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HANDSURGERY

Effectiveness and safety of endoscopic versus open carpal tunnel decompression

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Abstract
Purpose To evaluate the effectiveness and safety of endoscopic carpal tunnel release (ECTR) and open carpal tunnel release (OCTR) using a meta-analysis of data from randomized controlled trials.
Materials and methods Electronic searches of the Cochrane Register of Controlled Trials (CENTRAL, Issue 11 of 12, Nov 2012), PUBMED (1980 to Dec 2012), and EMBASE (1980 to Dec 2012) were used to identify randomized controlled trials that evaluated endoscopic vs open methods for treatment of carpal tunnel syndrome. Studies to be used were independently identified by two researchers. The methodological quality of the studies was assessed by the Cochrane Collaboration tool for assessing risk of bias.
Results Fifteen randomized controlled trials involving 1,596 hands were included. Based on the Cochrane Collaboration tool for assessing risk of bias, four studies were rated as high quality, five studies were rated as moderate quality, and six were rated as low quality. Our meta-analysis indicated that ECTR resulted in better recovery of pinch strength, earlier time of return to work, but a higher rate of reversible nerve problems (including neurapraxia and numbness) than OCTR. ECTR also resulted in a lower rate of irreversible nerve damage ($P > 0.05$), wound problems (including wound infection, wound hematoma and wound dehiscence) and reflex sympathetic dystrophy ($P > 0.05$) compared with OCTR. Our meta-analysis revealed no obvious statistical differences in relief of symptoms (pain and paraesthesia), recovery of grip strength and reoperation rate.
Conclusion Our meta-analysis of available randomized controlled trials demonstrated that ECTR and OCTR were similar in relief of symptoms, but ECTR resulted in better recovery of function and earlier return to work and was safer than OCTR.

Keywords Carpal tunnel syndrome · Effectiveness · Endoscopic carpal tunnel release · Meta-analysis · Open carpal tunnel release · Safety

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Introduction

Carpal tunnel syndrome (CTS) is the most frequent peripheral compression-induced neuropathy observed in patients worldwide [1]. The annual incidence of CTS among women in Sweden is 324 per 100,000, and in the US it is 542; among men the incidence in Sweden is 125 per 100,000 and that in the US is 303 [2]. In the UK, the annual age-standardized rates of CTS per 100,000 are estimated at 87.8 in men and 192.8 in women [3].

In the typical presentation of CTS, patients complain of pain, paresthesia, and numbness in the median nerve distribution of the hand. Conservative treatment methods are often used in mild to moderate case, whereas surgical treatment is performed when symptoms are severe or when conservative treatment fails [4]. Traditional open carpal tunnel release (OCTR) is the gold standard for carpal tunnel decompression [5]. This approach allows the surgeon to directly visualize the carpal tunnel and guarantees complete section [6]. Endoscopic carpal tunnel release (ECTR) is a relatively new procedure that is much less invasive than OCTR [7]. Two techniques are commonly used for ECTR. The first one is the single-portal technique designed by Agee [8]; the other is the two-portal technique reported by

Chow and Okutsu [9, 10]. A meta-analysis comparing the efficacy of OCTR and ECTR was published several years ago [11], but several high-quality randomized controlled trials have since been reported, and the previous meta-analysis did not address safety.

This meta-analysis reported here was conducted to systematically review the randomized controlled trials of carpal tunnel release. Our objective was to compare the effectiveness and safety of open methods and endoscopic methods for surgical treatment of CTS.

Methods

Eligibility criteria and literature search

We searched the Cochrane Register of Controlled Trials (CENTRAL, Issue 11 of 12, Nov 2012), PUBMED (1980 to Dec 2012), and EMBASE (1980 to Dec 2012) databases to identify all studies that discussed the effectiveness and safety of open vs endoscopic carpal tunnel decompression based on the following criteria: (CTS OR carpal tunnel release) AND (surgery OR treatment OR therapy OR complications OR adverse effect) AND randomized controlled trial; (CTS/complications [Mesh] OR CTS/surgery [Mesh] OR CTS/therapy [Mesh]) AND randomized controlled trial [ptyp]. We then selected only studies that included human subjects. The inclusion criteria were: (1) target population: included patients with a clinical diagnosis of CTS; (2) intervention: standard OCTR or ECTR by the single-portal technique or the two-portal technique; (3) methodological criteria: randomized controlled trials comparing OCTR with ECTR reporting either on effectiveness or safety for both procedures. The exclusion criteria were: (1) target population: patients with a clinical diagnosis of CTS associated with conditions such as pregnancy or hypothyroidism; (2) intervention: the intervention included standard OCTR without other instruments and modified incision such as mini-incision using Knife-light instrument [12], limited open technique using Strickland's instrument [13] and the limited open technique modified from Bromley [14]; (3) methodological criteria: case report, case–control study and cohort study.

The search strategy retrieved 651 studies: 201 from CENTRAL, 229 from PUBMED, and 221 from EMBASE. The study selection was conducted by two independent reviewers. After examination of the titles and abstracts of these references, 18 studies were identified for further analysis [8, 15–31]. A reading of the full text of certain studies indicated that they reported on the same clinical trial as an earlier report [19] and that the intervention was unclear [28]. We also found that Atroshi [29] and Atroshi [31] reported on the same patients at different follow-up times, so we included only one article of the multiple studies. The remaining 15 randomized controlled trials were deemed to be the primary relevant studies and were included in this meta-analysis (Fig. 1). Two reports were published in German [21, 24], and these papers were translated for this review.

Outcome assessment

The primary outcomes measured were the recovery of function (grip strength and pinch strength in 3 months). The secondary outcomes measured included relief of symptoms (pain decrease measured with VAS and parasthesia measured with Semmes–Weinstein monofilament) before or after 3 months, time of return to work, reoperation rate, and complications. Complications included irreversible nerve damage, reversible nerve problems (including neurapraxia and numbness), wound problems (including wound infection, wound hematoma, and wound dehiscence), and reflex sympathetic dystrophy.

Data extraction and quality assessments

For each trial, we gathered data on study type, sample size, interventions, length of follow-up, randomization process, allocation concealment process, blinding, selective reporting, and intention to treat analysis. In addition, the following clinical data were also extracted if available: information on relief of symptoms, extent of recovery of function, time of return to work, reoperation rate, and complications. Two researchers extracted data independently according to the pre-specified selection criteria. Disagreements were resolved by discussion.

The Cochrane Collaboration's tool for assessing risk of bias [32] was used to assess the quality of the included trials. For the Cochrane Collaboration's tool for assessing risk of bias, the quality of the studies was assessed using the following criteria: (1) randomization sequence generation: assessment for selection bias; (2) allocation concealment: assessment of selection bias; (3) level of blinding (blinding of participants and blinding of outcome assessment): assessment for performance bias and detection bias; (4) incomplete outcome data: assessment for attrition bias; and (5) selective reporting: assessment for reporting bias [32].

Statistical analyses

Statistical analyses were conducted using Review Manager, version 5.2 (The Nordic Cochrane Centre, the Cochrane Collaboration, 2012). In each study, the relative risk (RR) was calculated for dichotomous outcomes, and treatment effects for continuous outcomes include mean differences (MD) for studies with comparable outcome measures and

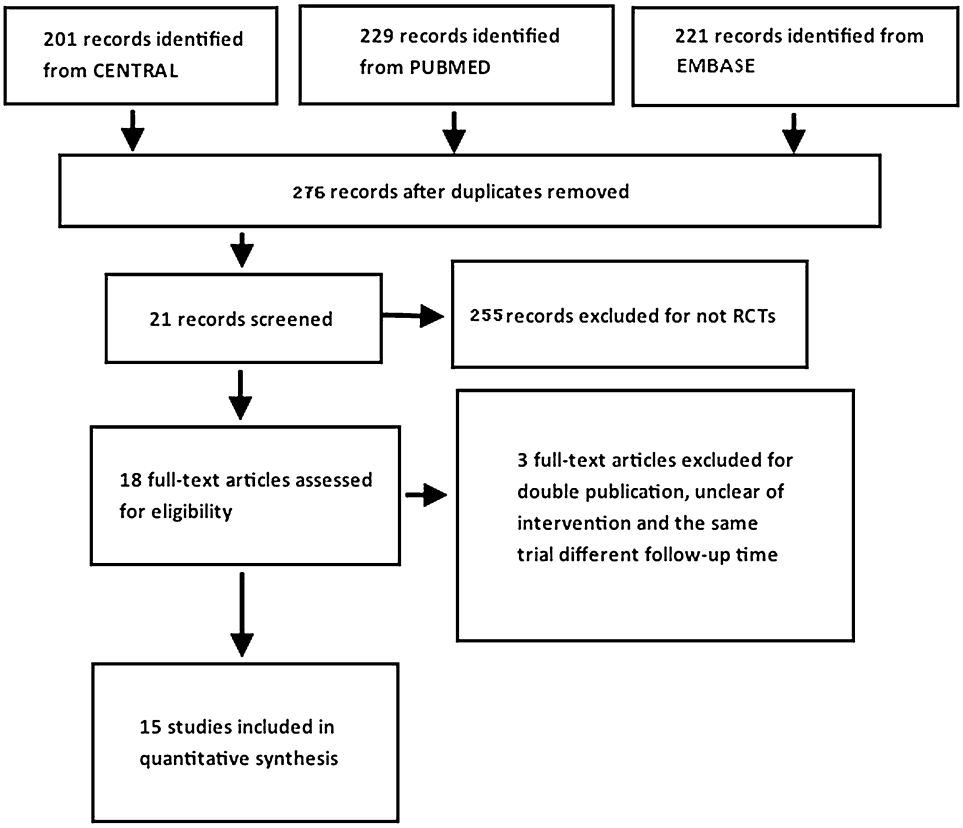

Fig. 1 Flow diagram depicting selection of studies for inclusion in meta-analysis

standardized mean differences (SMD) for data from disparate outcome measures, both used a 95 % confidence interval (CI). Heterogeneity was assessed by visual inspection of the forest plot and by Chi-square tests and I-square tests. Significance levels of less than 0.10 for the Chi-square test or more than 50 % for I-square test were interpreted as evidence of heterogeneity. The I-square was used to estimate total variation across studies. When there was no statistical evidence of heterogeneity, a fixed effect model was applied; if heterogeneous, a random effect model was chosen [32].

Results

Characteristics and qualities of included studies

Fifteen trials that evaluated treatment of a total of 1,596 hands were included in the analysis. Table 1 presents the study characteristics (study type, sample size, interventions, length of follow-up). As shown in Table 2, the Cochrane Collaboration's tool for assessing risk of bias indicated that nine studies [15–18, 22, 23, 26, 27, 29] used adequate randomization. Four studies [18, 26, 27, 29] used adequate allocation concealment. Five studies [15, 22, 23, 25, 26] reported outcome assessment blinding. However, patient blinding was not feasible in this study design. Ten studies [15, 17, 18, 20–23, 26, 27, 29] had loss to follow-up reporting. Only five studies [15, 20, 21, 26, 29] used intention to treat (ITT) analysis. Twelve of included studies [8, 15, 16, 20–23, 25–27, 29, 30] were free of selective reporting.

Primary outcomes

Recovery of function within 3 months

Data pooled from two trials [15, 29] including 297 hands suggested that there was no statistical difference between ECTR and OCTR in recovery of grip strength (1.96 kg, 95 % CI −0.47–4.38, $P = 0.11$, $I^2 = 0$ %) (Fig. 2, upper panel). Data pooled from two studies [15, 29] including 297 hands indicated that ECTR resulted in significantly better recovery of pinch strength than OCTR (0.83 kg, 95 % CI 0.31– 1.35, $P = 0.002$, $I^2 = 0$ %) (Fig. 2, lower panel).

Secondary outcomes

Relief of symptoms

Data pooled from the four studies [8, 15, 17, 21] involving 470 hands indicated that there was no statistical difference between ECTR and OCTR in relief of pain at or before

Table 1 Characteristics of included studies comparing endoscopic carpal tunnel release vs open carpal tunnel release for carpal tunnel syndrome

Authors group	Country	Study type	Intervention	Sample size Patient/hand	Length of Follow-up (weeks)	For analysis
Agee [8]	USA	RCT	ECTR vs OCTR	122/147	26	(1), (2), (3), (4), (8), (9), (10), (11)
Aslani [30]	Iran	RCT	ECTR vs OCTR	68/68	16	(7)
Atroshi [29]	Sweden	RCT	ECTR vs OCTR	128/128	260	(2), (5), (6), (7), (8)
Brown [15]	USA	RCT	ECTR vs OCTR	145/169	12	(1), (3), (5), (6), (10)
Dumontier [17]	France	RCT	ECTR vs OCTR	96/96	36	(1), (3), (10), (12)
Eichhorn [24]	Germany	RCT	ECTR vs OCTR	164/188	52	(8), (11)
Erdman [16]	UK	RCT	ECTR vs OCTR	71/105	52	(8), (9), (10), (11)
Ferdinand [22]	UK	RCT	ECTR vs OCTR	25/50	52	(9), (11)
Jacobsen [20]	Sweden	RCT	ECTR vs OCTR	29/32	36	(7), (10), (11)
MacDermid [25]	Canada	RCT	ECTR vs OCTR	123/123	52	(8)
Malhotra [27]	India	RCT	ECTR vs OCTR	60/61	24	(3), (4), (11), (12)
Saw [26]	UK	RCT	ECTR vs OCTR	150/150	12	(7), (8), (10), (11)
Sennwald [17]	Germany	RCT	ECTR vs OCTR	47/47	12	(10), (12)
Stark [21]	Sweden	RCT	ECTR vs OCTR	20/40	32	(1), (2), (3), (4)
Trumble [23]	USA	RCT	ECTR vs OCTR	147/192	52	(8), (12)

For analysis: (1) relief of pain in 3 months or less; (2) relief of pain after 3 months; (3) relief of paresthesia in 3 months or less; (4) relief of parasthesia after 3 months; (5) recovery of grip strength in 3 months; (6) recovery of pinch strength in 3 months; (7) time of return to work; (8) the rate of reoperation; (9) the irreversible nerve damage; (10) the reversible nerve damage; (11) the wound problems; (12) the reflex sympathetic dystrophy

Table 2 Quality assessment of randomized controlled trials comparing endoscopic carpal tunnel release vs open carpal tunnel release using Cochrane Collaboration's tool for assessing risk of bias

Authors group	Adequate randomization	Adequate allocation concealment	Adequate patient blinding	Adequate outcome assessment blinding	Loss to follow-up reporting	Intention to treat analysis	Free of selecting report
Agee [8]	N	Unclear	N/A	Unclear	Unclear	Unclear	Y
Aslani [30]	Unclear	Unclear	N/A	Unclear	Unclear	Unclear	Y
Atroshi [29]	Y	Y	N/A	N	Y	Y	Y
Brown [15]	Y	N	N/A	Y	Y	Y	Y
Dumontier [17]	Y	N	N/A	Unclear	Y	N	Unclear
Eichhorn [24]	Unclear	Unclear	N/A	Unclear	Unclear	N	Unclear
Erdman [16]	Y	Unclear	N/A	Unclear	Unclear	N	Y
Ferdinand [22]	Y	Unclear	N/A	Y	Y	Unclear	Y
Jacobsen [20]	Unclear	Unclear	N/A	N	Y	Y	Y
MacDermid [25]	Unclear	Unclear	N/A	Y	Unclear	Unclear	Y
Malhotra [27]	Y	Y	N/A	Unclear	Y	N	Y
Saw [26]	Y	Y	N/A	Y	Y	Y	Y
Sennwald [18]	Y	Y	N/A	Unclear	Y	N	Unclear
Stark [21]	Unclear	Unclear	N/A	Unclear	Y	Y	Y
Trumble [23]	Y	Unclear	N/A	Y	Y	Unclear	Y

Y low risk of bias, *N* high risk of bias, *Unclear* unclear risk of bias, *N/A* not applicable

3 months after surgery (RR 1.13, 95 % CI 0.98–1.31, $P = 0.10$, $I^2 = 0$ %) (Fig. 3, upper panel). The pooled risk ratio of three trials [8, 21, 29] including 340 hands for the relief of pain after 3 months indicated that there was no statistical difference between the two methods (RR 1.02, 95 % CI 0.92–1.14, $P = 0.71$, $I^2 = 0$ %) (Fig. 3, lower panel).

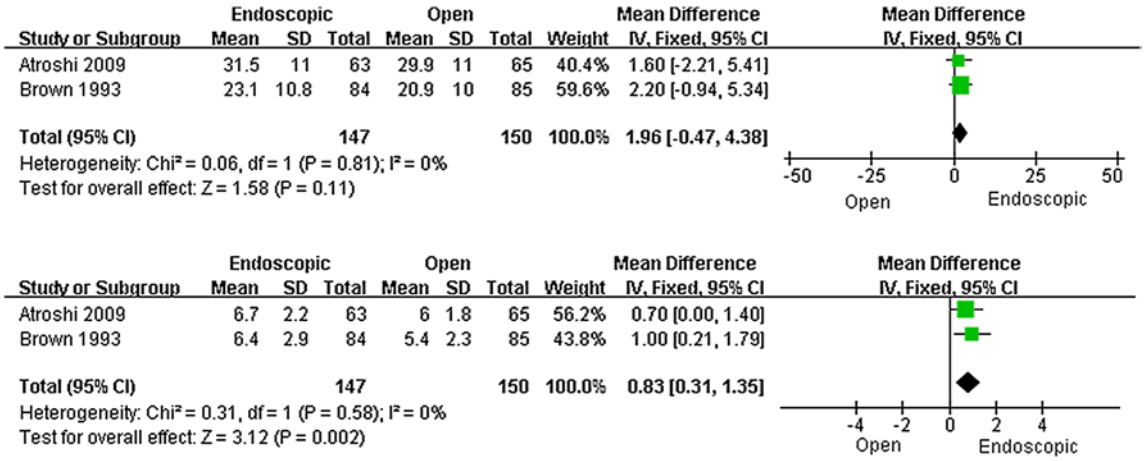

Fig. 2 *Upper panel* forest plot showing the recovery of grip strength in 3 months (Kg) for ECTR and OCTR. *Lower panel* forest plot showing the recovery of pinch strength in 3 months (Kg) for ECTR and OCTR. SD, standard deviation

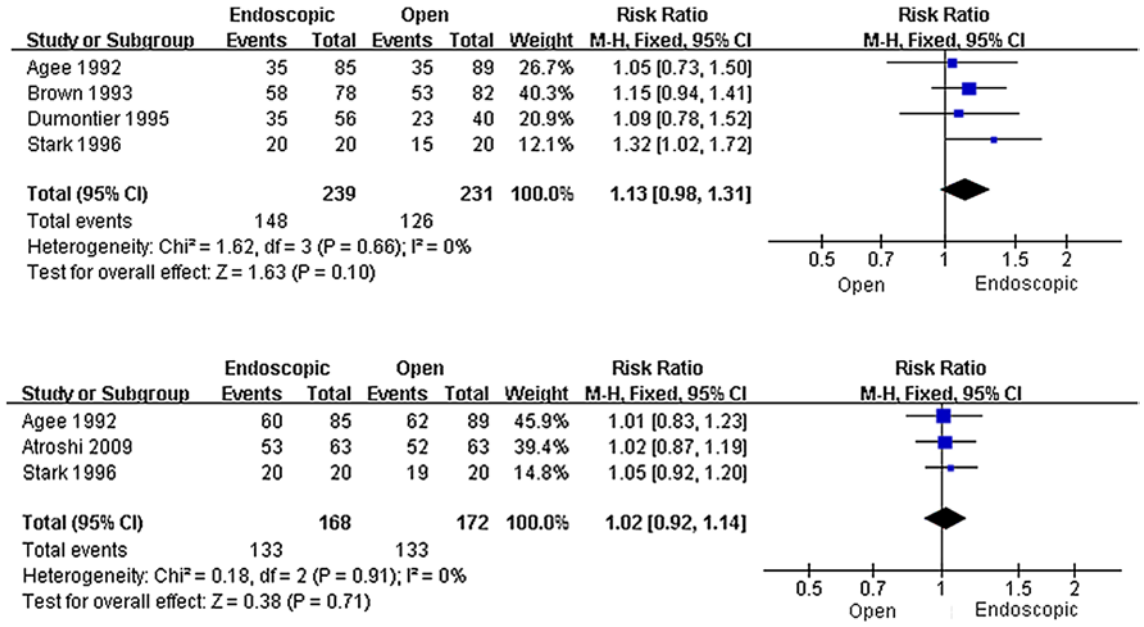

Fig. 3 *Upper panel* forest plot showing the relief of pain in 3 months or less for ECTR and OCTR. *Lower panel* forest plot showing the relief of pain after 3 months for ECTR and OCTR

A fixed-effects model meta-analysis of five trials [8, 15, 17, 21, 27] including 552 hands yielded a pooled risk ratio indicated that there was no statistical difference in relief of paresthesia at or before 3 months between ECTR and OCTR (RR 0.94, 95 % CI 0.85–1.04, $P = 0.21$, $I^2 = 43$ %) (Fig. 4, upper panel). Data pooled from three studies [8, 21, 27] involving 296 hands indicated that there was no statistical difference in relief of paresthesia more than 3 months after surgery between two methods (RR 1.07, 95 % CI 0.98–1.17, $P = 0.12$, $I = 0$ %) (Fig. 4, lower panel).

Time of return to work time (days)

Data pooled from four studies [20, 26, 29, 30] involving 362 hands indicated that OCTR resulted in significantly longer return to work than ECTR (−8.21 days, 95 % CI −9.79 to −6.63, $P < 0.00001$, $I^2 = 41$ %) (Fig. 5, upper panel).

Reoperation rate

Data pooled from seven trials [8, 16, 23–27] including 1,031 hands indicated that there was no statistical

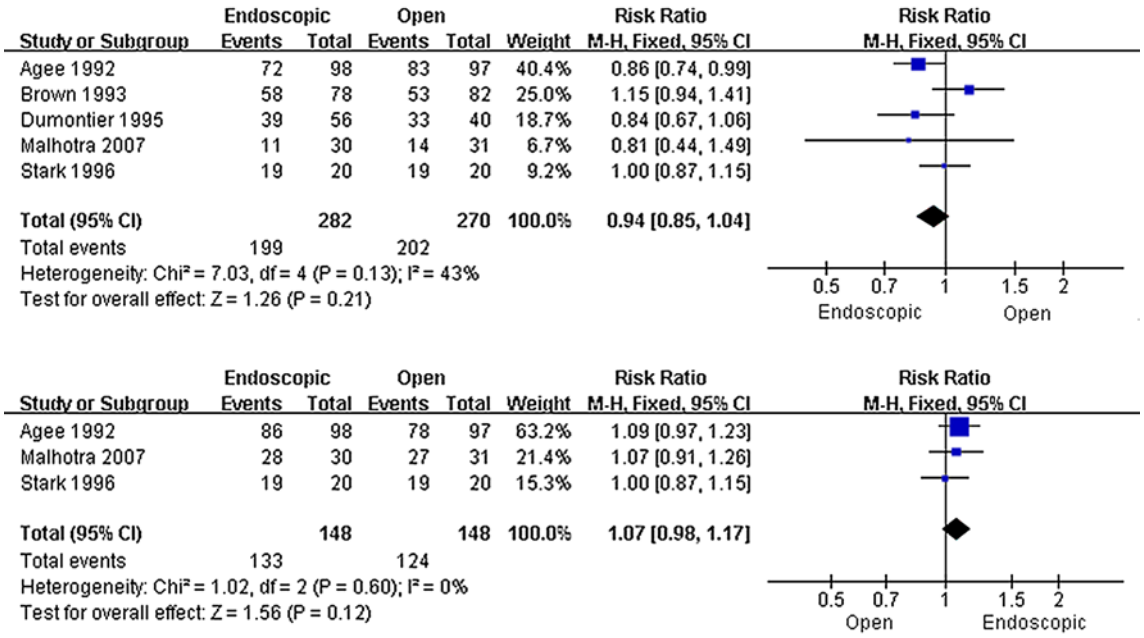

Fig. 4 *Upper panel* forest plot showing the relief of paresthesia in 3 months or less for ECTR and OCTR. *Lower panel* forest plot showing the relief of paresthesia after 3 months for ECTR and OCTR

difference in reoperation rate between ECTR and OCTR (RR 1.18, 95 % CI 0.53–2.63, $P = 0.68$, $I^2 = 0$ %) (Fig. 5, lower panel).

Complications

Data pooled from three studies [8, 16, 22] of 302 hands indicated a non-significant excess in irreversible nerve damage after OCTR relative to ECTR (RR 0.31, 95 % CI 0.05–1.91, $P = 0.21$, $I^2 = 0$ %) (Fig. 6, upper panel). Data pooled from seven trials [7, 14–17, 19, 25] including 746 hands indicated that a significantly higher number of reversible nerve problems occurred with ECTR than OCTR (RR 2.90, 95 % CI 1.14–7.36, $P = 0.02$, $I^2 = 0$ %) (Fig. 6, lower panel). Data from seven studies [8, 16, 20, 22, 24, 26, 27] involving 733 hands indicated that there were significantly more issues with wounds with OCTR than with ECTR (RR 0.34, 95 % CI 0.12–0.96, $P = 0.04$, $I^2 = 0$ %) (Fig. 7, upper panel). Data from four studies [17, 18, 23, 27] including 396 hands indicated a non-significant excess in the reflex sympathetic dystrophy after OCTR (RR 0.35, 95 % CI 0.10–1.24, $P = 0.10$, $I^2 = 0$ %) (Fig. 7, lower panel).

Discussion

This meta-analysis included data from 15 randomized controlled trials involving 1,596 hands with CTS. Our meta-analysis indicated that ECTR resulted in significantly better recovery of pinch strength, significantly earlier time of return to work, and a significantly higher rate of reversible nerve problems (including neurapraxia and numbness) than OCTR. ECTR resulted in non-significant excess in irreversible nerve damage and reflex sympathetic dystrophy compared to OCTR. There were statistically fewer wound problems (including wound infection, wound hematoma, and wound dehiscence) with ECTR compared with OCTR. Our meta-analysis also indicated that there were no statistical differences between the two procedures in relief of symptoms (pain and paresthesia), recovery of grip strength and reoperation rate.

As in most meta-analysis, we have to carefully consider the possible limitations of the study in interpreting the results. First, our meta-analysis was conducted with a common method and design to allow for reproducible research selection and inclusion. Studies were identified by electronic searches of CENTRAL, PUBMED, and EMBASE without restriction of language. Although the search strategy was broad and extensive, not all related randomized controlled trials were included mainly because of publication bias, which may exclude obvious outcome differences of the two treatment methods [33]. In this meta-analysis, we did not include the possibility of publishing bias because of the small number of studies included. Second, the results of an observational study may be influenced by unmeasured confounders such as physical activity, infective factors, and environmental effect. These may be

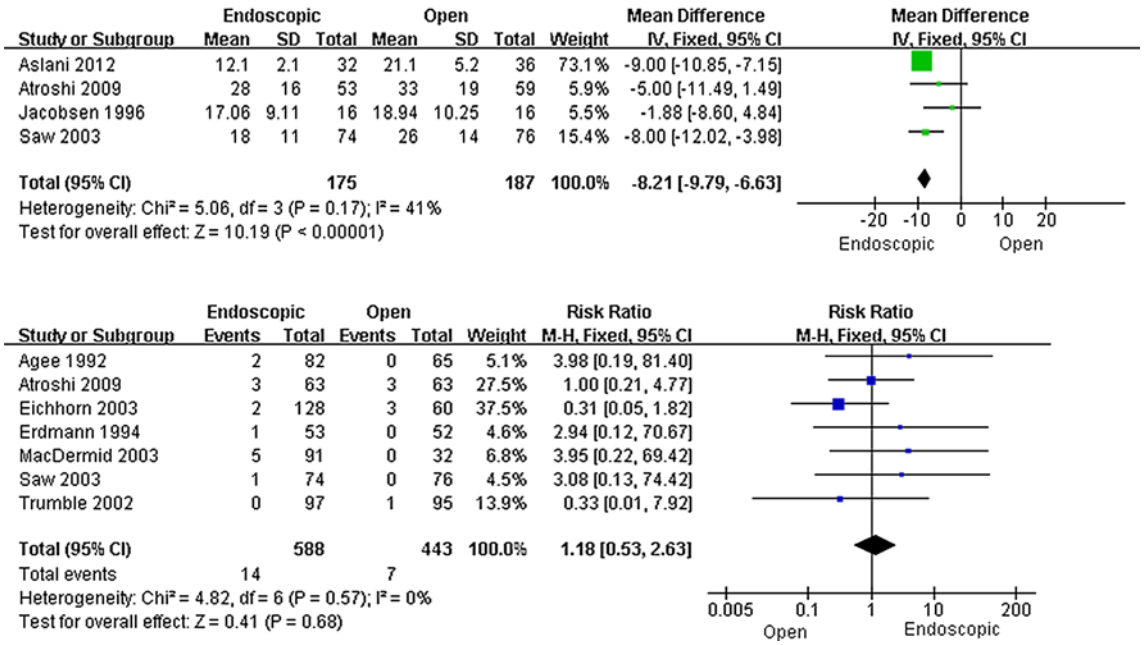

Fig. 5 *Upper panel* forest plot showing the time of return to work (days) for ECTR and OCTR. *Lower panel* forest plot showing the rate of reoperation for ECTR and OCTR. SD, standard deviation

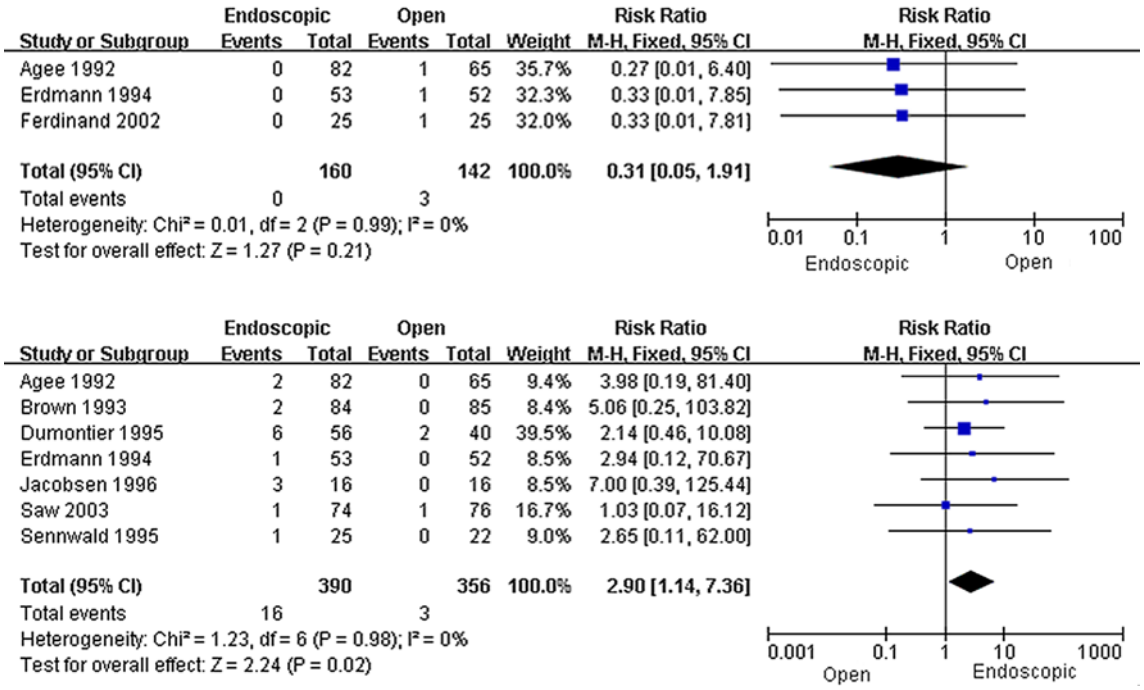

Fig. 6 *Upper panel* forest plot showing the irreversible nerve damage resulting from ECTR and OCTR. *Lower panel* forest plot showing the reversible nerve problems that result from ECTR and OCTR

related to the treatment of CTS, but not evaluated in our study. Third, the number of trials included in each analysis was low and a lack of treatment-provider blinding may have introduced detection bias, whereby the assessors are likely to have preferentially attributed injury occurrence to the control group.

Relief of symptoms is important for evaluation of the effectiveness of two methods. Thoma [11] found that there

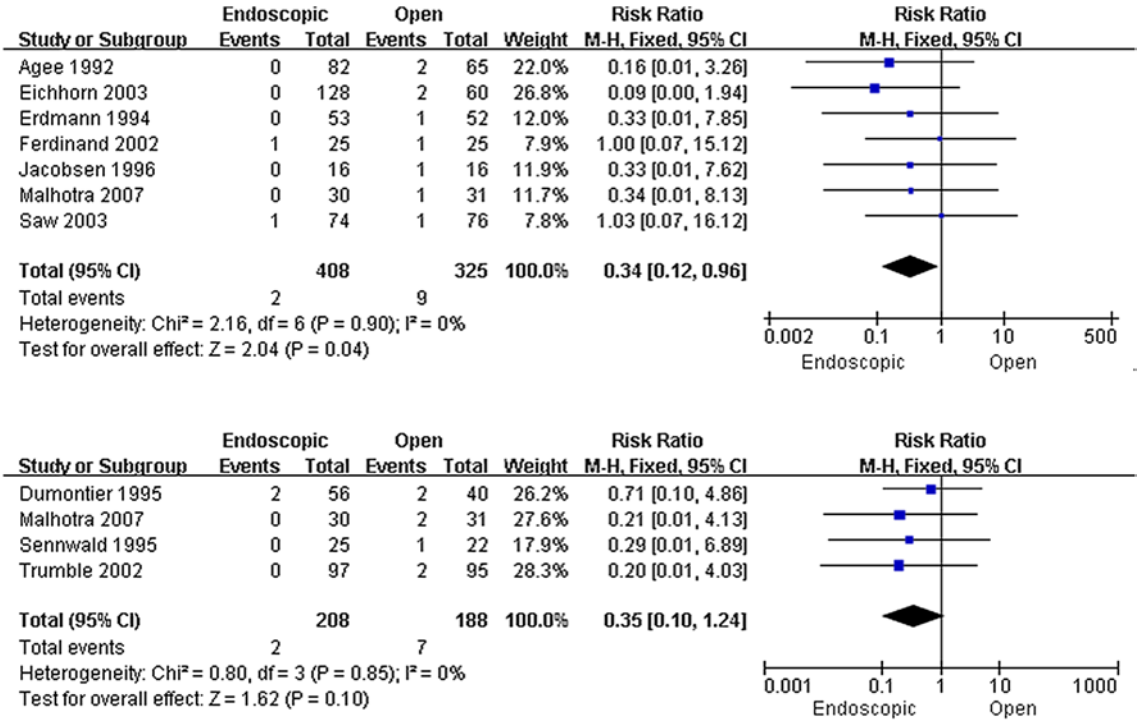

Fig. 7 *Upper panel* forest plot showing the wound problems resulting from ECTR and OCTR. *Lower panel* forest plot showing the reflex sympathetic dystrophy resulting from ECTR and OCTR

were no statistical differences in short-term pain outcomes between ECTR and OCTR. In our meta-analysis, we found no statistical differences between ECTR and OCTR in either short-term or long-term relief of symptoms including pain and paresthesia. Thoma [11] concluded that for grip and pinch strength, ECTR resulted in better outcomes at short-term follow-up. In our meta-analysis, we found that ECTR resulted in non-significant differences in recovery of grip strength but the better recovery of pinch strength compared with OCTR in short-term follow-up.

Scholten [7] previously reported a weighted mean difference in time to return to work as 6 days earlier in the ECTR group than the OCTR group. Thoma [11] analyzed data pooled from three studies and found no significant difference between the two techniques in return to work time. Our meta-analysis included several high-quality randomized controlled trials not included in the Thoma study. We found that ECTR resulted in 8 days earlier return to work than OCTR. Patients who suffered persistent symptoms after the surgical techniques often require reoperation. Scholten [7] found a slight, but not significant, excess of repeat surgery after ECTR. In our study, which included more randomized controlled trials, there was no statistical difference in reoperation rates.

The numbers of complications suffered by patients can be used to evaluate the safety of the methods. Thoma [11] reported that reversible nerve damage was three times more likely with ECTR than OCTR. In our analysis, the rate of reversible nerve problems was higher in ECTR hands than OCTR hands, and the rate of wound problems was lower for ECTR than OCTR. Most of the reversible nerve problems appear to resolve within a few weeks and are probably caused by neuropraxia due to the instrumentation [34]. Only three studies [8, 16, 22] reported the irreversible nerve problems, and all occurred after OCTR. We also found a non-significant excess in the reflex sympathetic dystrophy after OCTR. We consider ECTR safer than OCTR because of lower rates of irreversible nerve problems, wound problems, and reflex sympathetic dystrophy.

OCTR was the gold standard for carpal tunnel decompression [5] as we mentioned before. However, ECTR resulted in better recovery of function, earlier return to work and safer than OCTR based on our meta-analysis. So, we recognize that ECTR will be more widely used for the treatment of CTS in the future.

Conclusion

In summary, our meta-analysis included data from more randomized controlled trials than were previously available to demonstrate that ECTR and OCTR were similar in relief of symptoms. ECTR resulted in a better recovery of

function and earlier return to work and was determined to be safer than OCTR.

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