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Efficacy and Safety of Trans-anal versus Laparoscopic Total Mesorectal Excision for Mid and Low Rectal Cancer: A GRADE-Assessed Meta-Analysis and Trial Sequential Analysis of Randomized Controlled Trials

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Abstract

Background:

The existing pooled literature on Laparoscopic total mesorectal excision (LaTME) versus Trans-anal total mesorectal excision (TaTME) for rectal cancer is mostly based on observational studies. This meta-analysis aims to determine the safety and efficacy of these procedures purely based on randomised data.

Methods:

We searched three databases till May 2026 (PubMed, Cochrane CENTRAL and Embase) for randomised controlled trials comparing these two techniques, TaTME vs LaTME. Primary outcome was circumferential resection margin (CRM) positivity. R 4.3.3 was used for analysis.

Results:

Across the four included RCTs, a total of 2,355 patients were analyzed (1,360 TaTME vs 995 LaTME). The weighted average age across all study arms was approximately 61.1 years.

Meta-analysis showed no significant difference between TaTME and LaTME: regarding circumferential resection margin positivity (RR = 0.70, 95% CI: 0.22–2.25; Z = −0.60, P = 0.5509), R0 resection rate (RR = 1.02, 95% CI: 0.92–1.12; Z = 0.30, P = 0.7646), and completeness of mesorectal excision (RR = 1.05, 95% CI: 0.98–1.12; Z = 1.34, P = 0.1811). A significantly lower conversion to open surgery was found with TaTME compared to LaTME (RR = 0.14, 95% CI: 0.03–0.74; Z = −2.31, P = 0.0208). Otherwise, both procedures were comparable in efficacy and safety.

Conclusions:

Previous meta-analyses incorporating observational studies frequently favored TaTME across several perioperative and pathological outcomes. However, when evidence is restricted to randomised trials, many of these apparent advantages disappear. This highlights the susceptibility of surgical innovation literature to selection bias, centre expertise effects, and learning-curve phenomena.

Introduction

Colorectal cancer (CRC) is the third most common cancer globally and a leading cause of cancer-related deaths, with over 1.9 million new cases and approximately 930,000 deaths estimated in 2020 (1). Rectal cancer constitutes approximately one-third of CRC diagnoses and remains surgically challenging as curative treatment requires precise dissection within the narrow confines of the pelvis while preserving pelvic autonomic nerves and sphincter function. Total mesorectal excision (TME) has become the standard of care for curative rectal cancer surgery and is associated with substantial reductions in local

recurrence (LR) and improvements in cancer-specific survival compared with conventional rectal resection techniques (2, 3).

Over the past three decades, the surgical approach has evolved significantly towards minimally invasive laparoscopic and robotic techniques. Laparoscopic total mesorectal excision (LaTME) is a well-established minimally invasive technique for rectal cancer, providing faster postoperative recovery and shorter hospital stay while maintaining oncological adequacy, with reported local recurrence around 6% and 5-year cancer-specific survival of approximately 75% (4, 5). Studies show comparative 3-year disease-free survival with LaTME as Transanal total mesorectal excision (TaTME) and robotic TME (6–8). Despite the advantages, LaTME for mid and low rectal cancer is technically demanding due to restricted pelvic anatomy, particularly in male and obese patients and in low tumors, resulting in impaired visualization, difficult dissection, and higher conversion rates to open surgery, and morbidity compared with newer techniques (6, 9, 10).

In comparison, TaTME is a novel surgical technique introduced to overcome anatomical challenges in lower pelvis rectal cancer surgery by using a "bottom-to-up" approach that allows direct endoscopic visualization of the distal rectum. Most of the available evidence for TaTME originates from observational studies which suggested potential advantages of TaTME, including lower rates of conversion to open surgery, fewer postoperative complications, reduced anastomotic leaks, and lower circumferential resection margin (CRM) involvement compared to LaTME; however, concerns regarding conflicting evidence warrant evaluation using randomized data (11, 12). TaTME also tends to achieve comparable quality of mesorectal excision and oncological outcomes, including LR rates and survival at mid-term follow-up, although long-term data are still limited (13, 14). However, concerns about the oncological safety of TaTME have been observed due to the reports of unexpectedly high LR rates, particularly multifocal recurrences ranging from 7.9% to 12% in some cohorts (15, 16). The learning curve also appears critical as higher LR rates are associated with early implementation phases and less surgical experience, with recurrence rates decreasing significantly as experience grows (17).

Given the conflicting evidence between observational study data and early trial results, there is a need for a definitive evaluation of TaTME. Recently, major randomized clinical trials (RCTs), including the TaLaR trial, Ta-LaTME and COLOR III, have provided high-quality data (18–20). Therefore, this study aims to conduct a comprehensive, GRADE-assessed meta-analysis of RCTs comparing Transanal versus laparoscopic TME for mid and low rectal cancer and also to make a comparison with previously conducted meta-analysis which mainly synthesized their evidence from observational studies. By synthesizing the current evidence, we seek to provide definitive conclusions regarding the oncological safety, surgical morbidity, and functional outcomes of TaTME to guide future clinical practice.

Materials and Methods

Study design and reporting standards

This systematic review and meta-analysis compared transanal total mesorectal excision (TaTME) with laparoscopic total mesorectal excision (LaTME) for middle and low rectal cancer. The study was conducted in accordance with the PRISMA 2020 guidelines (21). The protocol predefined eligibility criteria, outcomes, and statistical methods prior to study selection. The protocol was registered on PROSPERO ID: CRD420261385336

Literature search strategy

A systematic search was performed using three databases: MEDLINE (PubMed), Embase, and Cochrane Library (CENTRAL) from inception to May 2026. Search terms combined MeSH and free-text keywords related to TaTME, LaTME, rectal cancer, and randomized trials. No restrictions on publication year were applied, and language restrictions were not enforced where feasible. Reference lists of included studies and relevant reviews were manually screened to identify additional eligible trials. Full search strategies are provided in Table S1.

Eligibility criteria and study selection

We included studies in our meta-analysis based on the following criteria: 1) Population: Adults (≥ 18 years) with histologically confirmed rectal adenocarcinoma of the middle or low rectum, generally defined as tumors within 10–12 cm of the anal verge or as specified by the original trials. Studies including patients receiving neoadjuvant therapy for locally advanced disease were eligible. 2) Intervention: Trans-anal total mesorectal excision (TaTME). 3) Control/comparator: Laparoscopic total mesorectal excision (LaTME). 4) Primary outcomes: circumferential resection margin (CRM) positivity, R0 resection rate, and completeness of mesorectal excision. 5) Study Design: Only randomized controlled trials (RCTs) were included in our meta-analysis.

Non-randomized designs, observational studies, case series, conference abstracts without full data, duplicate reports, and studies lacking extractable outcomes were excluded. In duplicate publications, the most complete dataset with the longest follow-up was used.

Data extraction:

All records were imported into EndNote version 21 (Clarivate Analytics), and duplicates were removed. Two reviewers independently screened titles, abstracts, and full texts. Disagreements were resolved by consensus or adjudication by a third reviewer.

Data were independently extracted using a standardized and piloted form, including study characteristics, patient demographics, tumor location, neoadjuvant therapy, operative details, pathological findings, perioperative outcomes, and long-term oncologic outcomes. Primary outcomes were circumferential resection margin (CRM) positivity, R0 resection rate, and completeness of

mesorectal excision (complete, near-complete, incomplete). Secondary outcomes included conversion to open surgery, postoperative complications, anastomotic leakage, operative time, blood loss, hospital stay, reoperation, and overall morbidity. Long-term outcomes included local recurrence, overall survival, and disease-free survival at 3 years where available.

Quality assessment:

Risk of bias was assessed independently using the Cochrane Risk of Bias 2 (RoB 2) tool (22). Included randomized controlled trials were assessed across domains of randomization, intervention adherence, missing data, outcome measurement, and selective reporting. Two authors (EA and SK) did the assessment independently and any discrepancy was resolved through involvement of third author (MO).

The overall certainty for each variable was further assessed GRADE assessment was also used for assessing overall strength of evidence.

Statistical analysis

All analyses were performed using RStudio (R version 4.3.3) with the meta, metafor, and dmetar packages. Dichotomous outcomes were pooled using risk ratios (RRs), and continuous outcomes using mean differences (MDs), both with 95% confidence intervals (CIs). Inverse variance and Mantel–Haenszel methods were applied as appropriate. Random-effects models were used for all analyses. Heterogeneity was assessed using the Cochran Q test and I^2 statistic, with I^2 thresholds of 25%, 50%, and 75% indicating low, moderate, and high heterogeneity. Between-study variance (τ^2) was estimated using Restricted Maximum Likelihood (REML), with uncertainty assessed via the Q-profile method. Influence analyses (leave-one-out) and Baujat plots were used in cases of substantial heterogeneity. Publication bias was not assessed using Egger's test due to limited study numbers; instead, Doi plots and the Luis Furuya-Kanamori (LFK) index were used, where values between − 1 and + 1 indicated no major asymmetry (23). Trial sequential analysis (TSA) was performed using Copenhagen Trial Unit software to assess robustness of primary outcomes, assuming a two-sided α of 5% and 80% power. Results were interpreted against conventional and sequential monitoring boundaries. A P value < 0.05 was considered statistically significant.

RESULTS

Screening results:

The initial search resulted in 14,349 records. From this number, 5345 were duplicates. The remaining 9,004 were screened by title and abstract. This filtered out 8665. The remaining 339 were screened in full text, resulting in 4 studies. The comprehensive workflow of the screening and selection process is detailed in Fig. 1.

Baseline characteristics:

Across the four included RCTs, a total of 2,355 patients were analyzed, including 1,360 patients in the TaTME group and 995 patients in the LaTME group. Overall, approximately 66.0% of the pooled population were male. The weighted average age across all study arms was approximately 61.1 years, indicating that most patients were in the sixth decade of life. Additional baseline characteristics are summarized in Table 1a and 1b.

Table 1
a: Study characteristics.

Study Design	Aracil et al. 2022	Denost et al. 2017	Tuynman et al. 2026	Zeng et al. 2025
	RCT	RCT	RCT	RCT
Country	Spain	France	International, multicentre trial	China
Year of Study	April 2015 - May 2021	June 2008 - February 2012	January 2017 - January 2024	April 2016 - June 2021
Blinding Status	open-label randomized controlled trial	Prospective randomized controlled trial, patient-blinded randomization	Randomised, open-label trial, no blinding of patients, surgeons, or outcome assessors	Randomized, open-label trial
Total Population	105 (TaTME:55, LaTME:50)	100 (TaTME:50, LaTME:50)	1061 (TaTME:711, LaTME:350)	1115 (TaTME:558, LaTME:557)
Intervention details	TaTME	TaTME	TaTME	TaTME
Control details	LaTME	LaTME	LaTME	LaTME
Main Inclusion Criteria	age > 18 yrs, rectal adenocarcinoma (cT1-3, N0-1, M0), Tumour ≤ 10 cm from the anal margin, suitable for TME with colorectal anastomosis, ASA fitness grade I–III	Low rectal cancer ≤ 6 cm from the anal verge, suitable for sphincter-preserving surgery	age ≥ 18 yearsc, histologically confirmed rectal adenocarcinoma, clinical stage (y)cT1–3, N0–2, M0, Tumor located ≤ 10 cm from the anal verge, eligible for curative TME with restorative intent	age 18–75 years, ASA physical status I–III, Clinical stage I–III rectal adenocarcinoma, tumor located below the peritoneal reflection (mid-low rectum), eligible for sphincter-preserving TME
Primary Outcome	Conversion to open surgery	Local recurrence, overall survival (OS), disease-free survival (DFS)	3-year local recurrence rate	3-year disease-free survival
Follow-up duration	39 months	60.2 months	5 years	36 months

Table 1
b: Baseline characteristics of patients.

	Aracil et al. 2022	Denost et al. 2017	Tuynman et al. 2026	Zeng et al. 2025
Number of patients in each group				
TaTME	55	50	711	544
LaTME	50	50	350	545
Age (Years), Mean (SD)				
TaTME	66(14.1)	61.7(31.9)	62.7 (11.1)	58.3 (12.3)
LaTME	68(14.1)	61.3(43.7)	63 (12.2)	59.7 (11.6)
Male, N (%)				
TaTME	42(76.4)	37(74)	478 (67)	359(66.0)
LaTME	34(68)	32(64)	239 (68)	333(61.1)
BMI, Mean (SD)				
TaTME	26.7(3.6)	25.2(11.8)	24.5 (3.3)	22.8 (3.1)
LaTME	26.7(4.4)	27.4(14.8)	24.4 (3.7)	22.8 (2.9)
Prior Abdominal Surgery, N (%)				
TaTME	NR	NR	130 (19)	NR
LaTME	NR	NR	74 (22)	NR
Distance from anal verge (cm), Mean (SD)				
TaTME	8(2.2)	4(3)	6.3 (2)	5 (1.6)
LaTME	9(2.2)	4(3)	6.3 (2.4)	5.5 (1.6)
Distance to ARJ (cm), Mean (SD)				
TaTME	NR	0.67(3.7)	3.4 (2)	NR
LaTME	NR	0.5(3)	3.5 (2.2)	NR
Length of Tumor (cm), Mean (SD)				
TaTME	NR	4.8(4.8)	2.9 (1.1)	NR
LaTME	NR	4.3(5.2)	2.8 (1.2)	NR
Neoadjuvant (chemo)radiotherapy, N (%)				
TaTME	38(69.1)	40(80)	366 (53)	211(38.8)

	Aracil et al. 2022	Denost et al. 2017	Tuynman et al. 2026	Zeng et al. 2025
Number of patients in each group				
LaTME	33(66)	44(88)	165 (49)	179(32.8)
Number of Harvested Lymph nodes, Mean (SD)				
TaTME	15(5.9)	16.3(20.7)	NR	14.3 (6.6)
LaTME	17(7.4)	22(23)	NR	15.3 (6.7)
ASA Classification				
I, N(%)				
TaTME	2(3.6)	NR	226 (32)	228(41.9)
LaTME	3(6.1)	NR	100 (29)	219(40.2)
II, N(%)				
TaTME	31(56.4)	NR	397 (57)	279(51.3)
LaTME	30(60)	NR	201 (58)	270(49.5)
III, N(%)				
TaTME	22(40)	NR	43 (13)	37(6.8)
LaTME	17(34.7)	NR	43 (13)	56(10.3)
Pre Operative Tumor stage				
T1, N(%)				
TaTME	2(1.9)	NR	80 (11)	105(19.3)
LaTME	1(0.9)	NR	44 (13)	89(16.3)
T2, N(%)				
TaTME	10(9.5)	NR	292 (41)	220(40.4)
LaTME	8(7.6)	NR	152 (44)	220(40.4)
T3, N(%)				
TaTME	43 (40.9)	NR	268 (38)	219(40.3)
LaTME	41 (39.0)	NR	122 (35)	213(39.1)
Pre Operative Nodal stage				
N0, N(%)				

	Aracil et al. 2022	Denost et al. 2017	Tuynman et al. 2026	Zeng et al. 2025
Number of patients in each group				
TaTME	26(47.3)	20(40)	610 (86)	NR
LaTME	25(49)	17(34)	291 (84)	NR
N1, N(%)				
TaTME	22(40)	NR	92 (13)	NR
LaTME	17(34.7)	NR	92 (13)	NR
N2, N(%)				
TaTME	7(12.7)	NR	4 (1)	NR
LaTME	8(16.3)	NR	5 (1)	NR

Quality Assessment:

Risk of bias assessment showed that most included studies had an overall low risk of bias across the evaluated domains. Denost et al. 2017, Aracil et al. 2022, and Zeng et al. 2025 were judged as low risk overall. Tuynman et al. 2026 had some concerns, mainly due to bias in outcome measurement, while other domains were low risk. Figure showing the quality assessment summary is presented in (Figure S1).

GRADE assessment showed overall moderate certainty of evidence (Table 2).

Table 2
GRADE Summary of findings:

Patient or population: Mid and Low Rectal Cancer

Intervention: TaTME

Comparison: LaTME/LapTME

Outcomes	**Anticipated absolute effects*** (95% CI)		Relative effect (95% CI)	№ of participants (studies)	Certainty of the evidence (GRADE)
	Risk with LaTME/LapTME	**Risk with TaTME**			
CRM positivity rate	16 per 1,000	**12 per 1,000** (4 to 37)	**RR 0.71** (0.22 to 2.30)	2336 (4 RCTs)	⨁⨁⨁◯ Moderate[a]
Conversion to open surgery	142 per 1,000	**10 per 1,000** (4 to 20)	**RR 0.07** (0.03 to 0.14)	1266 (3 RCTs)	⨁⨁⨁◯ Moderate[b]
Overall postoperative complications	222 per 1,000	**222 per 1,000** (171 to 287)	**RR 1.00** (0.77 to 1.29)	1266 (3 RCTs)	⨁⨁⨁◯ Moderate[a]
Completeness of mesorectal excision –	839 per 1,000	**873 per 1,000** (822 to 923)	**RR 1.04** (0.98 to 1.10)	2355 (4 RCTs)	⨁⨁⨁◯ Moderate[a]
R0 resection rate	914 per 1,000	**941 per 1,000** (895 to 996)	**RR 1.03** (0.98 to 1.09)	2355 (4 RCTs)	⨁⨁◯◯ Low[a,b]
Anastomotic leakage	90 per 1,000	**91 per 1,000** (62 to 133)	**RR 1.01** (0.69 to 1.48)	1227 (3 RCTs)	⨁⨁⨁◯ Moderate[a]
Reoperation rate	82 per 1,000	**97 per 1,000** (67 to 141)	**RR 1.18** (0.81 to 1.72)	1266 (3 RCTs)	⨁⨁⨁◯ Moderate[a]

Patient or population: Mid and Low Rectal Cancer **Intervention: TaTME** **Comparison: LaTME/LapTME**					
Overall morbidity	182 per 1,000	**191 per 1,000** (149 to 244)	**RR 1.05** (0.82 to 1.34)	1266 (3 RCTs)	⨁⨁⨁◯ Moderate[a]
***The risk in the intervention group** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI). **CI**: confidence interval; **MD**: mean difference; **RR**: risk ratio					
Explanations a. Wide Confidence interval crossing null effect. b. High heterogenity (i2 > 50%)					

Outcomes:

Primary outcomes:

1: Circumferential resection margin (CRM) positivity:

Four studies (n = 2,396) TaTME = 1310, LaTME = 938) reported CRM positivity rate. No significant difference was found between TaTME and LaTME (RR = 0.70, 95% CI: 0.22–2.25; Z = − 0.60, P = 0.5509), with moderate heterogeneity (I^2 = 38.5%, Chi^2 = 4.88, P = 0.1812) (Fig. 2**).**

When each study was removed one at a time, the overall result did not change, confirming the stability of the findings. However, removing Denost et al. (2022) brought heterogeneity down to 0%, suggesting it was the main source of variability between studies **(Figure S2a)**. The Baujat plot agreed with this, showing Denost et al. had the highest contribution to both heterogeneity and the overall result **(Figure S2b).** The DOI plot showed no publication bias (LFK index = − 0.36), well within the acceptable range of ± 1. **(Figure S2c)**

TSA Interpretation:

The cumulative Z-curve crossed the conventional upper significance boundary (+ 2) following the addition of Denost et al. (2017), suggesting an early signal of higher CRM positivity in the TaTME group. However, this signal was not sustained, as the Z-curve progressively declined with the addition of subsequent studies, ultimately returning within the significance boundaries. The Required Information Size of 20,484 patients was not reached, with current evidence representing only a small fraction of what is needed. This early boundary crossing followed by regression highlights the risk of drawing premature

conclusions, and larger well-designed trials are needed before firm conclusions can be drawn regarding CRM positivity rates. **(Figure S2d), (Table S2).**

2: R0 resection rate:

Four studies (n = 2,248, (TaTME = 1310, LaTME = 938)) reported R0 resection rate. No significant difference was found between TaTME and LaTME (RR = 1.02, 95% CI: 0.92–1.12; Z = 0.30, P = 0.7646). Substantial heterogeneity was observed across studies (I^2 = 93%, Chi^2 = 42.79, P < 0.0001). **(Fig. 3)**

Leave-one-out sensitivity analysis confirmed the robustness of the pooled estimate, as omission of any single study did not alter the direction or significance of findings. However, omission of Tuynman et al. (2026) notably reduced heterogeneity to 59.6%, suggesting it was a key contributor to between-study variability **(Figure S3a)**. The **Baujat plot** further identified Denost et al. (2017) as the study with the greatest influence on the overall result and the highest contribution to heterogeneity **(Figure S3b)**. The **DOI plot** demonstrated no significant publication bias, with an LFK index of − 0.2, well within the acceptable range of ± 1. **(Figure S3c)**

TSA Interpretation:

The cumulative Z-curve crossed the conventional lower significance boundary (− 2) following the addition of Aracil et al. (2022), suggesting a transient signal favouring LaTME for R0 resection. However, the curve subsequently returned within the boundaries with later studies, indicating this early signal was not sustained. The Required Information Size was not reached — with current evidence representing only 3.1% of the required sample — confirming that available evidence remains insufficient to draw firm conclusions regarding R0 resection rates between TaTME and LaTME. **Figure S3d**

3: Completeness of mesorectal excision:

Four studies (Aracil et al. 2022, Denost et al. 2017, Tuynman et al. 2026, Zeng et al. 2025; n = 2,355) reported completeness of mesorectal excision. No significant difference was found between TaTME and LaTME (RR = 1.05, 95% CI: 0.98–1.12; Z = 1.34, P = 0.1811), with moderate heterogeneity (I^2 = 51.6%, Chi^2 = 6.20, P = 0.1021) **(**Fig. 4**).**

When each study was removed one at a time, the overall result remained non-significant across all iterations, confirming stability of the findings. Omission of Aracil et al. (2022) and Tuynman et al. (2026) reduced heterogeneity to 20.6% and 22.9% respectively, suggesting these two studies were the main contributors to between-study variability **(Figure S4a)**. The Baujat plot confirmed this, placing Aracil et al. in the upper-right quadrant, indicating the highest influence on both the overall result and heterogeneity **(Figure S4b)**. The DOI plot showed no significant publication bias (LFK index = 0.92), just within the acceptable range of ± 1 (**Figure S4c)**

TSA Interpretations:

The cumulative Z-curve briefly crossed the conventional lower significance boundary (− 2) following the addition of Aracil et al. (2022), suggesting a transient signal favouring TaTME. However, the curve subsequently returned within the boundaries with the addition of subsequent studies. Furthermore, the Required Information Size was not reached (only 3.58% of required sample), indicating that the current evidence remains insufficient and underpowered to draw firm conclusions regarding completeness of mesorectal excision between TaTME and LaTME. (**Figure S4d).**

Secondary outcomes:

1: Anastomotic leakage:

Three studies (n = 1,227, (TaTME = 794, LaTME = 433)) reported anastomotic leakage. No significant difference was found between TaTME and LaTME (RR = 0.72, 95% CI: 0.29–1.80; Z = − 0.70, P = 0.4848), with moderate heterogeneity (I^2 = 52.7%, Chi^2 = 4.23, P = 0.1209). (**Figure S5a).**

When each study was removed one at a time, the overall result did not change, confirming stability of findings. However, omission of Tuynman et al. 2026 reduced heterogeneity to 0.0%, suggesting it was the main contributor to between-study variability (**Figure S5b)**

. The Baujat plot confirmed this, placing Tuynman et al. 2026 in the upper-left quadrant with the highest influence on the overall result (**Figure S5c)**. The DOI plot showed no publication bias (LFK index = − 0.44), within the acceptable range of ± 1. (**Figure S5d)**

2: Conversion to open surgery:

Three studies (n = 1,240) (TaTME = 801, LaTME = 439) reported conversion to open surgery. A significant difference was found in favor of TaTME over LaTME (RR = 0.14, 95% CI: 0.03–0.74; Z = − 2.31, P = 0.0208), with substantial heterogeneity (I^2 = 74.7%, Chi^2 = 7.91, P = 0.0192). (**Figure S6a)**

When each study was removed one at a time, omission of Tuynman et al. 2026 rendered the result non-significant (P = 0.1266) and reduced heterogeneity to 0.0%, identifying it as the primary driver of both the overall effect and between-study variability. Omission of the remaining studies did not alter the direction of the overall result (**Figure S6b)**. The Baujat plot confirmed this, placing Tuynman et al. 2026 in the upper-right quadrant, reflecting its dominant influence on both heterogeneity and the pooled estimate (**Figure S6c)**. The DOI plot showed no publication bias (LFK index = − 0.89), within the acceptable range of ± 1. (**Figure S6d)**

3: Hospital Stay:

Three studies (n = 1,266) (TaTME = 816, LaTME = 450) reported hospital stay. No significant difference was found between TaTME and LaTME (MD = 1.69, 95% CI: −1.90–5.28; Z = 0.92, P = 0.3568), with substantial heterogeneity (I^2 = 75.4%, Chi^2 = 8.12, P = 0.0173). (**Figure S7a)**

When each study was removed one at a time, the overall result did not change in terms of significance, confirming stability of findings. Omission of Denost et al. 2017 reduced heterogeneity most notably to 51.2%, suggesting it was the primary contributor to between-study variability (**Figure S7b)**. The Baujat plot confirmed this, placing Denost et al. 2017 in the upper-right quadrant, reflecting its dominant influence on both the overall result and heterogeneity (**Figure S7c)**. The DOI plot showed no publication bias (LFK index = 0.84), within the acceptable range of ± 1. (**Figure S7d)**

4: Overall Morbidity:

Three studies (n = 1,266), (TaTME = 816, LaTME = 450) reported overall morbidity. No significant difference was found between TaTME and LaTME (RR = 0.94, 95% CI: 0.61–1.46; Z = − 0.26, P = 0.7931), with low heterogeneity (I^2 = 32.7%, Chi^2 = 2.97, P = 0.2261). (**Figure S8a).**

When each study was removed one at a time, the overall result did not change, confirming stability of findings. However, omission of either Denost et al. 2017 or Tuynman et al. 2026 reduced heterogeneity to 0.0%, suggesting that both studies jointly contributed to between-study variability (**Figure S8b)**. The Baujat plot confirmed this, placing Denost et al. 2017 in the upper-right quadrant with the highest combined influence on the overall result and heterogeneity (**Figure S8c)**. The DOI plot showed no publication bias (LFK index = − 0.28), within the acceptable range of ± 1 (**Figure S8d).**

5: Post-operative complications:

Three studies (n = 1,229), (TaTME = 794, LaTME = 435) reported postoperative complications. No significant difference was found between TaTME and LaTME (RR = 0.99, 95% CI: 0.76–1.28; Z = − 0.07, P = 0.9464), with low heterogeneity (I^2 = 14.7%, Chi^2 = 2.34, P = 0.3098). (**Figure S9a).**

When each study was removed one at a time, the overall result did not change, confirming stability of findings. However, omission of either Denost et al. 2017 or Tuynman et al. 2026 reduced heterogeneity to 0.0%, suggesting both studies jointly contributed to between-study variability (**Figure S9b).** The Baujat plot confirmed this, placing Denost et al. 2017 in the right portion of the plot with the greatest contribution to heterogeneity, while Tuynman et al. 2026 showed higher influence on the overall result (**Figure S9c)**. The DOI plot showed no publication bias (LFK index = − 0.15), within the acceptable range of ± 1 (**Figure S9d).**

6: Reoperation rate:

Three studies (Aracil et al. 2022, Denost et al. 2017, Tuynman et al. 2026; n = 1,266) reported reoperation rate. No significant difference was found between TaTME and LaTME (RR = 1.04, 95% CI: 0.53–2.04; Z = 0.11, P = 0.9107), with low heterogeneity (I^2 = 0.0%, Chi^2 = 1.84, P = 0.3980). (**Figure S10a)**

When each study was removed one at a time, the overall result did not change, confirming stability of findings. Omission of Aracil et al. 2022 marginally increased heterogeneity to 16.0%, while omission of either Denost et al. 2017 or Tuynman et al. 2026 maintained heterogeneity at 0.0%, indicating that Aracil

et al. 2022 introduced minor divergence relative to the other two studies (**Figure S10b)**. The Baujat plot confirmed this, placing Tuynman et al. 2026 in the upper-left quadrant with the highest influence on the overall result, while Denost et al. 2017 contributed more to heterogeneity (**Figure S10c)**. The DOI plot showed no publication bias (LFK index = − 0.04), within the acceptable range of ± 1. (**Figure S10d)**

7: 3-Year Local Recurrence

Two studies (Aracil et al. 2022, Zeng et al. 2025; n = 1,194) reported 3-year local recurrence. No significant difference was found between TaTME and LaTME (RR = 0.77, 95% CI: 0.44–1.38), with no heterogeneity (I^2 = 0.0%, Chi^2 = 0.73, P = 0.3937). (**Figure S11a)**

Given that only two studies were included, leave-one-out sensitivity analysis, Baujat plot, and DOI plot were not applicable for this outcome.

8: 3-Year Overall Survival

Two studies (Aracil et al. 2022, Zeng et al. 2025; n = 1,194) reported 3-year overall survival. No significant difference was found between TaTME and LaTME (RR = 0.76, 95% CI: 0.53–1.09), with no heterogeneity (I^2 = 0.0%, Chi^2 = 0.45, P = 0.5030). (**Figure S11b)**

Given that only two studies were included, leave-one-out sensitivity analysis, Baujat plot, and DOI plot were not applicable for this outcome.

9: 3-Year Disease-Free Survival

Two studies (Aracil et al. 2022, Zeng et al. 2025; n = 1,194) reported 3-year disease-free survival. No significant difference was found between TaTME and LaTME (RR = 0.90, 95% CI: 0.69–1.16), with no heterogeneity (I^2 = 0.0%, Chi^2 = 0.00, P = 0.9817). (**Figure S11c)**

Given that only two studies were included, leave-one-out sensitivity analysis, Baujat plot, and DOI plot were not applicable for this outcome.

Discussion

This meta-analysis was conducted to synthesize the best available evidence by pooling data only from randomized controlled trials (RCTs) to evaluate the transanal total mesorectal excision (TaTME) vs laparoscopic total mesorectal excision (LaTME) for middle and low rectal cancer. Our results showed that there were no statistically significant differences between TaTME and LaTME in the main oncological and perioperative and long-term oncological endpoints. Conversion to open surgery was an exception, initially favoring TaTME, but losing significance on sensitivity analysis suggesting low robustness. Trial sequential analysis (TSA) further showed that the current evidence base was still weak for majority of the outcomes, with required information sizes far from being reached. In summary, earlier meta-analyses incorporating retrospective cohorts frequently favored TaTME across several

perioperative and pathological outcomes. However, when evidence is restricted to randomized trials, many of these apparent advantages disappear. This highlights the susceptibility of surgical innovation literature to selection bias, center expertise effects, and learning-curve phenomena.

Surgery for rectal cancer has advanced significantly over the past decades, with complete mesorectal excision (TME) being the gold standard for oncological resection. However, optimal dissection in the confined pelvis, especially in obese patients or those with large low tumors, remains technically difficult with standard laparoscopic approaches (24–26). TaTME was initially described as a revolutionary “bottom-up” approach to enhance vision and allow for accurate distal dissection, which in theory would result in improved oncological margins and functional outcomes (27,28). This early enthusiasm for TaTME was reinforced by observational studies demonstrating enhanced CRM negativity and reduced conversion rates. Nevertheless, issues regarding oncologic safety, particularly reports of unexpected patterns of local recurrence, have raised concerns and the need for high-quality randomized evidence (29, 30).

Our primary outcome study found no statistically significant difference in CRM positive between TaTME and LaTME, with sensitivity analyses demonstrating similar results and no evidence of publication bias. Interestingly, TSA showed an early signal in favor of LaTME (more CRM positive in TaTME) following the inclusion of earlier research such as Denost et al. but this signal disappeared with the inclusion of later trials. This pattern underscores the danger of early overestimation of treatment outcomes, a common problem in the surgical innovation literature (31, 32). In contrast, the updated meta-analysis by Zhang et al. (2024) including both observational data and RCTs, showed a trend for improved CRM outcomes with TaTME (33). This discrepancy highlights the selection bias previously noted, where high-volume centers preferentially adopting newer methods skew observational data toward TaTME. We limited our analysis to RCTs, which gives a more cautious and internally reliable estimate and indicates equivalence rather than superiority.

Mirroring the CRM trends, the apparent R0 advantages observed in prior non-randomized data disappear under controlled conditions, further demonstrating how procedural learning curves distort early surgical literature. TSA confirmed that the R0 data remains underpowered, having achieved only a fraction of the required information size. (34–36).

Completeness of mesorectal excision (which is a key driver of oncological outcomes) variable was also comparable across the two arms. Transient indications favoring TaTME were seen in TSA, but they were not persistent and heterogeneity was mostly related to individual investigations such as Aracil et al. (2022) (37). Consistent with our R0 and CRM findings, this equivalence in specimen quality undercuts previous observational claims, which were likely confounded by selective case-matching. Under controlled randomized conditions, we found that both approaches resulted in similar surgical quality (32, 38).

Regarding safety analysis of anastomotic leakage between the groups the diamond was on the line of null effect showing comparative evidence. Some studies predicted that enhanced distal vision with

TaTME might lead to less leakage, however this benefit was not observed in randomized data. Conversion to open surgery was initially much lower for TaTME, in line with its putative advantage in complex pelvic dissections (39, 40). However, this conclusion was mostly driven by one study (Tuynman et al. 2026) and the loss of significance when this study was removed suggests that the evidence is not robust (41). This is in contrast to Zhang et al. (2024) who showed a more consistent decline in conversion rates with TaTME, perhaps affected by observational data (33).

Other perioperative outcomes including hospital stay, total morbidity, surgical complications, and reoperation rates were also comparable with low to moderate heterogeneity and stable sensitivity analysis. The results support the idea that the two approaches are comparable in terms of short-term safety. Importantly, our investigation of long-term oncological outcomes, 3-year local recurrence, overall survival and disease-free survival likewise showed no significant differences, with no heterogeneity observed (42–44). While these long-term oncological safety signals are reassuring, achieving definitive conclusions will require the maturity of ongoing, larger-scale multi-center trials.

Strength and limitations

The main strength of this study is its inclusion only of RCTs, which reduced bias and increased confidence in the results. In contrast to previous meta-analyses that integrated observational and randomized data, our strategy minimizes heterogeneity due to confounding factors such as surgeon experience, institutional volume, and patient selection. Moreover, the analysis of TSA is a major methodological strength as it allows evaluating the sufficiency and robustness of the cumulative evidence, which is often not addressed in earlier analyses. However, there are a few limits to be mentioned. First, the total number of included RCTs and sample size is still limited and the requisite information size has not been attained for majority of the outcomes as indicated by TSA. Second, there was considerable heterogeneity for some outcomes, which was partly due to individual studies and reflected variety in surgical technique, learning curves, and perioperative regimens. Third, surgeon expertise and center volume, which are major drivers of TaTME outcomes, are difficult to standardize across trials. Fourth, only a fraction of studies reported on long-term oncologic outcomes, reducing the strength of conclusions about survival and recurrence. Finally, given that TaTME is a relatively new approach, data with longer follow-up are still being developed.

Future recommendations and implications

Future research should target large, multi-center RCTs with standardized surgical protocols and adequate follow-up to evaluate long-term oncological safety. The learning curve of TaTME and the impact of structured training programs on outcomes warrant special attention. Finally, patient-centered outcomes, such as functional results and quality of life, would need to be systematically evaluated, as these may ultimately differentiate the two approaches. Furthermore, the use of real-world registry data with robust methodological adjustments may serve as a complement to randomized evidence and broaden the knowledge of clinical practice.

Conclusion

In summary, this meta-analysis of RCTs showed that TaTME and LaTME provide similar oncological and perioperative outcomes for middle and low rectal cancer with no clear superiority of one over the other. TaTME was associated with added benefits of reduced conversion to open surgery and also the procedure is anatomically favorable compared to LaTME. While previous observational studies have suggested potential benefits of TaTME across more variables compared to our meta-analysis, these were not supported when analysis was limited to randomized controlled trials and excluding observational studies. However, the choice of surgical approach should be based on surgeon experience, institutional expertise and patient-specific factors, rather than assumed superiority of one technique over another.

Declarations

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Ethics Statement

Ethical approval was not required as this study is a systematic review and meta-analysis based solely on previously published data.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Figures

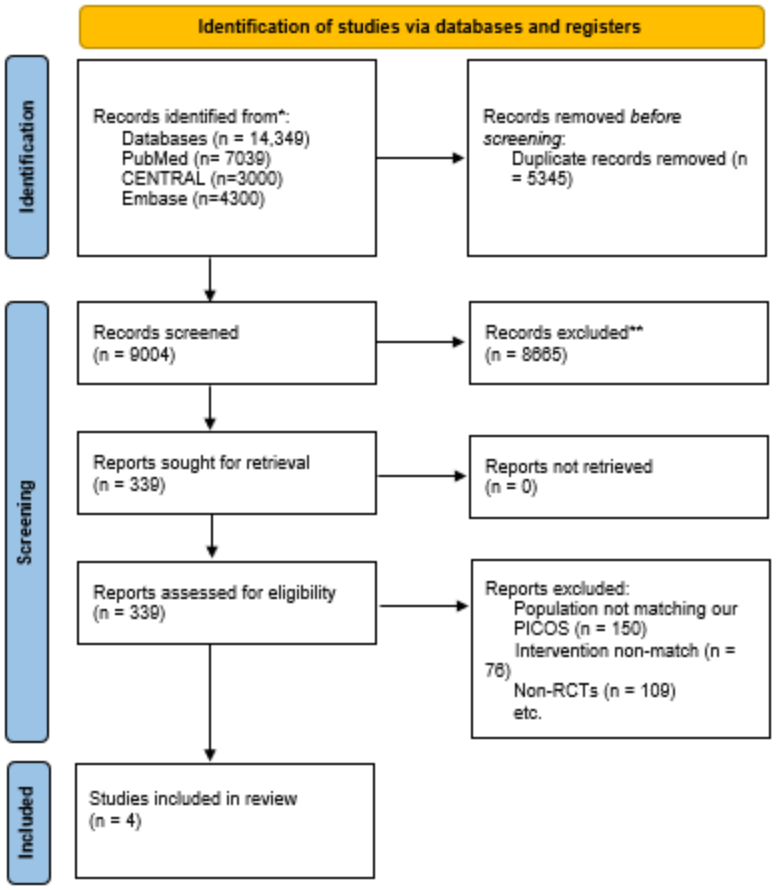


Figure 1

PRISMA flow chart.

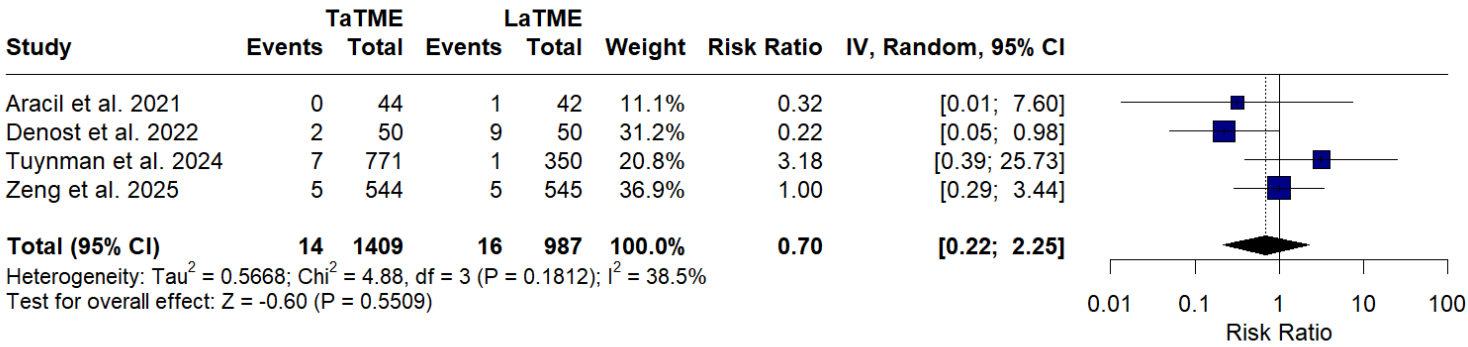


Figure 2

Forest plot of Circumferential resection margin (CRM) positivity.

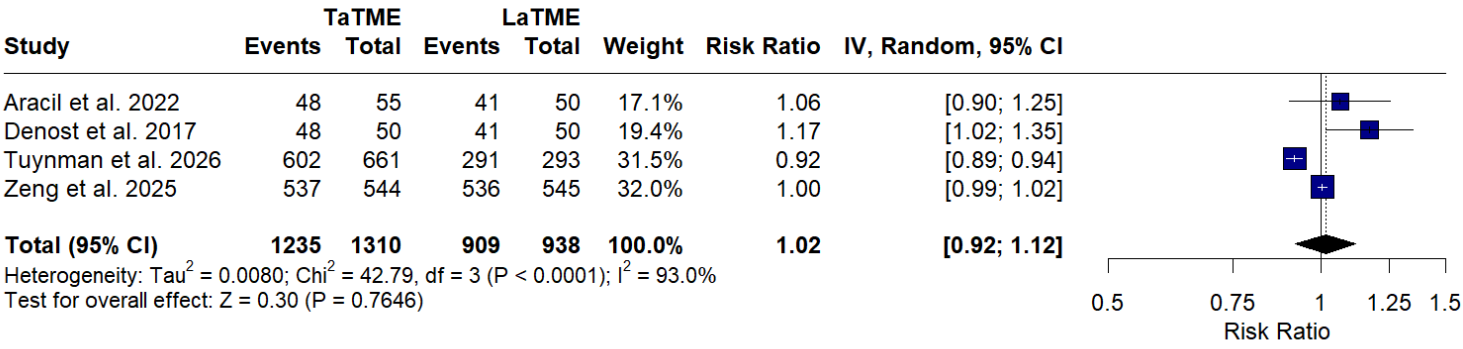


Figure 3

Forest plot of R0 resection rate.

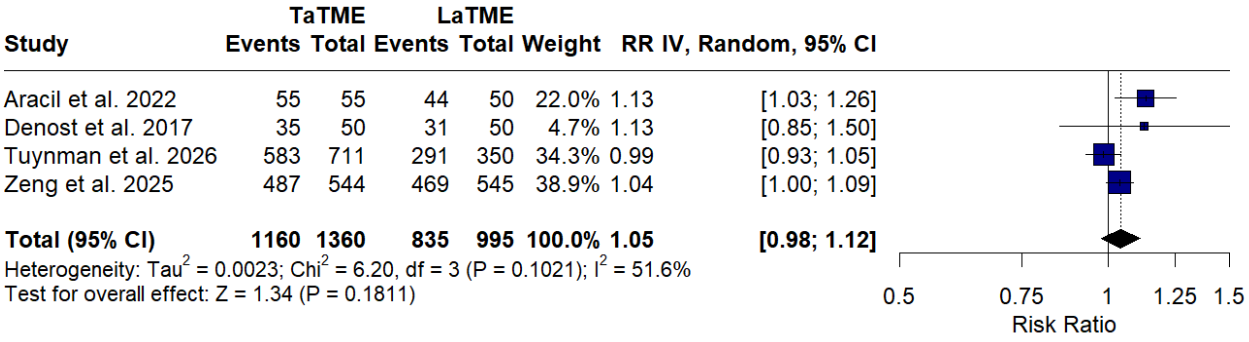


Figure 4

Forest plot of completeness of mesorectal excision.

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