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LITERATURE REVIEW

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Outcomes of endoscopic discectomy compared with open microdiscectomy and tubular microdiscectomy for lumbar disc herniations: a meta-analysis

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OBJECTIVE Endoscopic discectomy (ED) has been advocated as a less-invasive alternative to open microdiscectomy (OM) and tubular microdiscectomy (TM) for lumbar disc herniations, with the potential to decrease postoperative pain and shorten recovery times. Large-scale, objective comparisons of outcomes between ED, OM, and TM, however, are lacking. The authors' objective in this study was to conduct a meta-analysis comparing outcomes of ED, OM, and TM.

METHODS The PubMed database was searched for articles published as of February 1, 2019, for comparative studies reporting outcomes of some combination of ED, OM, and TM. A meta-analysis of outcome parameters was performed assuming random effects.

RESULTS Twenty-six studies describing the outcomes of 2577 patients were included. Estimated blood loss was significantly higher with OM than with both TM ($p = 0.01$) and ED ($p < 0.00001$). Length of stay was significantly longer with OM than with ED ($p < 0.00001$). Return to work time was significantly longer in OM than with ED ($p = 0.001$). Postoperative leg ($p = 0.02$) and back ($p = 0.01$) VAS scores, and Oswestry Disability Index scores ($p = 0.006$) at latest follow-up were significantly higher for OM than for ED. Serum creatine phosphokinase ($p = 0.02$) and C-reactive protein ($p < 0.00001$) levels on postoperative day 1 were significantly higher with OM than with ED.

CONCLUSIONS Outcomes of TM and OM for lumbar disc herniations are largely equivalent. While this analysis demonstrated that several clinical variables were significantly improved in patients undergoing ED when compared with OM, the magnitude of many of these differences was small and of uncertain clinical relevance, and several of the included studies were retrospective and subject to a high risk of bias. Further high-quality prospective studies are needed before definitive conclusions can be drawn regarding the comparative efficacy of the various surgical treatments for lumbar disc herniations.

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KEYWORDS herniated disc; microdiscectomy; minimally invasive; endoscopy; spine surgery; lumbar

With an estimated lifetime incidence of 13%–40%,[51] lumbar radiculopathy is a source of considerable morbidity and socioeconomic burden.[33] For patients who do not respond to conservative therapies for radicular pain, open microdiscectomy remains the standard surgical intervention. Efforts to shorten recovery times and reduce postoperative disability, however, have galvanized interest in minimally invasive surgical interventions for lumbar disc herniations.[5,13,52]

Endoscopic discectomy (ED) is a minimally invasive surgical technique for removing herniated disc material using an endoscope with one or more working channels,[16,53] potentially minimizing approach-related tissue trauma while still achieving the end goals of the operation. Early results from several case series appear promising,[17,23–25,31,36] but whether the minimally invasive nature of the ED approach translates into improvements in outcomes such as postoperative pain and recovery time when compared with traditional open microdiscectomy (OM) and other minimally invasive techniques (e.g., tubular microdiscectomy

ABBREVIATIONS CPK = creatine phosphokinase; CRP = C-reactive protein; ED = endoscopic microdiscectomy; ODI = Oswestry Disability Index; OM = open microdiscectomy; TM = tubular microdiscectomy; VAS = visual analog scale.

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[TM]) remains to be seen. Several comparative studies have not detected any significant difference between outcomes of ED and OM,[21,29,41,55] although these studies have been relatively small and underpowered.

The objective of this study was to perform a systematic review of the literature, evaluating the outcomes of ED in comparison to OM and TM in an effort to better understand the benefits of this technique and its role in the treatment of lumbar radiculopathy.

Methods

Study Selection

A systematic review and meta-analysis of the available literature was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)[40] and Grading of Recommendations, Assessment, Development and Education (GRADE) guidelines. The PubMed database was searched for articles published as of February 1, 2019, for comparative studies reporting outcomes of some combination of ED, TM, and traditional OM [search strategy: "(((Discectomy OR Microdiscectomy)) AND Lumbar) AND (Tubular OR tube OR endoscop*)"]. The search was not limited by date of publication. Reference lists were screened for additional articles relevant to the analysis.

Inclusion Criteria

All studies undergoing full-text screening were included if the following criteria were met. 1) The study was peer-reviewed, original, and written in the English language. 2) The study compared the outcomes of two or more of the following interventions for lumbar disc herniations in separate treatment arms: ED ("microendoscopic discectomy" and "endoscope-assisted discectomy" were excluded), TM or traditional OM. 3) Each treatment arm contained a minimum of 10 patients. 4) The outcomes described in the study must have included one of the following: operative time, estimated blood loss, hospital length of stay, procedure-related complications, postoperative pain assessment, or postoperative disability assessment. Only the most recent study was included when outcomes from a cohort of patients were reported in multiple series.

Data Extraction and Terminology

All included studies were evaluated for year of publication, sample size, and study design. Population characteristics extracted included mean age (years), number of females and males, level of disc herniation (e.g., L4–5, L5–S1), and location of the disc herniation with respect to the canal/foramen. Procedural details extracted included operative time, estimated blood loss, and whether the transforaminal or interlaminar approach was used for endoscopic cases. Outcomes extracted included mean hospital stay (days), mean return to work time (days), occurrence of complications, incidence of recurrent disc herniation, need for reoperation, and assessments of pain (visual analog scale [VAS] score) and disability (Oswestry Disability Index [ODI] score) in the postoperative period. Postoperative changes in serum levels of C-reactive protein (CRP) and creatinine phosphokinase (CPK) were also extracted from several studies. Several studies referred to ED as percutaneous endoscopic lumbar discectomy (often when the transforaminal approach was used) or percutaneous endoscopic interlaminar discectomy (when the interlaminar approach was used). In this analysis, ED will encompass both of these terms.

Meta-Analysis

The meta-analysis was conducted using Review Manager (RevMan, Version 5.3. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014). The odds ratio or mean difference was used as the summary statistic. Because the analysis was performed on a collection of studies of different populations, at different times, with interventions performed by different surgeons, the random-effects model was used. An I^2 value greater than 50% was interpreted as conveying substantial heterogeneity between studies included in a given subgroup. Because the analysis compared 3 treatment arms, the 3 groups were compared with each other in separate subgroup analyses. Only a single study was available that compared TM with ED,[26] and thus a subgroup analysis directly comparing these 2 techniques was not included in the analysis. Fisher exact tests were used to compare distributions for categorical variables (e.g., differences in L5–S1 operative frequency between groups). Several studies reported the mean for a continuous variable (e.g., operative time) without reporting the standard deviation, and in such cases this information could not be included in the meta-analysis.

Publication Bias Assessment

The Cochrane Collaboration's tool for assessing risk of bias was utilized to estimate risk of bias in the 26 included studies. The results of the assessment can be found in Supplemental Table 1.

Results

The search strategy initially yielded 860 studies (Fig. 1). After screening, 26 studies were included in the final analysis,[1,4,6–12,18–21,26,28–30,32,37,39,42,43,47–49,55] 12 of which were estimated to have a high risk of bias (Supplemental Table 1). Study baseline characteristics are detailed in Table 1, and raw extracted outcomes for each study are detailed in Table 2.

Patient Demographics and Levels Treated

The 26 included studies described the outcomes of 2577 patients undergoing traditional OM (n = 1226, 47.6%), TM (n = 742, 28.8%), or ED (n = 609, 23.6%) for lumbar disc herniations. The median of mean ages for the open, tubular, and endoscopic groups were 41.3, 41.6, and 42 years, respectively, and the median percentages of female patients for the open, tubular, and endoscopic groups were 40%, 48.2%, and 33.3%, respectively. The precise location of the disc herniation in the axial plane (e.g., central, paracentral, foraminal, far lateral) was explicitly stated in only a single study, involving 47 patients (1.8%) with far-lateral disc herniations.[26] For another 885 patients, from 11 of the included studies, the disc herniation was noted to be in-

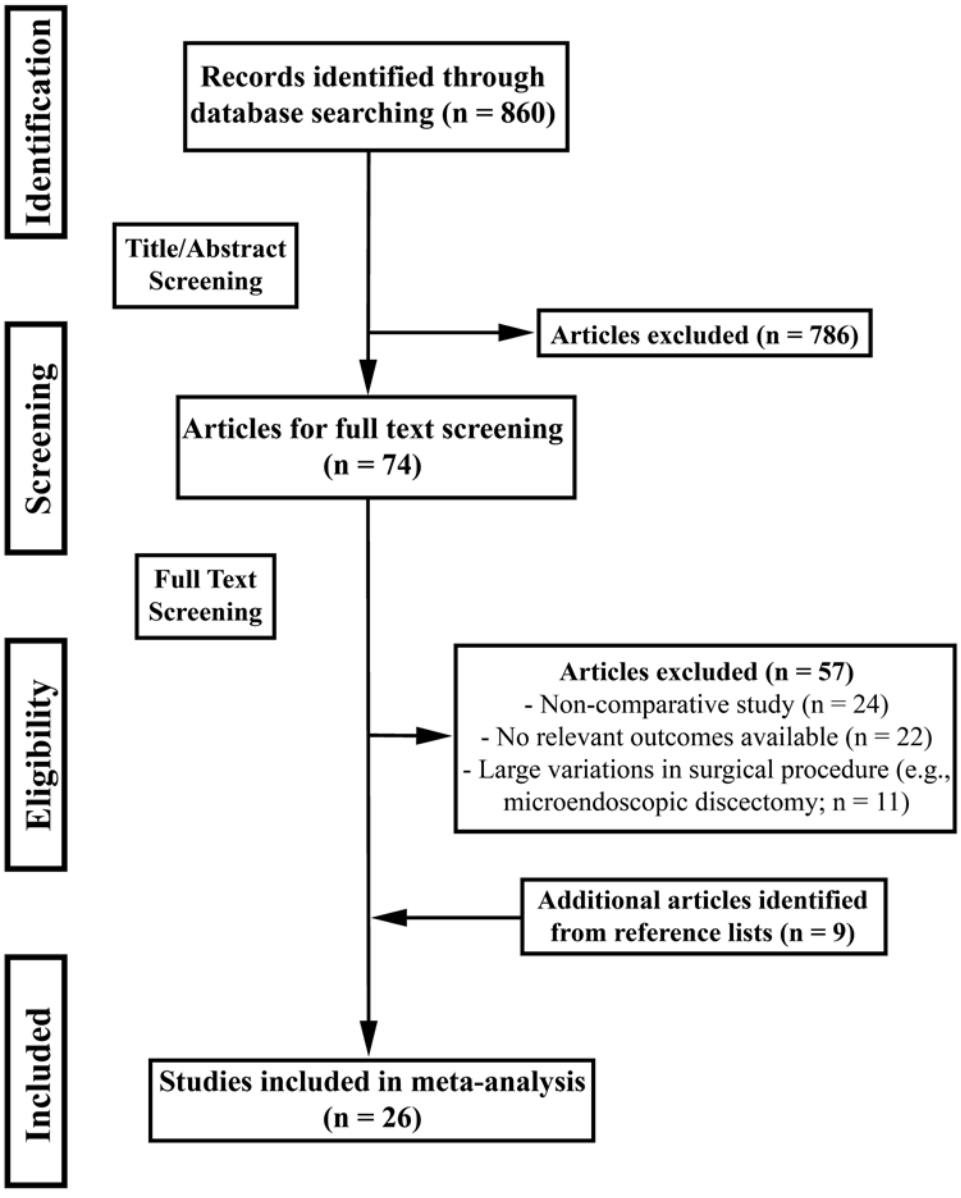

FIG. 1. Flowchart illustrating the study selection process.

tracanalicular without further elaboration, and in the remaining studies (14 studies, 1645 patients), the location of the disc herniation with respect to the spinal canal was not given. The large majority of interventions were performed from L4 to S1 (L4–5, 54.4%; L5–S1, 37.0%). The frequency of L5–S1 interventions was significantly lower in the endoscopic group than in the other groups ($p < 0.0001$).

Perioperative Details

Operative Time

There was no statistically significant difference in operative times between the OM group and either the TM (mean difference −11.16 minutes, 95% CI −25 to 2.68; studies = 5; $I^2 = 97\%$; $p = 0.11$) or ED (mean difference 8.6 minutes, 95% CI −0.62 to 17.81; studies = 9; $I^2 = 93\%$; $p = 0.07$) groups, although there was a trend toward faster operative times with OM compared with TM, and with ED compared with OM (Fig. 2A).

Estimated Blood Loss

OM was associated with significantly more blood loss than both TM (mean difference 65.28 mL, 95% CI 15.35–115.21; studies = 4; $I^2 = 99\%$; $p = 0.01$) and ED (mean difference 24.16 mL, 95% CI 18.05–30.26; studies = 2; $I^2 = 84\%$; $p < 0.00001$; Fig. 2B). Three studies were excluded from the OM versus ED estimated blood loss subgroup analysis due to an inability to accurately estimate blood loss in the ED group, instead providing terms such as "negligible," "minimal," or simply, "0."[1,10,11]

Complications

No significant difference was seen in complication rates

TABLE 1. Baseline characteristics of the included studies

		Procedures Compared												
		Group 1				Group 2				Group 3				
Authors & Year	Study Design	No. of Eligible Pts	Mean Age (yrs)	% Female	Procedure	No. of Eligible Pts	Mean Age (yrs)	% Female	Procedure	No. of Eligible Pts	Mean Age (yrs)	% Female	Procedure	FU Length (mos)
Ahn et al., 2016	Retro comparison	43	22.18 ± 1.51	0	OM	32	22.41 ± 1.68	0	ED (TF)					12
Arts et al., 2011[4]	RCT	106	40.8 ± 11.7	45.3	OM	110	41 ± 10	48.2	TM					12
Arts et al., 2011[6]	RCT	159	41.3 ± 11.7	44.7	OM	166	41.6 ± 9.8	49.4	TM					24
Bennis et al., 2009	NPC	26	43	34.6	OM	57	42	50.9	TM					3
Bhatia et al., 2016	Retro comparison	46	41.7 ± 11	37	OM	48	43 ± 10	31.3	TM (early group)	54	40.6 ± 10.7	42.6	TM (late group)	12–19
Brock et al., 2008	RCT	59	51	39	OM	66	51	39.4	TM					ND
Chen et al., 2015	Retro comparison	25	54.9 ± 16.6	44	OM	18	57.4 ± 12.4	33.3	ED (TF)					ND
Choi et al., 2016	Retro comparison	23	38 ± 11.6	47.8	OM	20	33.9 ± 11.1	30	ED (TF)					24
Choi et al., 2018	NPC	20	44.08 ± 11.38	60	OM	20	42.9 ± 6.53	45	ED (TF)	20	46 ± 8.91	55	ED (IL)	1
Gempt et al., 2013	RCT	19	37 ± 8.42	31.6	OM	19	37 ± 9.97	57.9	TM					33
Harrington & French, 2008	Retro comparison	35	41.2	37.1	OM	31	42.1	32.3	TM					3
Hermantin et al., 1999	RCT	30	40	43.3	OM	30	39	26.7	ED (TF)					31
Hsu et al., 2013	Retro comparison	66	50.4	31.8	OM	57	44.2	33.3	ED (TF/IL)					20.4
Jeong et al., 2006	Retro comparison	25	56 ± 9.12	36	TM	22	56.45 ± 10.89	36.4	ED (TF)					12
Lau et al., 2011	Retro comparison	25	42.24 ± 3.18	52	OM	20	44.55 ± 3.6	50	TM					8.2
Lee et al., 2006	Retro comparison	30	39.6	26.7	OM	30	39.3	26.7	ED (TF)					36.8–38.2
Lee et al., 2009	Retro comparison	29	47.7 ± 12.2	24.1	OM	25	42 ± 11.4	36	ED (TF)					34–34.3
Lee et al., 2018	Retro comparison	48	50.13 ± 11.56		OM	35	50.2 ± 12.87		ED (TF)					24
Liu et al., 2018	Retro comparison	69	34 ± 3.8	47.8	OM	60	36.2 ± 5.9	48.3	ED (TF)					28.2–30.1
Mayer et al., 1993	RCT	20	42.7 ± 10	30	OM	20	39.8 ± 10.4	40	ED (TF)					24
Overdevest et al., 2017	RCT	98	ND	ND	OM	106	ND	ND	TM					60
Pan et al., 2014	RCT	10	ND	ND	OM	10	ND	ND	ED (TF)					6
Ruetten et al., 2008	RCT	100	ND	ND	OM	100	ND	ND	ED (TF/IL)					24
Ruetten et al., 2009	RCT	50	ND	ND	OM	50	ND	ND	ED (TF/IL)					24
Ryang et al., 2008	RCT	30	39.1 ± 11.3	36.7	OM	30	38.2 ± 9.3	56.7	TM					16
Wang et al., 2017	Comparative study	50	53.67 ± 4.28	40	OM	60	ND	33.3	ED (TF)					3

FU = follow-up; IL = interlaminar; ND = no data; NPC = nonrandomized prospective comparison; Pts = patients; RCT = randomized controlled trial; Retro = retrospective; TF = transforaminal.

TABLE 2. Outcomes by study

Procedure, Authors, & Year	Op Time (mins)	Estimated Blood Loss (mL)	Length of Stay (days)	No. of Complications (%)	No. of Durotomies (%)	Score at Latest FU		
						Leg VAS	Back VAS	ODI
Open microdiscectomy								
Ahn et al., 2016	53.71 ± 8.49	41.26 ± 31.88	15.65 ± 4.8	4 (11.8)	1 (2.3)	2.32 ± 1.01	2.91 ± 0.67	10.68 ± 2.67
Arts et al., 20116	36 ± 16		3.3 ± 1.1	27 (17)	7 (4.4)	1.4 ± 0.18	1.94 ± 0.19	
Bennis et al., 2009	60	<50	3.43		3 (11.5)			
Bhatia et al., 2016	91 ± 8.3	148 ± 30	2.81 ± 1.1	6 (13)	3 (6.5)			
Chen et al., 2015	206.44	303.2	12.28	3 (12)	2 (8)			
Choi et al., 2016	136.7 ± 53	200.9 ± 86.9	7.2 ± 3.5	0 (0)	0 (0)	2.3 ± 0.8	3.7 ± 1.0	20.2 ± 7.2
Choi et al., 2018	80.83 ± 17.55		9.04 ± 3.24	0 (0)	0 (0)	1.67 ± 1.13	2.08 ± 0.58	13.96 ± 7.04
Gempt et al., 2013								18.53 ± 15.37
Harrington & French, 2008	84.1	51.4						
Hermantin et al., 1999					1 (3.3)			
Hsu et al., 2013	48.1 ± 9.2	48.9			0 (0)			3.29 ± 6.94
Lau et al., 2011	122.12 ± 7.22	42.25 ± 10.15	3 ± 0.26	6 (24)	4 (16)			
Lee et al., 2006	65.1 ± 23.17		3 ± 2.5					
Lee et al., 2009	73.8 ± 25.7		3.8 ± 1.4	3 (10.3)	2 (6.9)	3.5 ± 3.1	3.1 ± 2.5	18.2 ± 15.4
Lee et al., 2018				9 (18.8)	7 (14.6)	2.52 ± 1.25	2.85 ± 1.09	16.98 ± 4.13
Liu et al., 2018	60 ± 15	26 ± 15	3 ± 1	5 (7.2)		1.4 ± 0.7	1.4 ± 0.7	23 ± 9
Mayer et al., 1993	58.2 ± 15.2							
Overdevest et al., 2017						13.7 ± 4.2	19.9 ± 4.6	
Pan et al., 2014		99	5.6 ± 1.6					
Ruetten et al., 2008	43	45		12 (12)	0 (0)			
Ruetten et al., 2009	58	41		11 (21)	3 (6)			
Ryang et al., 2008	92 ± 28.6	63.8 ± 86.8	4.4 ± 2.8	6 (20)	2 (6.7)			12 ± 18.8
Wang et al., 2017	77.81 ± 18.44	52.56 ± 10.07	6.18 ± 2.35					29.21 ± 11.05
Tubular microdiscectomy								
Arts et al., 20116	47 ± 22		3.3 ± 1.2	39 (23)	14 (8.4)	1.53 ± 0.17	2.25 ± 0.19	
Bennis et al., 2009	55.3		3.25		5 (8.8)			
Bhatia et al., 2016 (early group)	125 ± 10.7	57 ± 13	2.76 ± 2.7	10 (20.8)	5 (10.4)			
Bhatia et al., 2016 (late group)	108 ± 18.9	41 ± 9.7	1.74 ± 0.9	6 (11.1)	4 (7.4)			
Gempt et al., 2013								12.95 ± 11.2
Harrington & French, 2008	76.8	69.7						
Jeong et al., 2006	110 ± 29.68		7.68 ± 2.59			1.7 ± 1.72		
Lau et al., 2011	122.65 ± 8.61	19 ± 4.49	2.889 ± 0.30	4 (20)	2 (10)			
Overdevest et al., 2017						13.9 ± 4	20.3 ± 4.4	
Ryang et al., 2008	82 ± 25.1	26.2 ± 29.7	4 ± 2.3	2 (7)	0 (0)			12 ± 14

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TABLE 2. Outcomes by study

Procedure, Authors, & Year	Op Time (mins)	Estimated Blood Loss (mL)	Length of Stay (days)	No. of Complications (%)	No. of Durotomies (%)	Score at Latest FU		
						Leg VAS	Back VAS	ODI
Endoscopic discectomy								
Ahn et al., 2016	48.66 ± 6.45	0	7.5 ± 2.63	4 (12.5)	0 (0)	2.06 ± 0.84	2.5 ± 0.62	9.63 ± 2.31
Chen et al., 2015	79.06		1.89	0 (0)	0 (0)			
Choi et al., 2016	67 ± 12		1.5 ± 1.1	0	0	1.7 ± 1.2	2.0 ± 0.6	12.5 ± 7.5
Choi et al., 2018 (TF)	56.43 ± 15.74		4.14 ± 3.82	0 (0)	0 (0)	1.81 ± 1.12	2.00 ± 0.63	11.00 ± 3.78
Choi et al., 2018 (IL)	85.52 ± 17.79		6.48 ± 2.17	0 (0)	0 (0)	1.68 ± 1.11	2.00 ± 0.63	10.39 ± 4.5
Hermantin et al., 1999					0 (0)			
Hsu et al., 2013	86.5 ± 45.9				0 (0)			6.42 ± 9.82
Jeong et al., 2006	78 ± 36.71		2.73 ± 2.62			1.29 ± 2.27		
Lee et al., 2006	42.6 ± 14.21		0.81 ± 1.3					
Lee et al., 2009	45.8 ± 11.1		0.9 ± 0.5	1 (4)	0 (0)	2.9 ± 2.5	2.9 ± 2.4	20.7 ± 15.9
Lee et al., 2018				0 (0)	0 (0)	2.23 ± 0.65	2.23 ± 0.65	15.31 ± 2.97
Liu et al., 2018	43 ± 13	5 ± 3	2 ± 1	5 (8.3)		1.2 ± 0.5	0.9 ± 0.7	19 ± 6
Mayer et al., 1993	40.7 ± 11.3							
Pan et al., 2014		8.35	1.9 ± 0.74					
Ruetten et al., 2008	22	0		3 (3)	0 (0)			
Ruetten et al., 2009	24	0		3 (6)	1 (2)			
Wang et al., 2017	75.04 ± 20.32	25.33 ± 7.26	2.65 ± 1.06					18.54 ± 9.63

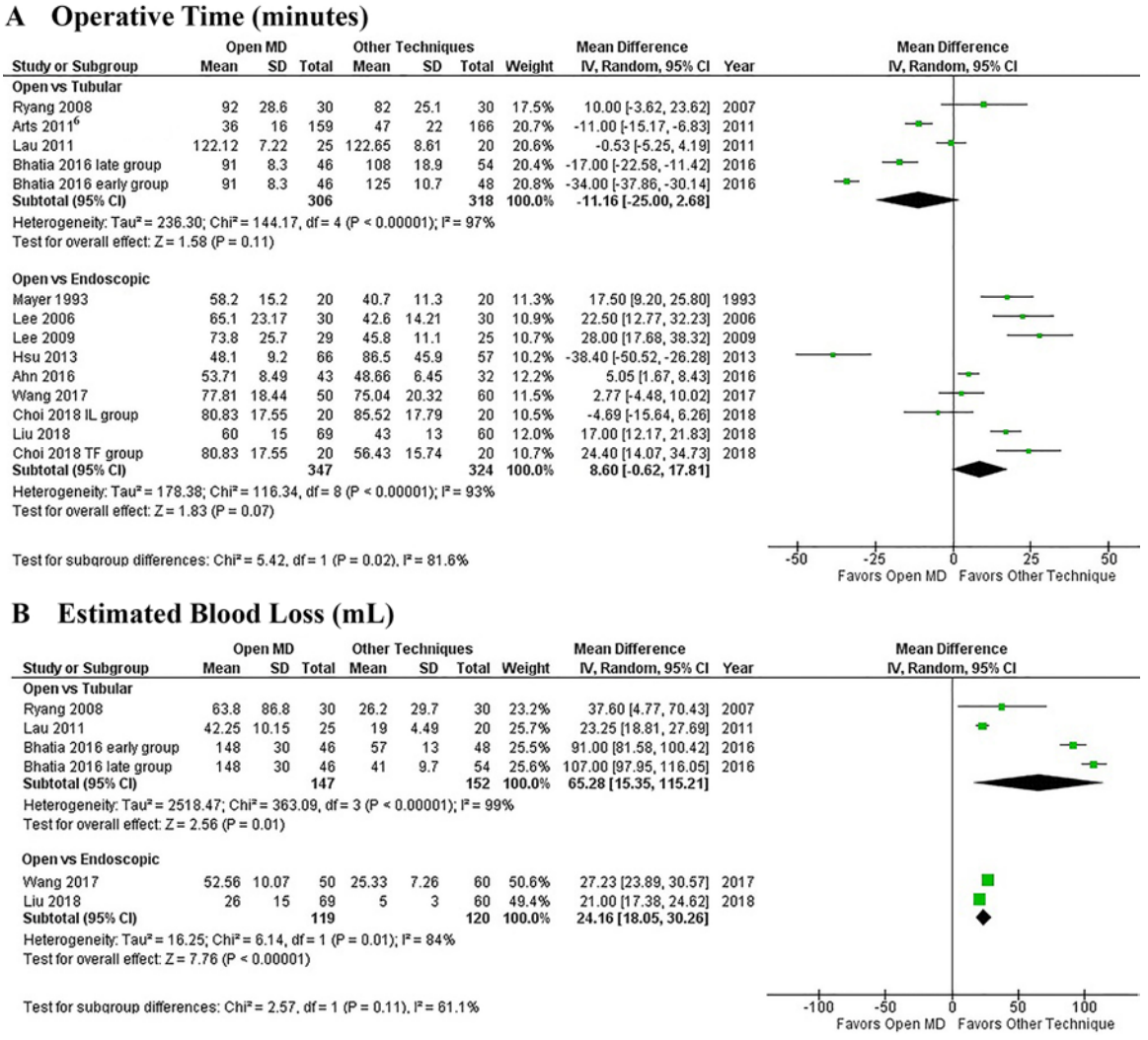

FIG. 2. Forest plots comparing operative details (operative time [**A**] and estimated blood loss [**B**]) between OM, TM, and ED. IL = interlaminar; IV = inverse variance; TF = transforaminal. Figure is available in color online only.

overall between OM and TM (OR 1.09, 95% CI 0.56–2.10; studies = 4; $I^2 = 0\%$; p = 0.81). A trend was seen toward a higher overall complication rate in OM when compared with ED (OR 2.12, 95% CI 0.97–4.64; studies = 8; $I^2 = 35\%$; p = 0.06), but this trend did not reach statistical significance (Fig. 3A).

Durotomy

No significant difference was seen in the incidence of durotomies between OM and TM (OR 0.82, 95% CI 0.44–1.54; studies = 5; $I^2 = 0\%$; p = 0.54), but OM was associated with a significantly higher rate of durotomies when compared with ED (OR 4.17, 95% CI 1.27–13.66; studies = 6; $I^2 = 0\%$; p = 0.02; Fig. 3B).

Nerve Root Injury

No significant difference was seen in the rate of nerve root injuries between OM and either TM (OR 1.27, 95% CI 0.31–5.12; studies = 2; $I^2 = 0\%$; p = 0.74) or ED (OR 0.63, 95% CI 0.04–9.65; studies = 2; $I^2 = 33\%$; p = 0.74).

Wound Infection

No significant difference was seen in the rate of wound infections between OM and either TM (OR 2.46, 95% CI 0.42–14.51; studies = 3; $I^2 = 0\%$; p = 0.32) or ED (OR 2.37, 95% CI 0.37–15.38; studies = 3; $I^2 = 0\%$; p = 0.36).

Recurrent Disc Herniation

No significant difference was seen in the rate of postoperative recurrent disc herniations between OM and either TM (OR 0.68, 95% CI 0.33–1.41; studies = 4; $I^2 = 0\%$; p = 0.3) or ED (OR 0.95–95% CI 0.45–1.99; studies = 6; $I^2 = 0\%$; p = 0.89).

Reoperation for Residual Disc Herniation

No significant difference was seen in the rate of reoperations for residual disc herniation after surgery between OM and either TM (OR 0.91, 95% CI 0.22–3.85; studies = 2; $I^2 = 0\%$; p = 0.90) or ED (OR 0.33, 95% CI 0.07–1.58; studies = 4; $I^2 = 0\%$; p = 0.16; Fig. 3C).

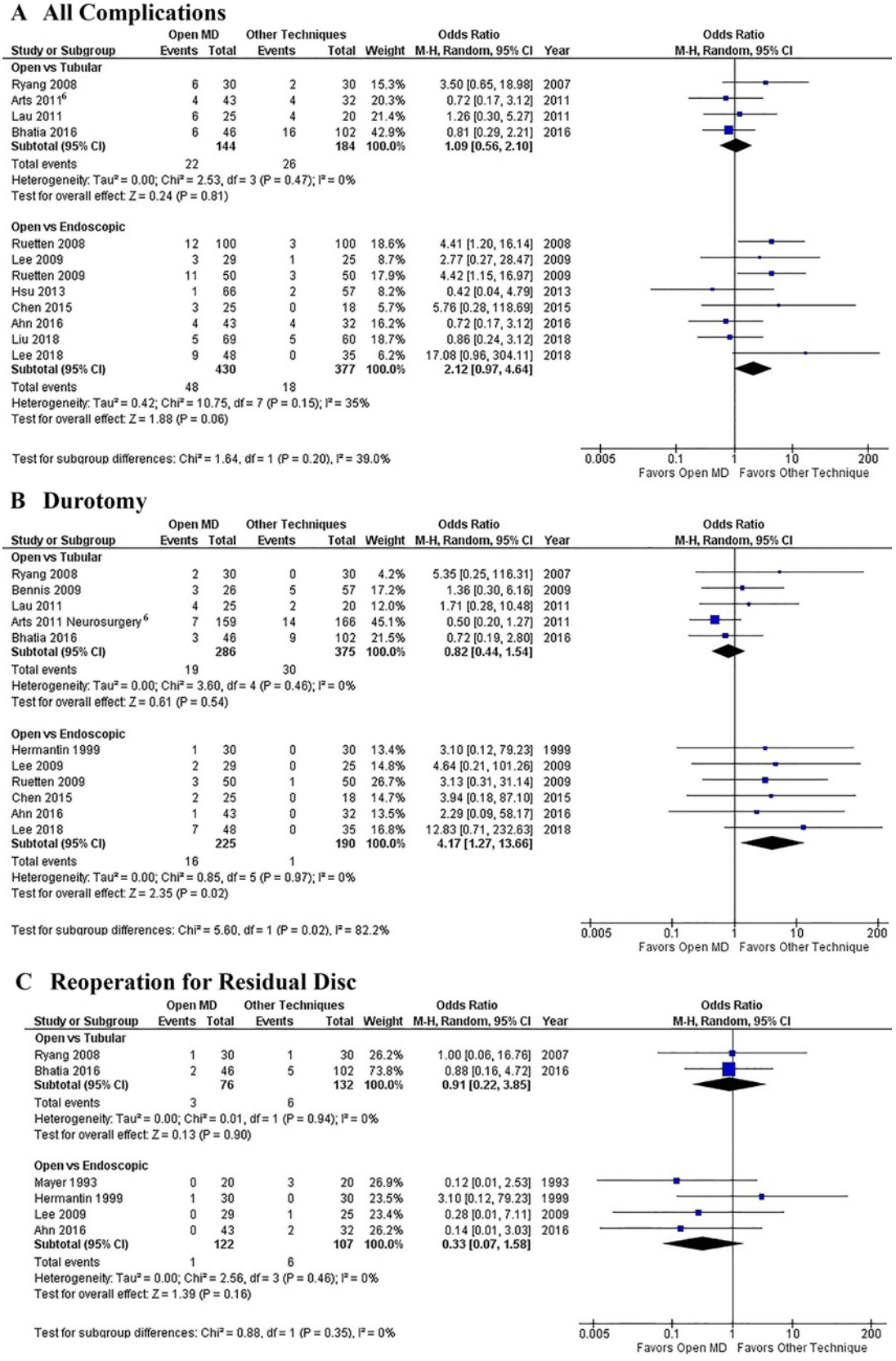

FIG. 3. Forest plots comparing complications (all complications [**A**], durotomy [**B**], and reoperation for residual disc herniation [**C**]) between open microdiscectomy, tubular microdiscectomy, and endoscopic discectomy. M-H = Mantel-Haenszel. Figure is available in color online only.

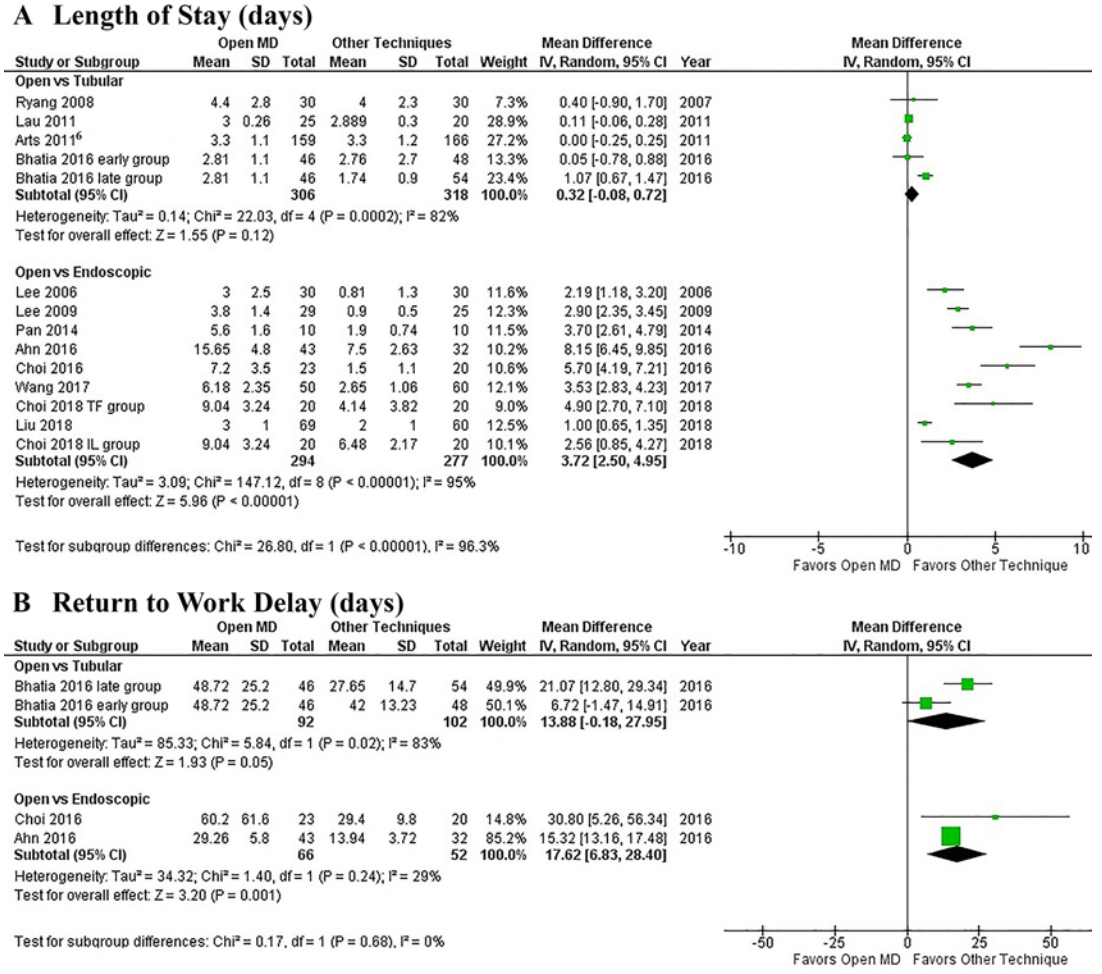

FIG. 4. Forest plots comparing hospital length of stay (days; **A**) and postoperative return to work delay (days; **B**) between OM, TM, and ED. Figure is available in color online only.

Clinical Outcomes

Length of Stay

No significant difference was seen with regard to length of hospital stay after surgery between OM and TM (mean difference 0.32 days, 95% CI −0.08 to 0.72; studies = 5; I^2 = 82%; p = 0.12), but OM was associated with a significantly longer length of stay when compared with ED (mean difference 3.72 days, 95% CI 2.5–4.95; studies = 9; I^2 = 95%; p < 0.00001; Fig. 4A).

Return to Work

A trend was seen toward a slower return to work with OM than with TM (mean difference 13.88 days, 95% CI −0.18 to 27.95; studies = 2; I^2 = 83%; p = 0.05), although this trend did not reach statistical significance. OM was associated with a significantly slower return to work time when compared with ED, however (mean difference, 17.62 days, 95% CI 6.83–28.4; studies = 2; I^2 = 29%; p = 0.001; Fig. 4B).

Postoperative Leg VAS Score

No significant difference was seen in postoperative leg VAS scores at latest follow-up between OM and TM (mean difference −0.02, 95% CI −0.13 to 0.09; studies = 2; I^2 = 0% p = 0.70), but OM was associated with significantly higher postoperative leg VAS scores at latest follow-up when compared with ED (mean difference 0.18, 95% CI 0.03–0.34; studies = 7; I^2 = 0%; p = 0.02; Fig. 5A). The only included study to directly compare postoperative leg VAS scores between TM and ED found no significant difference between the two at 1 year postoperatively (p = 0.492), although this study was estimated to have a high risk of bias.[26]

Postoperative Back VAS Score

No significant difference was seen in postoperative back VAS scores at latest follow-up between OM and TM (mean difference 0.16, 95% CI −0.35 to 0.67; studies = 2; I^2 = 70%; p = 0.55), but OM was associated with significantly higher postoperative back VAS scores at latest follow-up when compared with ED (mean difference 0.55, 95% CI 0.11–0.98; studies = 6; I^2 = 85%; p = 0.01; Fig. 5B).

Postoperative ODI Score

OM was associated with significantly higher postoperative ODI scores at latest follow-up when compared with

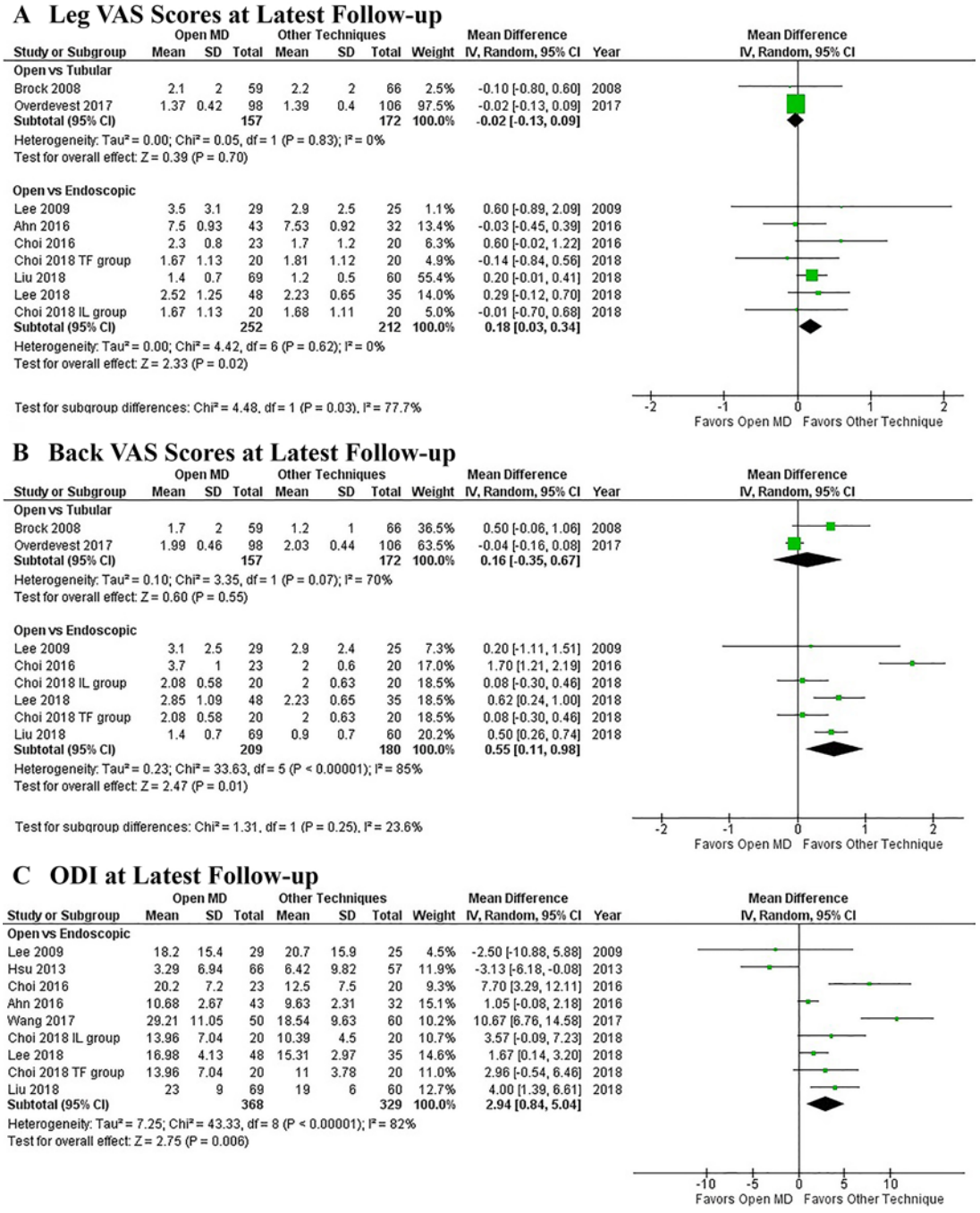

FIG. 5. Forest plots comparing leg VAS scores (**A**), back VAS scores (**B**), and ODI (**C**) at latest follow-up between OM, TM, and ED. Figure is available in color online only.

ED (mean difference 2.94, 95% CI 0.84–5.04; studies = 9; I^2 = 82%; p = 0.006; Fig. 5C). The only 2 studies to compare postoperative ODI scores between TM and OM both evaluated ODI score in the same cohort of patients (at different time points), and both were estimated to have a low risk of bias, although no significant difference in postoperative ODI score at latest follow-up was seen in either study.[18,49]

Inflammatory Markers and Muscle Injury

OM was associated with significantly higher serum CPK values on postoperative day 1 compared with ED (mean difference 84.67, 95% CI 14.15–155.20; studies = 3; I^2 = 90%; p = 0.02; Fig. 6A). The only included study to directly compare serum CPK values on postoperative day 1 between TM and OM found no significant difference between the two (p = 0.69) and was estimated to have a low risk of bias.[4]

OM was associated with significantly higher serum CRP values on postoperative day 1 compared with ED (mean difference 1.41, 95% CI 1.08–1.74; studies = 3; I^2 = 18%; p < 0.00001; Fig. 6B).

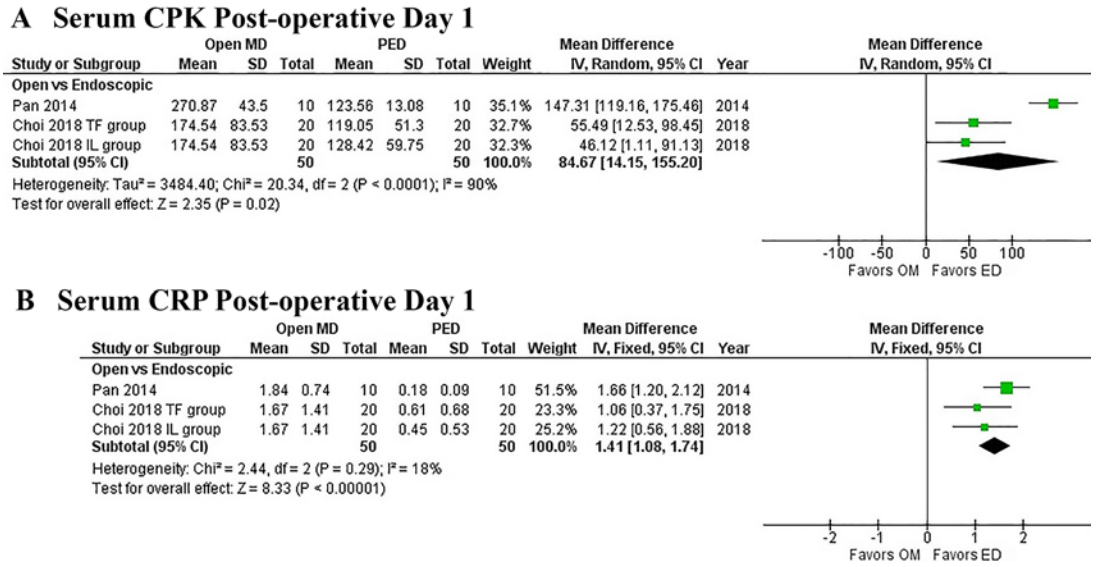

FIG. 6. Forest plots comparing serum CPK (**A**) and serum CRP (**B**) on postoperative day 1 between OM and ED. Figure is available in color online only.

Discussion

Our meta-analysis did not detect any significant differences between TM and OM with respect to any of the outcome measures evaluated, except for estimated blood loss (which was significantly lower in the TM group than in the OM group). TM was also associated with trends in faster return to work times, and slower operative times, when compared with OM, but these trends did not reach statistical significance.

On the other hand, ED was associated with significant improvements in estimated blood loss, incidence of durotomies, and all clinical outcomes investigated (length of stay, return to work time, leg VAS at latest follow-up, back VAS at latest follow-up, ODI at latest follow-up, and muscle injury as estimated by serum CPK on postoperative day 1) when compared with OM. ED was also associated with a trend toward both faster operative times and fewer overall complications when compared with OM, although these trends did not reach statistical significance. Although many of these differences were statistically significant, the magnitude of many of these differences was small and likely of minimal clinical significance.

ED is a procedure designed to achieve the goals of lumbar discectomy or sequestrectomy while minimizing injury to the tissues traversed during the surgical approach. The transforaminal ED technique, in particular, allows for access to lumbar herniated discs by way of a natural corridor (the intervertebral foramen), without the need for muscle dissection, bony removal, and nerve root retraction seen with OM and TM. Evidence for the benefit of the ED approach on minimizing trauma to tissues can be inferred through postoperative comparisons of serum markers for inflammation and/or muscle injury (e.g., postoperative serum CPK and CRP, both of which were significantly lower with the ED group when compared with OM in this meta-analysis). Others have found that serum levels of other inflammatory markers such as interleukin-6[43] and TNF-α,[55] as well as markers of oxidative stress such as malondialdehyde (MDA),[55] myeloperoxidase (MPO),[55] superoxide dismutase (SOD),[55] and total antioxidant capacity (TAC)[55] are significantly lower postoperatively in patients undergoing ED when compared with those undergoing traditional open microdiscectomy. Although TM is also designed to minimize muscle injury during the approach to the spine by sequentially dilating or displacing muscle rather than dissecting it away from the spine subperiosteally, a large prospective, randomized trial comparing postoperative serum CPK values between TM and OM found no significant difference between the two ($p = 0.74$).[4]

While the differences in certain clinical outcomes (e.g., VAS back scores, length of stay, return to work time) seen in this study with the ED group when compared with the OM group could conceivably be attributable to this minimization of tissue destruction seen with the ED approach,[47] as mentioned previously, the magnitude of some of these differences (VAS back score mean difference, 0.55) were small and of uncertain clinical significance. While the magnitude of the differences between the ED and OM groups with regard to length of stay and return to work time were larger (3.72 days and 17.62 days, respectively), it could be argued that these outcomes are at least partially related to surgeon- or hospital-specific postoperative guidelines for minimally invasive procedures. Similarly, while differences in the amount of nerve root retraction required with endoscopic versus open procedures, and/or differences in the amount of epidural scar formation resulting from open and endoscopic discectomies could theoretically play a role in differential postoperative VAS leg scores between the techniques,[15,47,50] the magnitude of difference between postoperative VAS leg scores in ED and OM groups in the current study (VAS leg score mean difference, 0.18) was small enough to be considered clinically negligible.

Several other meta-analyses comparing surgical treatments for lumbar disc herniations can be found in the lit-

erature.[3,13,14,27,34,35,44–46] As opposed to many of these other analyses, our analysis excluded microendoscopic discectomy, endoscope-assisted discectomy, and other procedural variations that varied substantially from others in the data set in an attempt to improve the specificity of the results achieved. Our analysis also utilized a random-effects model in an attempt to improve the generalizability of the results beyond the included studies and minimize false elevations in the number of statistically significant findings.[54]

Limitations and Generalizability

Twelve of the 26 included studies were retrospective analyses and were estimated to have a high risk of bias, leaving the overall analysis with a moderate risk of bias. Various patient-specific (patient comorbidities, preoperative symptoms) and pathology-specific variables (e.g., size of disc herniation, location of disc herniation in the axial plane, presence of osteophytes and other degenerative pathologies) that could conceivably influence outcomes were often not explicitly given by the authors of the included studies, which is another potential source of bias. Similarly, variability between the included studies with regard to the length of clinical follow-up was relatively high, subjecting the outcomes of the overall analysis to additional bias.

Furthermore, although clinical outcomes were seen to be statistically improved in ED when compared with OM, the magnitude of these differences was overall relatively small (with the exception of postoperative length of stay and return to work time). Estimated blood loss, for example, was significantly greater with OM when compared with both TM and ED, but the magnitude of this difference is clinically negligible at 24.16–65.28 mL, notwithstanding that the variability and intraobserver error associated with the estimation of blood loss in volumes less than 100 mL is likely to be considerable. Additionally, several of the differences observed between groups with regard to clinical outcomes could arguably be attributed to preoperative patient expectations of the efficacy of one surgical technique versus another in retrospective or unblinded prospective studies (e.g., a placebo effect on postoperative VAS scores in patients receiving what they perceive to be a better surgical treatment modality) or to surgeon- or hospital-specific procedural guidelines (e.g., hospital stay, return to work times). Relatively high heterogeneity was also seen in some studies, and several subgroup analyses only included 2–3 studies per subgroup. Finally, several clear outliers were present within some of the subgroup analyses, which may be a factor of differences in practitioner experience or other variables.

The analysis does not investigate differences between OM, TM, and ED in terms of radiation exposure to the patient and surgeon due to the lack of a sufficient number of trials evaluating these outcomes in the literature. Several small series, however, have indicated that the radiation exposure to the surgeon is significantly greater with TM than with OM,[38] and that the radiation exposure with ED is likely to be greater than that seen with TM, particularly during a surgeon's early experience with endoscopic discectomy.[2,22]

Conclusions

The results of this analysis suggest that TM and OM for lumbar disc herniations are equivalent in terms of safety and efficacy. While this analysis demonstrated that several clinical variables were significantly improved in patients undergoing ED when compared with OM, the magnitude of many of these differences was small and of uncertain clinical relevance, and several of the included studies were retrospective and subject to a high risk of bias. Further study is needed before definitive conclusions can be drawn regarding the comparative efficacy of the various surgical treatments for lumbar disc herniations.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Barber, Gokaslan. Acquisition of data: Barber. Analysis and interpretation of data: Barber. Drafting the article: Barber, Nakhla, Konakondla, Fridley, Oyelese. Critically revising the article: Barber, Nakhla, Konakondla, Fridley, Oyelese, Gokaslan. Reviewed submitted version of manuscript: Telfeian, Barber. Administrative/technical/material support: Telfeian. Study supervision: Telfeian.

Supplemental Information

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