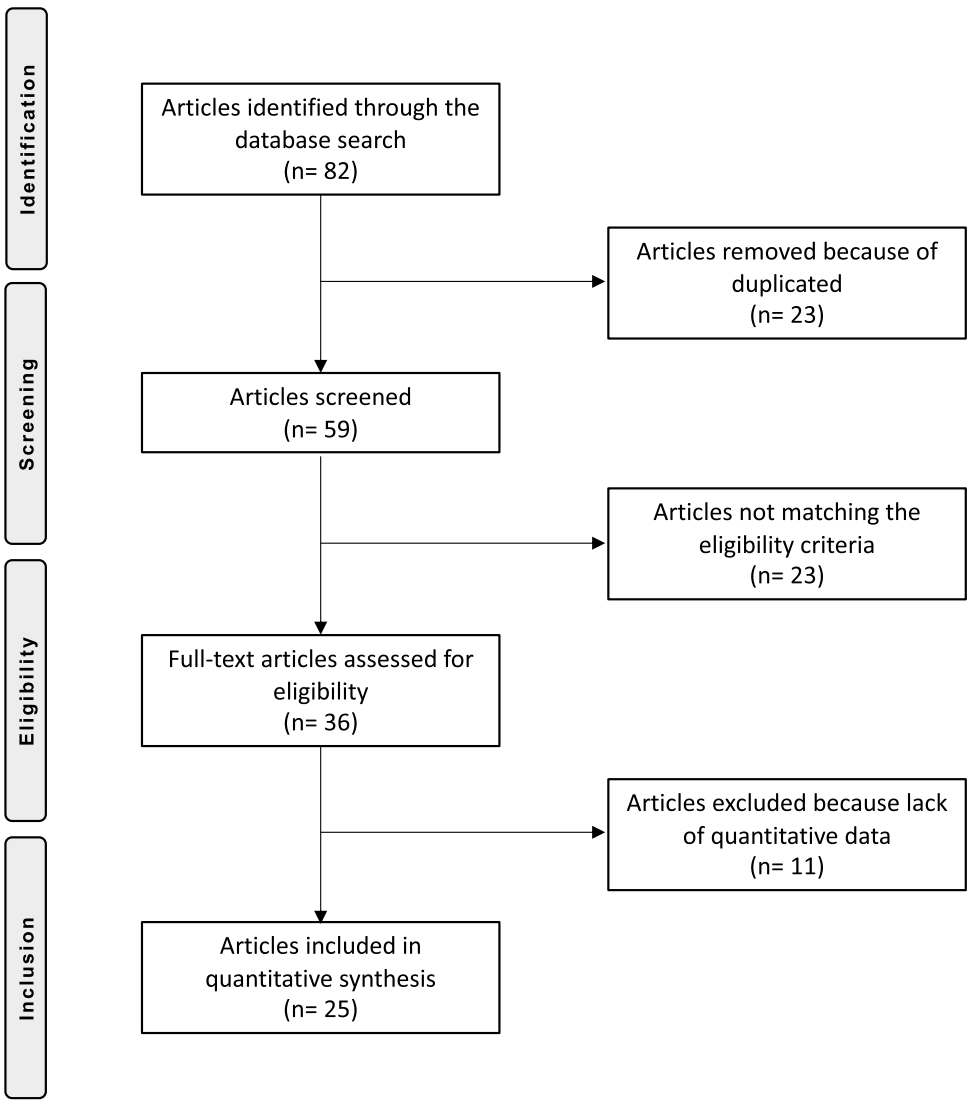

Fig. 1 PRISMA flowchart of the literature search

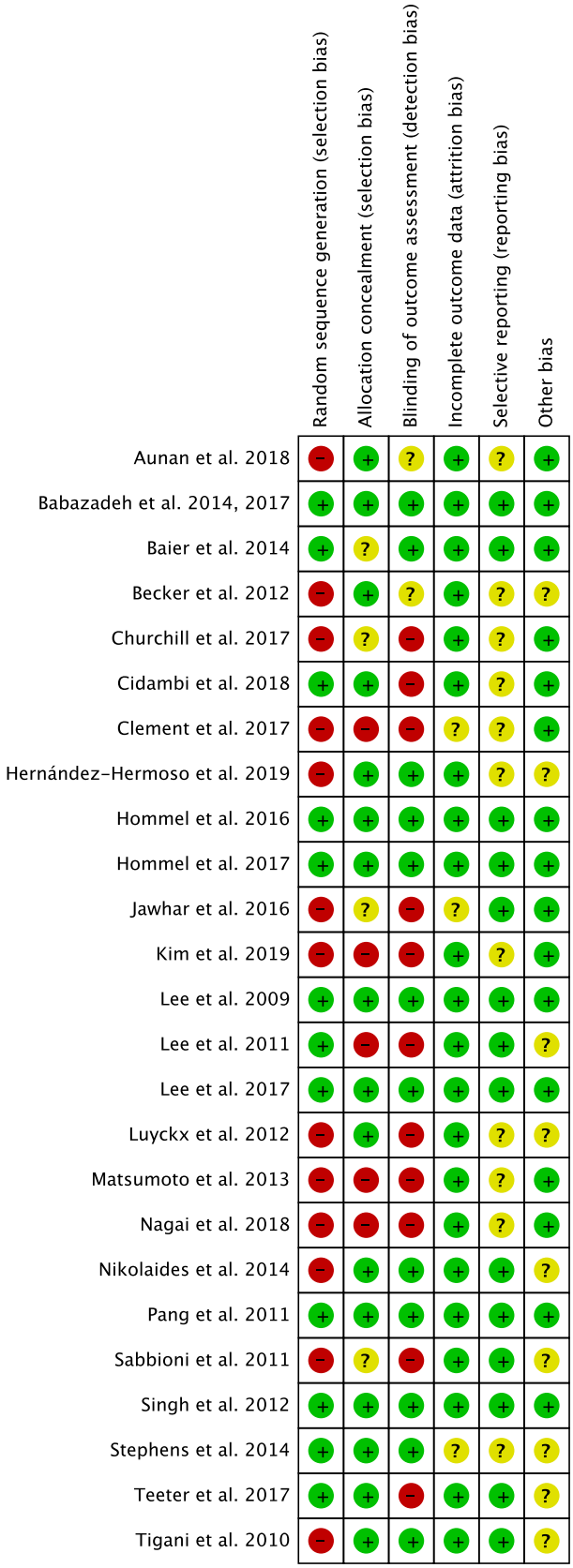

Fig. 2 Cochrane risk of bias summary tool

$P = 0.7$), SF-12 Physical (SMD −0.41; 95% CI −0.65, −0.17; Higgins I^2 0%; $P = 0.06$), ROM (SMD −0.10; 95% CI −0.32, 0.13; Higgins I^2 72%; $P = 0.4$), KSS (SMD −0.11; 95% CI −0.23, 0.01; Higgins I^2 24%; $P = 0.06$), KSS Function (SMD −0.20; 95% CI −0.46, 0.06; Higgins I^2 76%; $P = 0.1$; Fig. 3), OKS (SMD −0.11; 95% CI −0.42, 0.21; Higgins I^2 61%; $P = 0.5$), WOMAC (SMD 0.01; 95% CI −0.18, 0.20; Higgins I^2 58%; $P = 0.9$). A quicker surgical procedure was detected in the MR group (SMD −1.14; 95% CI −1.54, −0.74; Higgins I^2 68%; $P = 0.001$).

No differences were found in terms of revision surgery at a mean of 62.55 months follow-up (OR: 1.32; 95% CI 0.59, 2.99; Higgins I^2 0%; $P = 0.6$), 75.40 months (OR 1.24; 95% CI 0.53, 2.89; Higgins I^2 0%; $P = 0.6$), and 95.10 months (OR 1.54; 95% CI 0.58, 4.10; Higgins I^2 0%; $P = 0.4$). Similarly, no differences were found in terms of aseptic loosening (OR 1.67; 95% CI 0.64, 4.35; Higgins I^2 0%; $P = 0.3$) and infections (OR 0.71; 95% CI 0.19, 2.64; Higgins I^2 0%; $P = 0.6$). The GB cohort achieved insignificant more accurate restoration of mechanical axis (SMD 0.27; 95% CI −0.10, 0.63; Higgins I^2 78%; $P = 0.2$) and increased femoral rotational alignment (SMD −0.02; 95% CI −0.39, 0.035; Higgins I^2 82%; $P = 0.9$, Fig. 4) but a significant elevated joint line (SMD −0.48; 95% CI −0.70, −0.27; Higgins I^2 62%; $P < 0.0001$).

No statistically significant difference was found between the gaps: medial gap extension (SMD 0.26; 95% CI 0.02, 0.49; Higgins I^2 38%; $P = 0.3$), lateral gap extension (SMD 0.42; 95% CI 0.19, 0.65; Higgins I^2 0%; $P = 0.7$), medial gap flexion (SMD 0.37; 95% CI 0.14, 0.60; Higgins I^2 38%; $P = 0.06$), lateral gap flexion (SMD 0.22; 95% CI −0.25, 0.69; Higgins I^2 76%; $P = 0.4$). Mean flexion gaps (SMD 1.43; 95% CI 0.56, 2.31; Higgins I^2 94%; $P = 0.1$), mean extension gaps (SMD −1.07; 95% CI −4 to 45, 2.30; Higgins I^2 100%; $P = 0.5$).

Table 2 reports the main findings of the comparisons.

Discussion

According to the main findings of the present meta-analysis, the GB group demonstrated a proximalisation of the joint line and required longer operating time. Mechanical axis and femoral rotational alignment showed high data heterogeneity and no differences between the groups were detected. The analysis of clinical scores, flexion and extension gaps detected no statistically significant difference. Surgical revision rate, aseptic loosening and infections did not show any worthy difference between the two techniques. The present analysis showed comparability between MR and GB technique. Indeed, at mean follow-up of approximately 5, 6 and 8 years, no difference concerning surgical revision

Table 1 Summary of demographic data of the studies included

Author, year	Type of study	Follow-up (months)	Measured Resection				Gap Balancing			
			Knee (*n*)	Mean age	Female (%)	BMI	Knee (n)	Mean age	Female (%)	BMI
Aunan and Rohrl (2018) [14]	Prospective	36	43	70	53	29	86	69	58	29
Babazadeh et al. (2014, 2018) [19, 20]	Prospective, randomized	60	52	70	60	31	51	70	74	31
Baier et al. (2014) [21]	Prospective, randomized	6	21	70	75		19	70	75	
Becker et al. (2012) [22]	Prospective	11	63	69		29	53	69		31
Churchill et al. (2018) [23]	Prospective	36	116	66		32	105	66		32
Cidambi et al. (2018) [15]	Prospective, randomized		43		45		48		45	
Clement et al. (2017) [24]	Retrospective	70	69	69	46	31	44	69	70	31
Hernández-Hermoso et al. (2019) [3]	Prospective	24	38	70	76		40	70	78	
Hommel et al. (2017a, b) [25, 26]	Prospective, randomized	120	100	67	63	30	100	67	62	30
Hommel et al. (2017b) [26]	Prospective, randomized	12	50	68	44	28	50	68	40	28
Jawhar et al. (2016) [27]	Prospective	34	27	69			81	70		
Kim et al. (2019) [16]	Retrospective	30	51	70	90	25	49	69	96	26
Lee et al. (2010) [28]	Prospective, randomized	28	56	67	96		60	66	95	
Lee et al. (2011) [29]	Retrospective	24	30	69	93		30	69	93	
Lee et al. (2017) [30]	Prospective, randomized	24	51	99	68.6		50	98	70.8	
Luyckx et al. (2012) [31]	Prospective		48	65	61		48	64	69	
Matsumoto et al. (2014) [32]	Retrospective	24	120	74	91		135	75	88	
Nagai et al. (2018) [33]	Retrospective		148	82	25		127	85	26	
Nikolaides et al. (2014) [34]	Prospective	< 1	34	71	94		29	70	86	
Pang et al. (2011) [35]	Prospective, randomized	24	70	70	83	29	70	68	86	29
Sabbioni et al. (2011) [36]	Retrospective		36	69	78		31	67	81	
Singh et al. (2012) [37]	Prospective, randomized	24	26	73	60		26	73	60	
Stephens et al. (2014) [38]	Prospective, randomized		100				100			
Teeter et al. (2017) [39]	Prospective, randomized	12	12	70	28		12	67	37	
Tigani et al. (2010) [40]	Prospective	7	66	69	70		57	67	74	

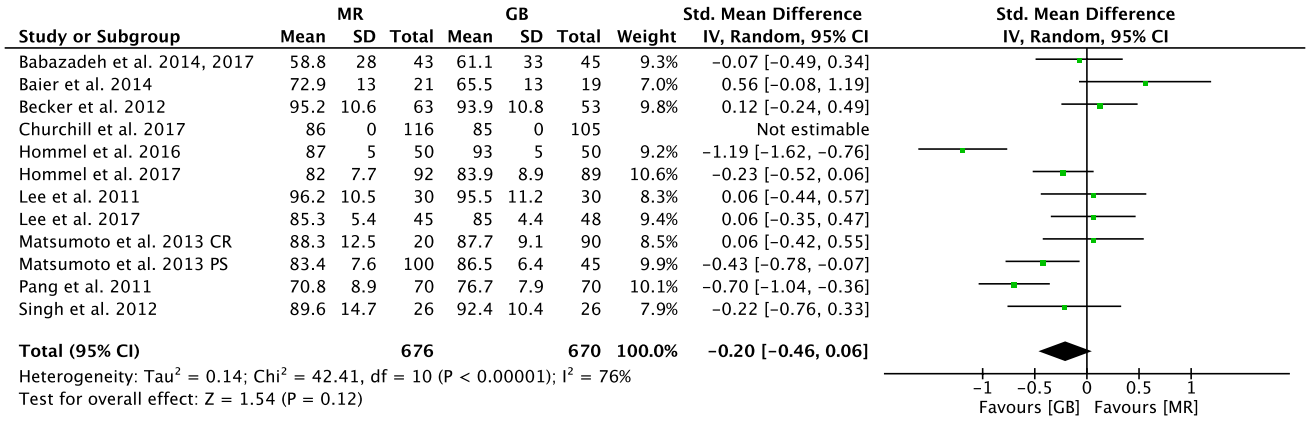

Fig. 3 Forrest plot of the comparison KSS-function

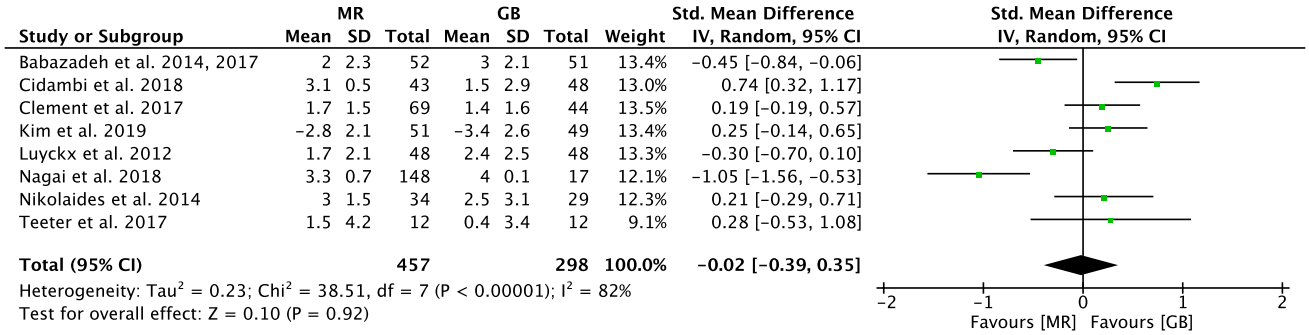

Fig. 4 Forest plot of the comparison femoral rotational alignment

rate between both groups have been detected concluding that both techniques, MR and GP are safe and feasible.

The goal of TKA is to achieve mechanical axis alignment in the range of 180° (±3°). According to the Higgins I^2 test, heterogeneity was moderate, and the final effect showed that mechanical axes were comparable among the two cohorts. In fact, these two techniques should not affect the coronal alignment. Femoral rotation alignment is defined as the difference between the femoral component and the transepicondylar axis of the knee [41]. In the present study, no differences among the groups were detected. Femoral rotation alignment is crucial to obtain a rectangular balanced flexion gap, optimal joint kinematics and patellofemoral tracking and soft tissue balancing [42, 43]. Indeed, excessive implants intra- or extra-rotation may result in anterior knee pain, instability infection and patellar fracture [44]. Rotational alignment was hardly debated. MR-TKA alignment is more dependent on surgeon's experience in locating anatomical landmarks and axes around the knee [45]. This can improve the risk of component malposition [46, 47]. Fehring et al. [44] reported that rotational errors through bony landmarks > 3° occurred in 45% of patients. A cadaveric study conducted by Katz et al. [48] reported no significant differences in component rotation between MR and GB technique. Theoretically, GB-TKA promoting exact gaps tension during the range of motion, offer more accurate rotational alignment. However, results from the present study clearly stated similarity among the techniques. Even though this comparison was affected by high heterogeneity, the final effect was close to the no-effect line and the test for overall significance found no difference between the two techniques in terms of femoral rotational alignment.

The comparison of joint line positioning was characterized by low value of heterogeneity and statistically significant higher position in favour of the GB group. This comparison showed high reliability. Resecting bone tissue according to margin gaps symmetry and to the soft tissue balancing, the final result will be over resection of the femoral bone compared to the MR technique. Changes in the position of the joint line are prevalent in revision setting and can lead to soft tissue disbalance and patellofemoral instability [49, 50]. A biomechanical study of Fornalski et al. [51] found that position of joint line affects the patellofemoral joint and the tibial implants, and may result in a reduced ROM,

Table 2 Overview of the meta-analysis results

Outcome	Patients ($n=2971$)		Effect estimate [95% CI]	Higgins I^2 (%)	P
	MR	GP			
SF-12 physical	134	133	−0.41 [−0.65, −0.17]	0	0.06
SF-12 mental	134	133	−0.05 [−0.29, 0.19]	44	0.7
ROM	627	605	−0.10 [−0.32, 0.13]	72	0.4
KSS	572	577	−0.11 [−0.23, 0.01]	24	0.6
KSS function	676	670	−0.20 [−0.46, 0.06]	76	0.1
OKS	218	226	−0.11 [−0.42, 0.21]	61	0.5
WOMAC	209	266	0.01 [−0.18, 0.20]	58	0.9
Surgical duration	200	200	−1.14 [−1.54, −0.74]	68	0.001
Medial gap extension	122	192	0.26 [0.02, 0.49]	38	0.3
Medial gap flexion	135	192	0.37 [0.14, 0.60]	38	0.06
Lateral gap extension	135	192	0.42 [0.19, 0.65]	0	0.7
Lateral gap flexion	135	192	0.22 [−0.25, 0.69]	76	0.4
Extension gap	258	276	1.43 [0.56, 2.31]	100	0.5
Flexion gap	258	276	−1.07 [−4.45, 2.30]	94	0.1
Mechanical axis	278	280	0.27 [−0.10, 0.63]	78	0.2
Femoral rotational alignment	457	298	−0.02 [−0.39, 0.35]	82	0.9
Joint line elevation	184	169	−0.48 [−0.70, −0.27]	62	<0.0001
Revisions rate at mean 63 months FU	355	319	1.32 [0.59, 2.99]	0	0.6
Revisions rate at mean 75 months FU	285	249	1.24 [0.53, 2.89]	0	0.6
Revisions rate at mean 95 months FU	169	164	1.54 [0.58, 4.10]	0	0.4
Aseptic loosening	328	294	1.67 [0.64, 4.35]	0	0.3
Infections	355	319	0.71 [0.19, 2.64]	0	0.6

anterior knee pain and finally component wear. In 2019, Van Lieshout et al. performed a systematic review involving 1255 primary TKAs. They found analysed that a higher joint line can negatively influence the KSS. Recent meta-analyses found similar result, attesting clinical relevance to this outcome [8–10].

To obtain soft tissue balancing, surgeons try to implement symmetrical, equivalent and rectangular gaps. It has been stated that for acceptable GB, gaps in both, full extension and 90° flexion have to be ≤3 cm. This circumstance may explain the prolonged time of surgery reported in the GB group. In the present meta-analysis, we found no significant difference among medial and lateral gap balancing during extension and 90° of flexion drawing the conclusion that MR achieves sufficient gap balancing. Similar results have been reported by high-quality meta-analyses [10].

Analysis of the clinical scores, complications detected no statistically significant difference. Similar results have been found by Li et al. [9] in over 2259 samples. Conversely, Huang et al. [10] reported improved score results in the GB cohort in approximately 300 TKAs. Hence, more precise investigations and further high-quality studies are required.

The main limitation of the present study is the reduced number of studies included and related samples considered for analysis. Furthermore, the studies included differed for type of implant and surgical approach, and especially the gaps tensions of the GB studies differed. These factors may explain, at least partially, some of the heterogeneities in evidence in the present study. Further high-quality studies with longer follow-up are required to investigate long-term survivorships among the two techniques.

Conclusion

According to the main findings of the present meta-analysis, GB and MR achieve similar outcomes in TKA. The GB group presented a proximalisation of the joint line and required longer operating time. Regarding further outcomes of interest, the present analysis demonstrates comparability between MR and GB.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent For this type of study, informed consent is not required.

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