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REVIEW

Robotic assisted Total Knee Arthroplasty (TKA) is not associated with increased patient satisfaction: a systematic review and meta-analysis

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Abstract

Purpose Total knee arthroplasty (TKA) is a common orthopedic surgery, yet postoperative dissatisfaction persists in around 20% of cases. Robotic total knee arthroplasty (rTKA) promises enhanced precision, but its impact on patient satisfaction compared to conventional TKA remains controversial (cTKA). This systematic review aims to evaluate patient satisfaction post-rTKA and compare outcomes with cTKA.

Methods Papers from the following databases were identified and reviewed: PubMed, Scopus, Web of Science, and the Cochrane Online Library, using keywords like "Knee replacement," "Total knee arthroplasty," "Robotic," and "Patient satisfaction." Extracted data included patient satisfaction measures, Knee Society Score, Oxford Knee Score, Forgotten Joint Score, SF-36, HSS, and KOOS. Statistical analysis, including odds ratio and 95% CI was performed using R software. Heterogeneity was assessed using Cochrane's Q test.

Results The systematic review included 17 articles, involving 1148 patients (571 in the rTKA group and 577 in the cTKA group) assessing patient satisfaction following rTKA. An analysis of proportions reveals rTKA satisfaction rate was 95%, while for cTKA, it was 91%. A meta-analysis comparing rTKA and cTKA found no statistically significant difference in patient satisfaction. Additionally, various patient-reported outcome measures (PROMs) were examined, showing mixed results across different studies and follow-up periods.

Conclusions The results of this study found no difference in patient satisfaction outcomes in the short to mid-term for rTKA compared to conventional methods. This study does not assert superiority for the robotic approach, highlighting the need for careful consideration of various factors influencing outcomes in knee arthroplasty.

Keywords Patient Satisfaction · Robotic Surgery · Robotic-assisted · Total Knee Arthroplasty

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Introduction

Osteoarthritis, including knee osteoarthritis, has become an increasing global challenge, with its burden growing notably in recent years [1–3]. Total knee arthroplasty (TKA) is one of the most frequently performed orthopaedic surgeries, with an estimated 1,065,000 patients undergoing the procedure in the United States in 2020. This number is anticipated to reach 3,416,000 by 2040 [4]. While TKA proves to be an effective and viable treatment, approximately 20% of patients express dissatisfaction post-surgery. This dissatisfaction is influenced by various factors, including patients' expectations before the surgery, the extent of improvement in knee function, and the relief of pain following the procedure [5].

Recently, the introduction of robotic technologies has led to significant improvements in the accuracy and predictability of bone cuts performed during TKA with the intention of accurately restoring alignment, reducing the extent of soft tissue releases required and ultimately improving patient satisfaction and long term outcomes [6]. Currently, there are controversial findings regarding the differences between conventional total knee arthroplasty (cTKA) and rTKA in terms of functional outcomes and patient satisfaction [7, 8]. Some studies have reported a significantly higher proportion of satisfied or very satisfied patients in rTKA compared to conventional methods [9–11]. However, other studies have found no significant difference in patient satisfaction between rTKA and cTKA [12, 13]. Additionally, longer operative duration, higher intraoperative costs, and iatrogenic injuries associated with robotic surgeries could potentially have a negative impact on patient satisfaction [14].

The aim of the present study was to systematically review the existing literature on satisfaction rates following rTKA and compare patient satisfaction between rTKA and cTKA.

Methods

This study adhered to the PRISMA guidelines. The study protocol was registered with the International Prospective Register of Systematic Reviews (PROSPERO) under the code [CRD42023479878].

Search strategy

A search was conducted across the following databases: PubMed, Scopus, Web of Science (WOS), and the Cochrane Online Library. The search utilized the keywords "Knee replacement," "Total knee arthroplasty," "Robotic," and "Patient satisfaction." Additionally, a manual search of the reference lists of identified articles was performed to uncover any additional relevant studies. The search spanned from the inception of each database to August 2nd, 2023. The complete search strategy was provided in supplementary file (Table S1).

Inclusion and exclusion criteria

Studies were included if they met the following criteria: (1) randomized controlled trials (RCTs), case–control studies, and prospective or retrospective cohorts investigating either unilateral or bilateral primary knee arthroplasty using robotic arm-assisted techniques; (2) provided information about patient satisfaction and preferences; (3) were published in English. The exclusion criteria comprised (1) case reports, letters, correspondents, pilot studies, reviews, editorials, and commentaries; (2) studies with incomplete data on patient satisfaction and (3) revision TKA.

Study selection and data extraction

Two independent reviewers screened the titles and abstracts of all retrieved articles. Full texts were obtained for potentially eligible studies. The two reviewers (SE, AHG), independently assessed the eligibility of each full-text article using the inclusion and exclusion criteria. Disagreements were resolved by consulting a third independent reviewer (AHH).

Data were extracted from the included studies by two reviewers (SE, AHG). The extracted data included: year of publication, study design, number of participants, mean age in years, Body Mass Index (BMI), robot brand, mean length of follow-up, patient satisfaction outcome measures, Knee Society Score (KSS), Oxford Knee Score (OKS), Forgotten Joint Score (FJS), Short Form (SF-36) Hospital for Special Surgery (HSS), and Knee Injury and Osteoarthritis Outcome Score (KOOS).

Quality assessment

Two individual reviewers [SE, AHG] assessed the risk of bias. The Joanna Briggs Institute Critical Appraisal Tool (JBI) [15] was employed for estimating the risk of bias in cohort and case series studies. This tool assesses studies with meticulous attention to key factors, including participant selection bias, accuracy of outcome measurement, appropriateness of statistical analysis and reported results selection, and potential bias arising from missing data.

Data synthesis and statistical analysis

Patient satisfaction disparities between rTKA and cTKA were assessed utilizing R software, version 4.2.2, provided by the R Foundation for Statistical Computing in Vienna, Austria (http://www.R-project.org). The analysis involved the

Mantel–Haenszel model, presenting the odds ratio (OR) and its corresponding 95% confidence interval (CI). Additionally, proportion analysis was employed, utilizing the inverse variance method to calculate the overall patient satisfaction rate following rTKA. Heterogeneity was determined using Cochrane's Q test, generating I^2. If the P-value of the heterogeneity test was below 0.05 or I^2 exceeded 50%, the random-effects model was applied; otherwise, the common-effects model was used. Egger's Regression test and Begg's funnel plot were utilized to evaluate potential publication bias.

Results

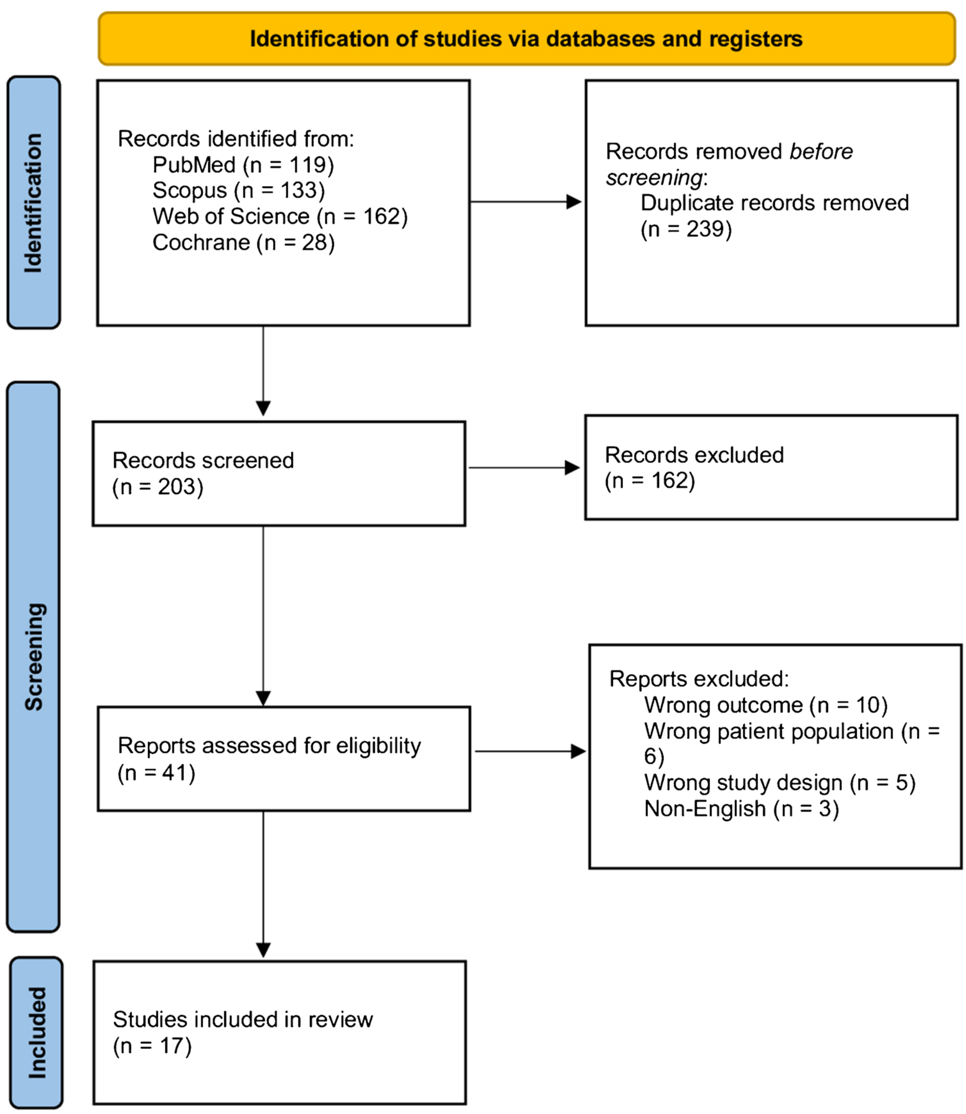
Study selection

While searching across four databases, including PubMed, Scopus, Web of Science (WOS), and the Cochrane Online Library, a total of 203 articles were identified after eliminating duplicates. The initial assessment focused on titles and abstracts, resulting in 41 articles progressing to the next stage, which entailed a thorough full-text review. Subsequently, a comprehensive examination of the full texts resulted in the inclusion of 17 articles in this systematic review. Among these, nine articles involved a two-group comparison [9–11, 16–21], focusing on patient satisfaction between cTKA and rTKA, while the remaining eight single-group articles exclusively examined patient satisfaction following rTKA [22–29]. The Prisma chart in Fig. 1 visually illustrates the various stages of the screening process.

Quality of assessment

Seven studies utilized a prospective design [9, 11, 17, 18, 21, 24, 26], while the remainder employed a retrospective approach. The JBI critical appraisal tool for cohort and case

Fig. 1 PRISMA graph



series studies was employed to assess the quality of the studies. Detailed results of the qualitative assessment for the articles are available in the supplementary file (Tables S2 and S3).

Baseline characteristics

This review analyzed a total of nine comparative studies, involving 1148 patients (571 in the rTKA group and 577 in the cTKA group) [9–11, 16–21]. Furthermore, eight single-group studies comprised 1533 patients who underwent rTKA [22–29]. Among the eight comparative studies that reported gender distribution, 345 were male, and 743 were female [9–11, 16–20]. Across all the articles included, pertaining to patients who underwent rTKA, there were 786 males and 1311 females. The mean age in the comparative studies ranged from 65 to 70.1 years, and among rTKA patients in all included studies, mean age fell within the same range of 65 to 70 years. Mean BMI in the comparative studies ranged from 26.7 to 34.7, while among rTKA patients in all included studies, it ranged from 26.4 to 33.2. The minimum follow-up duration in the included studies was three months, and the maximum was extended to 24 months (Table 1).

Among the studies, the MAKO (Stryker) robotic system was the most frequently employed, and featured in seven studies [11, 18, 20, 23, 24, 27, 28]. Following this, the NAVIO (Smith & Nephew) system was used in three studies [16, 19, 22], the ROBODOC (Curexo) [17, 21] and OMNIBotics (Corin) [25, 26] systems were each utilized in two studies, and the ROSA (Zimmer Biomet) system was used in one study [9] (Table 1).

Overall patient satisfaction rate after rTKA

After performing a proportion analysis on patient satisfaction across 11 articles (comprising 6 single-group studies and five double-group comparative studies) following rTKA, the results indicated that 94% of patients expressed satisfaction with rTKA, with a confidence interval between 92 and 96% ($I^2 = 54\%$) (Fig. 2). Notably, Egger's test revealed the presence of publication bias in this analysis ($p = 0.0145$, Fig. 3). Following a Trim-and-fill analysis, incorporating three additional studies, the patient satisfaction rate was adjusted to 93.2% with a confidence interval spanning from 90.4% to 95.2%.

In single-group research, Abhari et al., Daffara et al., and Richards et al. evaluated satisfaction levels using the Likert scale, obtaining mean scores of 4.6, 4.5, and 4.7 out of a possible five, respectively [23, 28, 29]. Additionally, Winnock de Grave et al. documented an average VAS satisfaction score of 8.9, and Turan et al. indicated a score of 8.3 ± 1.5 [16, 22] (Table 2).

Comparing patient satisfaction following rTKA and cTKA

An proportions analysis of comparative studies reveals that the satisfaction rate among patients who underwent rTKA was 95% ([95% CI: 88–98%]; Fig. 4A), while for cTKA patients, it was 91% ([95% CI: 85–95%]; Fig. 4B). A meta-analysis examining patient satisfaction rates after TKA indicates that there is no statistically significant difference between the two groups of rTKA and cTKA (OR [95% CI] = 2.62 [7.73–0.89], $I^2 = 0\%$) (Fig. 4C).

Choi et al. observed no significant disparity in KSS satisfaction and expectation scores among patients who underwent rTKA and cTKA at the three-month postoperative stage. However, at the one-year and two-year follow-up points, the mean scores were higher in the rTKA group [20]. Khlopas et al. reported no difference in the three-month mean of KSS satisfaction and expectation scores between the two groups [18]. Also, Smith et al.'s study noted that the difference in KSS satisfaction score was statistically nonsignificant [11]. Moreover, Turan et al. reported the mean satisfaction score on the Visual Analog Scale (VAS), revealing no significant difference between the two groups [16] (Table 3).

Mulpur et al. divided satisfaction levels into four categories: very satisfied, satisfied, dissatisfied, and very dissatisfied. Their findings showed a notably higher proportion of satisfied patients following rTKA compared to those who underwent cTKA [10]. Likewise, Smith et al., who categorized satisfaction into three levels, observed a significantly greater ratio of very satisfied and satisfied individuals among patients who received rTKA [11] (Table 3).

Another metric for assessing patient satisfaction involves their willingness to undergo surgery again, a topic investigated in studies conducted by Eerens et al. and Kenanidis et al. In Eerens et al.'s study, a larger percentage of patients in the cTKA group expressed a willingness for repeat surgery, suggesting higher satisfaction [19]. In contrast, in Kenanidis et al.'s publication, this percentage was notably elevated in the rTKA group [9] (Table 3).

Liow et al. found that there was no statistically significant difference in the ratio of patients with fulfilled expectations for TKA, both six months and two years after the operation [21] (Table 3).

Song et al. conducted a study involving patients who underwent simultaneous bilateral TKA using both robotic and manual techniques. Before the operation, most patients expressed a preference for cTKA. However, at the three-month follow-up 33.3% favored cTKA, 33.3% preferred rTKA, and 33.3% found both methods equally preferable. In the final follow-up, 20% preferred cTKA, 40% favored rTKA, and 40% found both methods equally appealing [17] (Table 3).

Table 1 Baseline characteristics of the eligible studies

Study ID	Country	Design	Robot system	Population, n	Age, year	Male/Female	BMI, kg/m^2	Follow up, month	lost to follow up, n
rTKA vs. mTKA									
Choi et al. [20]	Korea	Retrospective	MAKO (Stryker)	rTKA: 60 mTKA: 60	rTKA: 70.0 ± 5.7 mTKA: 70.1 ± 5.7	rTKA: 13/47 mTKA: 13/47	rTKA: 27.1 ± 3.5 mTKA: 26.7 ± 2.6	24	NM
Eerens et al. [19]	Belgium	Retrospective	NAVIO (Smith & Nephew)	rTKA: 73 mTKA: 74	rTKA: 69.6 ± 9.7 mTKA: 68.9 ± 8.6	rTKA: 31/42 mTKA: 32/42	NM	24	7
Kenanidis et al. [9]	Greece	Prospective	ROSA (Zimmer Biomet)	rTKA: 30 mTKA: 30	rTKA: 69.3 ± 6.8 mTKA: 69.1 ± 7.0	rTKA: 6/24 mTKA: 6/24	rTKA: 27.8 ± 3.2 mTKA: 27.9 ± 2.7	6	0
Khlopas et al. [18]	USA	Prospective	MAKO (Stryker)	rTKA: 102 mTKA: 150	rTKA: 68 (34–85) mTKA: 65 (43–83)	rTKA: 43/59 mTKA: 55/95	rTKA: 30.4 (17–40 mTKA: 30.7 (20–40)	3	NM
Liow et al. [21]	Singapore	Prospective	Digimatch ROBODOC (Curexo)	rTKA: 31 mTKA: 29	NM	NM	NM	24	0
Mulpur et al. [10]	India	Retrospective	NM	rTKA: 55 mTKA: 55	rTKA: 66.6 ± 7.5 mTKA: 66.6 ± 7.5	rTKA: 20/35 mTKA: 20/35	rTKA: 29.4 ± 5.3 mTKA: 29.4 ± 5.3	at least 12	5
Smith et al. [11]	USA	Prospective	MAKO (Stryker)	rTKA: 120 mTKA: 103	rTKA: 68 (40–86) mTKA: 66 (44–87)	rTKA: 48/72 mTKA: 38/65	rTKA: 31.2 (18–47) mTKA: 34.7 (20–47)	at least 12	NM
Song et al. [17]	Korea	Prospective	ROBODOC (Curexo)	rTKA: 30 mTKA: 30	rTKA: 67 ± 6.3 mTKA: 67 ± 6.3	rTKA: 0/30 mTKA: 0/30	rTKA: 27 ± 6.5 mTKA: 27 ± 6.5	at least 12	NM
Turan et al. [16]	Turkey	Retrospective	NAVIO (Smith & Nephew)	rTKA: 70 mTKA: 46	rTKA: 65.7 ± 8.6 mTKA: 68.1 ± 7.2	rTKA: 12/58 mTKA: 8/38	rTKA: 30.9 ± 8.2 mTKA: 33.5 ± 7.2	24	NM
rTKA									
Abhari et al. [29]	USA	Retrospective	NM	225	65	87/138	33.2	at least 24	NM
Daffara et al. [28]	Italy	Retrospective	MAKO (Stryker)	164	71.7 ± 8.9	61/103	28.7 ± 4.7	at least 24	0
Winnock de Grave et al. [27]	Belgium	Retrospective	MAKO (Stryker)	80	68.7	32/48	29.6	12	NM
Keggi et al. [26]	USA	Prospective	OMNIBotics (Corin)	280	66.8 ± 8.2	119/161	31.6 ± 4.9	12	NM
Lee et al. [25]	USA	Retrospective	OMNIBotics (Corin)	134	67 ± 8	79/55	31.3 ± 4.9	12	NM
Probst et al. [24]	Germany	Prospective	MAKO (Stryker)	351	70 ± 10.2	144/207	30 ± 5.4	3	NM
Richards et al. [23]	USA	Retrospective	MAKO (Stryker)	190 (214 knee)	63	74/140	30.2	at least 12	NM
Turan et al. [16]	Turkey	Retrospective	NAVIO (Smith & Nephew)	109 (142 knee)	66.3 ± 9.3	17/92	26.4 ± 12.7	12	NM

rTKA robotic Total Knee Arthroplasty, *mTKA* manual Total Knee Arthroplasty, *n* number, *NM* Not Mentioned

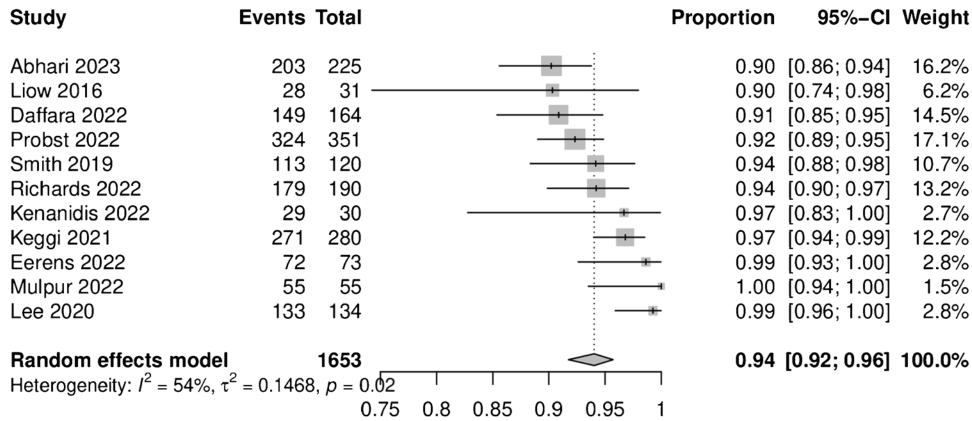


Fig. 2 Forest plot displaying the proportion analysis of satisfaction rates among patients who underwent rTKA

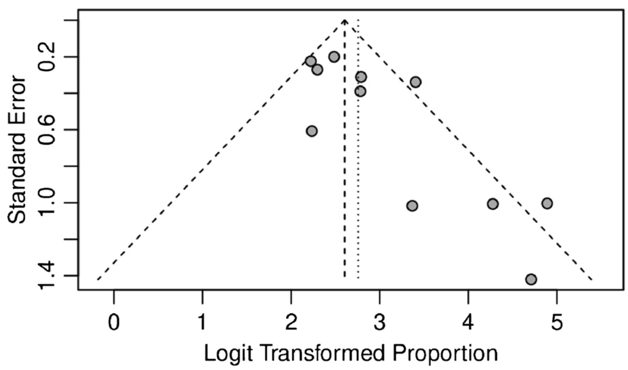


Fig. 3 Funnel plot of the proportion analysis of satisfaction rates for rTKA

Table 2 Patient satisfaction following robotic TKA

Study ID	Satisfied patient, n(%)	Likert scale (1–5)	VAS satisfaction
Abhari et al. [29]	203 (90.2%)	4.6	NM
Daffara et al. [28]	149 (90.9%)	4.5	NM
Winnock de Grave et al. [27]	NM	NM	8.9
Keggi et al. [26]	271 (96.8%)	NM	NM
Lee et al. [25]	133 (99.3%)	NM	NM
Probst et al. [24]	324 (92.3%)	NM	NM
Richards et al. [23]	179 (94.2%)	4.7	NM
Turan et al. [16]	NM	NM	8.3 ± 1.5

VAS Visual Analogue Scale, *n* number, *NM* Not Mentioned

Patient-Reported Outcome Measures (PROMs)

We also examined PROMs as a secondary outcome. Both Song et al. and Choi et al. found no significant disparity in mean WOMAC scores among patients who underwent rTKA and cTKA at three months and one year postoperative stages [17, 20]. However, in Choi et al.'s study, a notable difference emerged at the two-year postoperative follow-up, with the mean score being lower in the rTKA group [20] (Table 4).

In Choi et al.'s study, the initial mean KSS knee score varied between the two groups, but this distinction lost significance by the final follow-up [20]. Also, Liow et al. noted no significant difference. In contrast, Smith et al. found a notably higher mean score in the rTKA group [21]. The average KSS function score in Choi et al.'s study consistently showed significant superiority in the rTKA group across all follow-up periods, a pattern that is similarly evident in Smith et al.'s research [11, 20]. In contrast to these two investigations, the studies conducted by Liow and Khlopas did not reveal any notable differences in this regard [18, 21] (Table 4).

Four studies reported the OKS [9, 10, 16, 21], and among them, only Kenanidis et al.'s study showed a significant difference (in favor of rTKA) [9]. The FJS was also documented in four studies [10, 16, 19, 20], and except for Turan et al.'s study [22], all others indicated a significant advantage for rTKA.

In Kenanidis et al.'s study, the mean SF-36 Physical Component Summary (PCS) was notably higher in the rTKA group [9]. Conversely, Liow et al.'s study did not indicate any significant differences in either PCS or Mental Component Summary (MCS) [21] (Table 4).

At three months and one year postoperatively, Song et al. found no significant difference in the mean HSS scores between the two groups [17]. Likewise, in Turan et al.'s study, none of the components of the KOOS exhibited significant differences between the two groups [16] (Table 4).

Discussion

Patient satisfaction is an important component of decision-making in orthopaedic surgery [30, 31]. While significant focus has been placed on comparing the radiological and

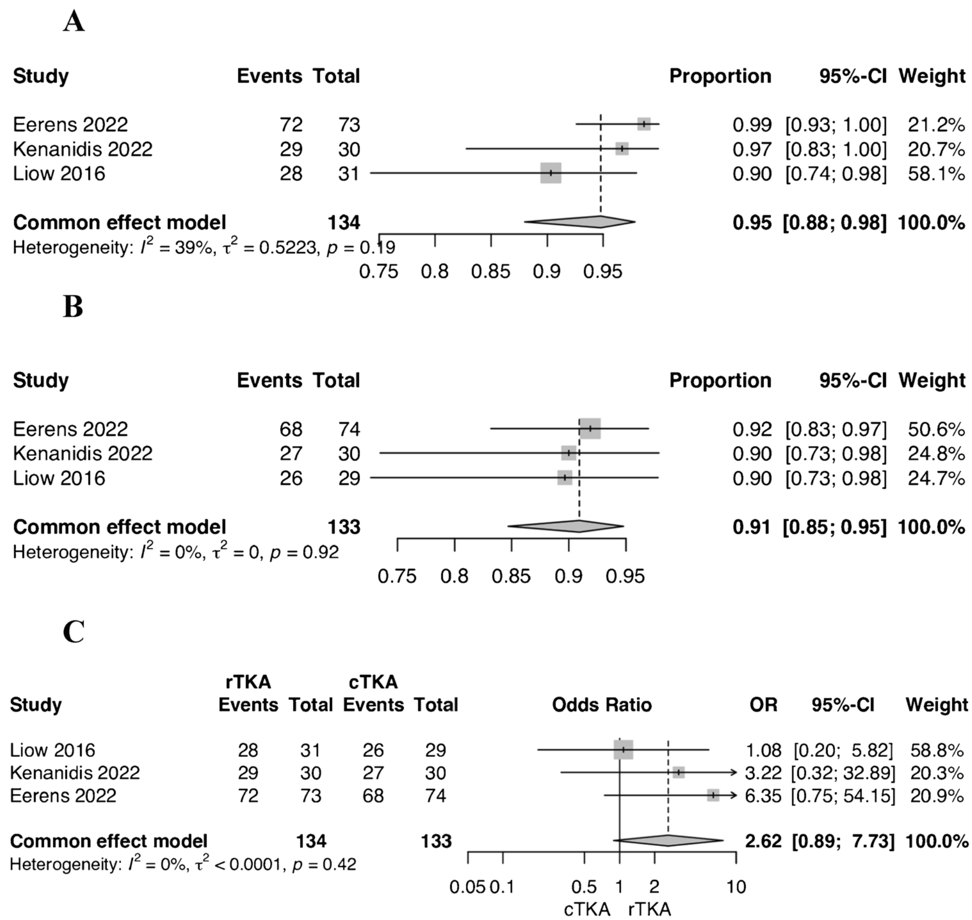


Fig. 4 Forest plots illustrating proportion analysis of satisfaction rates among patients who underwent rTKA (**A**) and cTKA (**B**), along with meta-analysis comparing patient satisfaction rates between rTKA and cTKA (**C**)

clinical outcomes of rTKA with cTKA, patient satisfaction and patient-reported outcomes stand as critical metrics in surgical decision-making [32, 33]. Results of this study suggest that rTKA is a reliable method with high levels of patient satisfaction. Additionally, the level of satisfaction in cTKA was high and close to that in rTKA. The results of this study suggest that rTKA and cTKA achieve comparable results in these domains.

rTKA is a reliable and safe method in total knee replacement that has achieved satisfactory results in radiological and clinical outcomes [34–37]. Literature shows that utilizing robotic assistance in TKA can achieve more precise radiological outcomes. rTKA comes with significantly fewer outliers in component positioning in the femoral coronal and tibial sagittal axes and mechanical alignment [34]. Such outcome measures reflect the success of the operation in achieving the desired component position and alignment. Although proper alignment and soft tissue balancing are crucial for maintaining knee function, the extent to which observed differences in these measures affect the final clinical outcomes and patient satisfaction is debatable [38, 39].

Several studies indicate that functional outcomes and implant survivorship can be affected by improved accuracy in alignment and implant positioning. However, a long-term follow-up, seems to be needed in order to notice differences in these outcomes [38]. Most current evidence comparing rTKA and cTKA for patient satisfaction consisted of a short follow-up length, with a maximum duration of two years in our included studies. Additionally, newer robotic systems, claiming improved technical properties, have not been in use long enough to provide medium or long term results.

Most studies which examine the results of rTKA and cTKA show similar results, with rTKA showing slightly better functional and range of motion goals than cTKA [34, 35, 37]. The majority of the studies comparing the two techniques argue that improved radiological outcomes following rTKA, may not be clinically meaningful in the short- to mid-term follow-up [34, 35, 37]. Also, no remarkable difference seems to exist regarding the rate of complications associated with both techniques [34]. Aside from slight differences in blood loss, post-surgery drainage, operative time, and periprosthetic joint infection [8, 21, 36, 40], evidence comparing complication rates between these methods does not robustly favor one over the other.

The previous systematic review and meta-analysis performed by Zhang et al. showed better PROMs for rTKA based on KSS and WOMAC scores, while still arguing that

Table 3 Patient satisfaction following robotic and manual TKA

Study ID	Outcome measure	Robotic TKA	Manual TKA	p-value
Choi et al. [20]	KSS satisfaction (Mean ± SD)	3 m: 22.9 ± 12.8	3 m: 18.3 ± 8.4	> 0.05
		1y: 32.2 ± 9.6	1y: 24.5 ± 7.7	< 0.001
		2y: 34.3 ± 9.9	2y: 27.1 ± 7.4	0.001
	KSS expectation (Mean ± SD)	3 m: 10.7 ± 3.5	3 m: 11.9 ± 0.6	> 0.05
		1y: 14.3 ± 2.3	1y: 11.8 ± 2.6	< 0.001
		2y: 14.2 ± 2.6	2y: 12.3 ± 2.5	0.004
Eerens et al. [19]	Satisfied with TKA	72 (98.6%)	68 (91.9%)	NM
	Patients willing to have surgery again	62 (84.9%)	65 (87.8%)	NM
Kenanidis et al. [9]	Satisfied with TKA	29 (96.7%)	27 (90.0%)	0.301
	Patients willing to have surgery again	30 (100.0%)	26 (86.7%)	0.038
Khlopas et al. [18]	KSS satisfaction (Mean (range))	Pre-op: 12.8 (0–32)	Pre-op: 13.8 (2–30)	0.268
		3 m: 29.4 (0–40)	3 m: 29.1 (6–40)	0.298
	KSS expectation (Mean (range))	Pre-op: 14.2 (6–15)	Pre-op: 13.8 (6–15)	0.134
		3 m: 9.5 (3–15)	3 m: 9.9 (3–15)	0.112
Liow et al. [21]	Satisfied with TKA	6 m: 28 (90.3%)	6 m: 26 (89.7%)	> 0.05
		2y: 28 (90.3%)	2y: 26 (89.7%)	> 0.05
	Expectations fulfilled	6 m: 28 (90.3%)	6 m: 26 (89.7%)	> 0.05
		2y: 29 (93.5%)	2y: 27 (92.6%)	> 0.05
Mulpur et al. [10]	Patient satisfaction (4-level ordinal type)	Very satisfied: 40 (72.7%)	Very satisfied: 35 (63.6%)	0.026
		Satisfied: 15 (27.3%)	Satisfied: 20 (36.4%)	
		Dissatisfied: 0 (0%)	Dissatisfied: 0 (0%)	
		Very dissatisfied: 0 (0%)	Very dissatisfied: 0 (0%)	
Smith et al. [11]	KSS satisfaction (Mean)	33.6	32.0	0.16
	Patient satisfaction (3-level ordinal type)	Very satisfied or satisfied: 113 (94%)	Very satisfied or satisfied: 84 (82%)	0.036
		Neutral: 5 (4%)	Neutral: 13 (13%)	> 0.05
		Dissatisfied or very dissatisfied: 2 (2%)	Dissatisfied or very dissatisfied: 6 (6%)	> 0.05
Song et al. [17]	Patient preferences	Pre-op: 8 (26.7%)	Pre-op: 16 (53.3%)	NM
		3 m: 10 (33.3%)	3 m: 10 (33.3%)	
		1y: 10 (33.3%)	1y: 8 (26.7%)	
		Last follow-up: 12 (40%)	Last follow-up: 6 (20%)	
Turan et al. [16]	VAS satisfaction (Mean ± SD)	7.7 ± 1.4	7.4 ± 1.8	> 0.05

KSS Knee Society Score, *VAS* Visual Analogue Scale, *SD* standard deviation, *NM* Not Mentioned

no minimal clinically important difference (MCID) was notable [8]. Since there is a great heterogeneity in the tools used to evaluate PROMs in the included studies, a meta-analysis was not feasible in our study. On the other hand, while some studies reported significantly better outcomes for rTKA [9–11, 19, 20], others suggested comparable results [16–18, 21]. Also, no significant difference in PROMs between the two techniques were observed in the current study.

An essential consideration when comparing rTKA with cTKA could be the diversity and lack of consistent reporting in alignment and balancing techniques across various studies. Other factors such as surgeon experience, pre operative discussions with the patients and biases based on funding sources for studies need to be considered as these all potentially influence results.

The idea of implementing a uniform alignment approach in all cases of TKA has been challenged recently [41, 42]. While mechanical alignment is the most utilized surgical alignment goal for TKA, a more personalized goal accounting for the constitutional alignment of each patient may be the key to addressing patient dissatisfaction [43]. Since rTKA has been successful in fulfilling the objectives of mechanical alignment with high precision, improving patient satisfaction may involve understanding the significance of presurgical knee morphology. The true potential of technological advancements such as robotic and computer

Table 4 Patient-reported outcomes following robotic and manual TKA

Study ID	WOMAC	KSS (Knee)	KSS (Function)	OKS	FJS-12	SF-36 (PCS)	SF-36 (MCS)	HSS	KOOS
Choi et al. [20]	**Pre-op**: rTKA: 48.9 ± 7.9 mTKA: 50.5 ± 12.6 **3 m**: rTKA: 25.8 ± 15.2 mTKA: 30.0 ± 13.6 (p > 0.05) **1y**: rTKA: 17.8 ± 9.4 mTKA: 22.9 ± 14.1 (p = 0.35) **2y**: rTKA: 13.6 ± 12.3 mTKA: 19.2 ± 10.1 (p = 0.047)	**Pre-op**: rTKA: 38.5 ± 27.8 mTKA: 46.3 ± 17.7 **3 m**: rTKA: 89.5 ± 7.4 mTKA: 82.6 ± 13.2 (p = 0.005) **1y**: rTKA: 93.8 ± 6.9 mTKA: 88.2 ± 12.0 (p = 0.004) **2y**: rTKA: 94.5 ± 6.4 mTKA: 90.0 ± 12.9 (p > 0.05)	**Pre-op**: rTKA: 38.5 ± 16.8 mTKA: 38.7 ± 12.6 **3 m**: rTKA: 65.3 ± 22.3 mTKA: 50.9 ± 17.1 (p = 0.002) **1y**: rTKA: 68.7 ± 18.0 mTKA: 56.3 ± 16.3 (p = 0.001) **2y**: rTKA: 76.9 ± 15.1 mTKA: 59.2 ± 14.6 (p = 0.01)	NM	**3 m**: rTKA: 39.3 ± 35.6 mTKA: 8.7 ± 11.7 (p < 0.001) **1y**: rTKA: 50.8 ± 30.2 mTKA: 24.6 ± 23.1 (p < 0.001) **2y**: rTKA: 79.6 ± 30.1 mTKA: 34.8 ± 28.4 (p < 0.001)	NM		NM	NM
Eerens et al. [19]	NM	NM	NM	NM	rTKA: 75.6 ± 25.8 mTKA: 56.4 ± 19.4 (p < 0.001)	NM		NM	NM
Kenanidis et al. [9]	NM	NM	NM	**Pre-op**: rTKA: 13.9 ± 4.7 mTKA: 15.8 ± 5.2 **3 m**: rTKA: 27.2 ± 3.0 mTKA: 25.9 ± 3.3 (p = 0.123) **6 m**: rTKA: 37.8 ± 3.8 mTKA: 34.8 ± 4.0 (p = 0.006)	NM	**6 m**: rTKA: 71.6 ± 8.3 mTKA: 61.9 ± 8.1 (p < 0.001)		NM	NM
Khlopas et al. [18]	NM	NM	**Pre-op**: rTKA: 44.7 (8–86) mTKA: 46.0 (13–95) **3 m**: rTKA: 65.5 (18–99) mTKA: 67.2 (16–100) (p = 0.522)	NM	NM	NM		NM	NM

Table 4 (continued)

Study ID	WOMAC	KSS (Knee)	KSS (Function)	OKS	FJS-12	SF-36 (PCS)	SF-36 (MCS)	HSS	KOOS
Liow et al. [21]	NM	**Pre-op**: rTKA: 34.3 ± 14.6 mTKA: 34.0 ± 17.1 **6 m**: rTKA: 78.3 ± 18.0 mTKA: 82.6 ± 14.7 (p > 0.05) **2y**: rTKA: 81.8 ± 14.9 mTKA: 87.9 ± 10.6 (p > 0.05)	**Pre-op**: rTKA: 55.4 ± 16.9 mTKA: 51.0 ± 20.4 **6 m**: rTKA: 70.5 ± 20.3 mTKA: 70.0 ± 15.6 (p > 0.05) **2y**: rTKA: 77.0 ± 17.1 mTKA: 73.9 ± 19.6 (p > 0.05)	**Pre-op**: rTKA: 33.6 ± 7.8 mTKA: 38.2 ± 9.5 **6 m**: rTKA: 19.9 ± 7.9 mTKA: 19.6 ± 6.8 (p > 0.05) **2y**: rTKA: 18.3 ± 7.0 mTKA: 17.7 ± 4.2 (p > 0.05)	NM	**Pre-op**: rTKA: 32.4 ± 9.6 mTKA: 29.1 ± 9.2 **6 m**: rTKA: 46.2 ± 9.1 mTKA: 46.7 ± 11.6 (p > 0.05) **2y**: rTKA: 50.3 ± 7.0 mTKA: 46.2 ± 13.9 (p > 0.05)	**Pre-op**: rTKA: 53.9 ± 8.2 mTKA: 50.0 ± 12.6 **6 m**: rTKA: 57.0 ± 8.8 mTKA: 52.6 ± 9.7 (p > 0.05) **2y**: rTKA: 59.3 ± 9.8 mTKA: 54.7 ± 10.3 (p > 0.05)	NM	NM
Mulpur et al. [10]	NM	NM	NM	rTKA: 40.42 ± 1.9 mTKA: 39.8 ± 2.2 (p = 0.085)	rTKA: 73.0 ± 11.0 mTKA: 70.3 ± 10.7 (p < 0.01)	NM	NM	NM	NM
Smith et al. [11]	NM	**Pre-op**: rTKA: 41 mTKA: 39 **1y**: rTKA: 85 mTKA: 82 (p = 0.046)	**Pre-op**: rTKA: 44 mTKA: 43 **1y**: rTKA: 80 mTKA: 73 (p = 0.005)	NM	NM	NM	NM	NM	NM
Song et al. [17]	**Pre-op**: rTKA: 80 ± 16.0 mTKA: 75 ± 15.0 **3 m**: rTKA: 36.8 ± 12.0 mTKA: 36.4 ± 12.4 (p > 0.05) **1y**: rTKA: 18.5 ± 4.0 mTKA: 20.1 ± 8.5 (p > 0.05)	NM	NM	NM	NM	NM	NM	**Pre-op**: rTKA: 65 ± 7.0 mTKA: 66 ± 7.4 **3 m**: rTKA: 91.1 ± 6.7 mTKA: 90.5 ± 6.6 (p > 0.05) **1y**: rTKA: 95.9 ± 5.2 mTKA: 94.7 ± 5.5 (p > 0.05)	NM

Table 4 (continued)

Study ID	WOMAC	KSS (Knee)	KSS (Function)	OKS	FJS-12	SF-36 (PCS)	SF-36 (MCS)	HSS	KOOS
Turan et al. [16]	NM	NM	NM	**Pre-op**: rTKA: 13.8 ± 5.7 mTKA: 11.5 ± 4.0 **Post-op**: rTKA: 32.5 ± 5.3 mTKA: 30.3 ± 5.9 ($p > 0.05$)	rTKA: 68.4 ± 11.6 mTKA: 63.9 ± 12.6 ($p > 0.05$)	NM	NM	NM	**Pain**: rTKA: 82.3 ± 12.6 mTKA: 77.4 ± 7.2 ($p > 0.05$) **Symptoms**: rTKA: 87 ± 12.3 mTKA: 84.9 ± 8.7 ($p > 0.05$) **ADL**: rTKA: 77.8 ± 10.7 mTKA: 75.9 ± 7.8 ($p > 0.05$) **QOL**: rTKA: 74.8 ± 13.4 mTKA: 67.7 ± 13.4 ($p > 0.05$) **Sport**: rTKA: 46.9 ± 13.3 mTKA: 46.7 ± 9.0 ($p > 0.05$) **JR**: rTKA: 72.7 ± 13.4 mTKA: 70.3 ± 7.5 ($p > 0.05$)

mTKA manual Total Knee Arthroplasty, *rTKA* robotic Total Knee Arthroplasty, *KSS* Knee Society Score, *OKS* Oxford Knee Score, *FJS* Forgotten Joint Score, *SF* Short Form, *PCS* Physical Component Scale, *MCS* Mental Component Scale, *HSS* Hospital for Special Surgery, *KOOS* Knee Injury and Osteoarthritis Outcome Score, *NM* Not Mentioned assistance [44] may emerge by defining more personalized surgical goals rather than solely attempting to optimize the precision of the currently defined single target alignment.

In contrast to TKA, robotic-assisted uni-compartment arthroplasty (rUKA) was associated with better patient satisfaction in our previous review [45]. Several factors may contribute to this difference. Firstly, the importance of highly optimizing alignment and soft tissue balance may differ between procedures. A successful outcome in UKA largely depends on both precision of implant alignment and soft tissue balance [46, 47], while TKA seems to tolerate variability in component alignment to some extent [38, 48, 49]. Importantly, studies comparing rUKA and conventional manual uni-compartment arthroplasty (mUKA) mostly consisted of longer follow-up durations [45], which could unravel the clinical effect of radiological precision achieved by robotic assistance. However, such a hypothesis could be easily challenged with findings regarding the long-term studies on PROMs following robotic-assisted total hip arthroplasty (THA), which still indicate comparable results with the conventional method [50]. The potential effect of variety in the recruited robotic systems in these operations should also be kept in mind.

Our study was subject to some limitations. This review only encompassed the short- to mid-term patient satisfaction outcomes. Therefore, studies with longer durations may help reveal any notable differences among these techniques. Second, many key aspects of the procedures other than the use of robotic assistance (e.g., alignment and balancing methods, surgeon experience both in terms of years of practice and volume of procedures) were not considered in most studies, limiting the interpretability of such comparisons. Achieving optimal outcomes in rTKA may necessitate relatively different alignment approaches than those available in conventional methods. Additionally, due to the high degree of heterogeneity of included studies in the tools used for assessing PROMs, a meta-analysis was not feasible to draw robust conclusions. Finally, the extent to which utilizing different robotic systems could impact the outcome could not be determined. Although the majority of the studies reporting better outcomes for rTKA had utilized either MAKO or NAVIO robotic systems, other studies reporting similar results to cTKA with the same systems were also present.

In conclusion, rTKA achieves reliable and acceptable patient satisfaction in short- to mid-term follow-up, comparable to the outcomes of conventional TKA. rTKA has been associated with improved precision of bone cuts and radiological outcomes. Patient satisfaction is a complex construct, and uniform measurements among studies are crucial for sound judgement [51, 52].

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Declarations

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