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Endoscopy-assisted versus open tissue expander placement in plastic and reconstructive surgery: a meta-analysis

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ABSTRACT

Tissue expansion can be used to overcome challenges due to tissue deficiency in plastic and reconstructive surgery; however, the long expansion process is often accompanied by numerous complications. This meta-analysis aimed to determine whether endoscopy-assisted expander placement could decrease complications and shorten treatment time. This study followed the principles of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) and was registered in PROSPERO (CRD42021226116). A literature search was performed in eight databases from their inception dates up to 25 August 2021, to identify clinical studies on endoscopy-assisted and/or open tissue expander placement in plastic and reconstructive surgery. Seven studies met the inclusion criteria. In seven studies, 194 underwent endoscopy-assisted expander placement, and 565 underwent open expander placement. The overall complication rate in the endoscopy-assisted group was significantly lower than that in the open group (risk difference (RD) -0.28 , 95% confidence interval (CI), -0.38 , -0.18 , $p < .001$). Subgroup analysis showed significantly lower incidence rates of hematoma, infection and dehiscence in the endoscopy-assisted group. The complication rate in the head/neck was lower with low heterogeneity (RD, -0.18 ; 95% CI, -0.26 to -0.09 , $p < .001$; $I^2 = 0\%$). The endoscopy-assisted group had shorter surgery time, hospital stay and time to full expansion (weighted mean difference (WMD), -13.97 min, -16.88 h, -27.54 days; 95% CI, -15.85 , -12.08 min, -24.36 , -9.40 h, -38.85 , -16.24 days; both $p < .001$, respectively). Endoscopy-assisted expander placement may help lower the risk of complications, especially in the head/neck, and reduce surgery time, hospital stay, and time to full expansion.

Abbreviations: CI: confidence interval; CNKI: China National Knowledge Infrastructure Database; CSTJ, China Science and Technology Journal Database; NOS: the Newcastle–Ottawa Scale; PRISMA: preferred reporting items for systematic reviews and meta-analyses; RCT: randomized controlled trial; RoB: the cochrane risk-of-bias; RD: risk difference; WMD: weighted mean difference; SE: standard error; SND: standard normal deviate

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Introduction

Severe tissue deficiency can pose major challenges during plastic and reconstructive surgery for conditions, such as battlefield wounds, scar deformity involving large areas, and superficial organ deformation [1–3]. Traditional methods, such as skin graft, local flap, distant flap, regional flap and free-tissue transfer are all at the expense of tissue loss in donor areas and possible new damage and scarring [4]. Tissue expansion, introduced by Neumann, Radovan, Austad and other scholars, has many obvious advantages in such situations and has become one of the most popular techniques in plastic and reconstructive surgery [5–7].

While tissue expansion techniques can generate extra skin and soft tissue of the exact color and texture necessary for reconstruction in a specific area, without the risk of inducing defects or scarring in a donor area [2,8], the lengthy process and the high complication rate are important disadvantages. In previous studies, the complication rate of tissue expansion ranged from 4% to 63% (mean, 17%) [9]. The expansion time of several weeks or months also entails much inconvenience and pain to patients. Traditionally, expanders were placed through an incision made at the edge of

the defect. These incisions needed to be of sufficient length to allow unimpeded vision during dissection of the pocket [10]. The large surgical incisions and the delayed injection of expanders often result in longer hospital stay. However, with the introduction of endoscopy, it has become possible to place an expander under direct visualization through a small incision. Many plastic surgeons believe that endoscopic placement of expanders reduces complications and shortens surgery time and the time to full expansion, as well as hospital stay [8,11–16]. However, to date, no evidence-based study has evaluated the benefits of endoscopy-assisted expander placement versus traditional techniques (open expander placement). This meta-analysis aimed to determine whether endoscopy-assisted expander placement can lower the complication rate of tissue expansion and shorten the treatment time.

Methods

This study followed the principles of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [17]. The protocol for this meta-analysis is available in PROSPERO

(<https://www.crd.york.ac.uk/prospero/>; registered number: CRD42021226116).

Search strategy

On 25 August 2021, the online databases of PubMed, Embase, Web of Science, Cochrane Library, China National Knowledge Infrastructure Database (CNKI), China Science and Technology Journal Database (CSTJ), Wanfang Data and SinoMed were searched for studies that evaluated endoscopy-assisted expander placement and/or open expander placement in plastic and reconstructive surgery. The search was conducted using the medical subject headings terms 'tissue expansion', 'tissue expansion devices', 'endoscopy' or related free terms. There were no restrictions on the publication time. The search strategy is reported in detail in Supplement 1.

Study selection criteria

Studies were eligible for inclusion in this meta-analysis only if (1) they were written in English or Chinese languages; (2) they were randomized controlled trials (RCTs), prospective cohorts, retrospective cohorts or retrospective case-control studies; (3) patients underwent tissue expansion by the open and/or endoscopic method; and (4) complication rate was reported, with or without other outcomes, such as surgery time, hospital stay and time to full expansion. Complications of expander placement were defined as abnormalities of soft tissues around the expander between expander placement and removal; thus, the complications included seroma, hematoma, infection, wound dehiscence, extrusion, deflation or failure of expansion.

Case reports or series, reviews, letters, animal/*in vitro* studies and duplicated publications were excluded.

Risk-of-bias assessment

Two researchers (CD and ZY) independently assessed the methodological quality of the studies; disagreements were resolved by discussion or by consultation with a third researcher (X-JM). The Cochrane risk-of-bias (RoB) tool was used to evaluate RCTs [18]. Only if all key domains showed low risk of bias was the RCT classified as high quality; if any key domain showed high risk of bias, the RCT was classified as low quality [18]. The Newcastle–Ottawa Scale (NOS) was used to evaluate the quality of cohort studies [19]; a score ≥ 7 stars was considered to indicate a low risk of bias [20].

Data extraction

Two researchers (CD and ZY) independently reviewed the selected publications and recorded the following: name of first author, year of publication, language of article, country, mean patient age and other characteristics, study design, number of patients receiving endoscopic expander placement and open expander placement surgery time, hospital stay, time to full expansion, follow-up time, and total and individual complication rates. Disagreements between researchers were resolved through discussions.

Statistical analysis

A random effects model was used for the meta-analysis. The risk difference (RD) was calculated for complication rates, and the weighted mean difference (WMD) for other outcomes, and 95%

confidence intervals (95% CIs) were also calculated. The Mantel–Haenszel chi-square test was used to evaluate heterogeneity, and the I^2 statistic was used to assess its impact on the meta-analysis. In this study, $p < .10$ or $I^2 > 50\%$ was considered to indicate significant heterogeneity [21]. Subgroup analysis was performed to determine the influence of different complications (hematoma, infection, extrusion, dehiscence and deflation) on the pooled effects. Sensitivity analysis was performed by excluding studies one by one and observing whether the new pooled result changed significantly (i.e. whether the new point estimate was outside the 95% CI of the original total pooled effect) [22]. Publication bias was assessed using funnel plots, Egger's regression test and Begg's rank test [23–25]. Meta-regression analysis, with restricted maximum-likelihood, was used to evaluate associations between treatment effect (RD of total complications) and study characteristics (research type, article language, study population) [26]. Review Manager 5.4 software (The Cochrane Collaboration, 2020; London, UK) and Stata 15 software (StataCorp LLC, 2017, College Station, TX) were used for data analysis. All tests were two-tailed, and statistical significance was set at $p < .05$, unless otherwise specified.

Results

Study selection

The initial database search identified a total of 494 publications (PubMed, 84; EMBASE, 76; Web of Science, 61; Cochrane library, 18; CNKI, 28; CSTJ, 18; Wanfang Data, 22; and SinoMed 187). After screening the titles and abstracts, 453 studies were eliminated. The full texts of the remaining 41 studies were read, and seven studies that met all eligibility criteria were finally included in this meta-analysis. Figure 1 illustrates the study selection process.

Study characteristics

Of the seven included studies, two were RCTs and five were retrospective cohort studies [8,11–16]. They were studies from China, the USA, Russia and Iran. Four articles were in English and three were in Chinese. The seven studies included a total of 759 patients and more than 1142 expanders. While 194 patients received endoscopy-assisted expander placement, 565 patients received open expander placement. Table 1 lists the characteristics of the included studies and the follow-up durations.

Risk of bias within studies

The Cochrane RoB tool showed an unclear risk of bias in one RCT and a high risk of bias in the other RCT (Figure 2). The NOS showed a low risk of bias (≥ 7 stars) in all five cohort studies (Table 2).

Synthesis of results

The overall complication rate was significantly lower in patients who underwent endoscopic expander placement than in those who had open placement (RD, -0.28 , 95% CI, -0.38 , -0.18 , $p < .001$; Figure 3). Furthermore, as shown in Figure 4, endoscopic expander placement was associated with significantly shorter surgery time (WMD, -13.97 min; 95% CI, -15.85 , -12.08 min, $p < .001$), shorter hospital stay (WMD, -16.88 h; 95% CI, -24.36 to -9.40 h, $p < .001$) and shorter time to full expansion (WMD, -27.53 days, 95% CI, -38.82 , -16.24 days, $p < .001$). Notable heterogeneity was observed among studies evaluating total

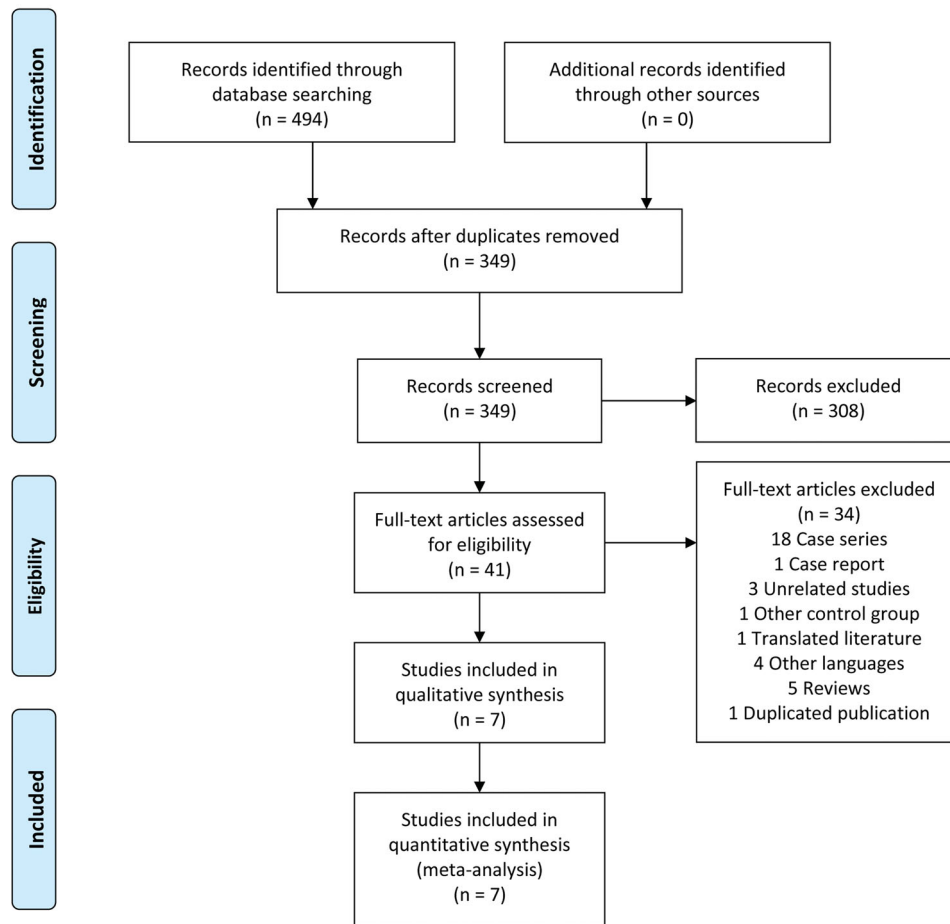


Figure 1. Study selection flowchart.

complications ($I^2=65\%$, $p<.001$) and time to full expansion ($I^2=94\%$, $p<.001$).

Subgroup analyses

Subgroup analyses were performed for different complications and anatomical locations. Z statistics for the overall effect of hematoma (RD, -0.09 ; 95% CI, -0.15 to -0.03), infection (RD, -0.12 ; 95% CI, -0.18 , -0.05) and dehiscence (RD, -0.06 ; 95% CI, -0.10 to -0.03) exhibited significant differences at 2.89 ($p=.003$), 3.63 ($p<.001$) and 3.65 ($p<.001$), respectively. However, there were no statistically significant differences in the extrusion rate (RD, -0.06 ; 95% CI, -0.15 , 0.03 , $p=.200$) and deflation rate (RD, 0.05 ; 95% CI, -0.06 to 0.17 , $p=.360$). Moreover, the overall complication rate in the head/neck was significantly lower, along with low heterogeneity (RD, -0.18 ; 95% CI, -0.26 to -0.09 , $p<.001$, $I^2=0\%$). However, in the trunk, the difference in complication rate between endoscopic techniques and open techniques was not statistically significant (RD, -0.38 ; 95% CI, -0.88 , 0.12 , $p=.14$). Only one study compared the two techniques in the extremities. The forest plots in Figures 5 and 6 show the results of subgroup analyses.

Sensitivity analysis

When the included studies were excluded one by one, all the point estimates were within the 95% CI of the total pooled RD of total complications (Table 3), indicating a robust sensitivity.

The funnel plot was symmetrical (if one study was disregarded), indicating no significant publication bias for total complications (Figure 7). Furthermore, Egger's regression test ($p=.548$, Figure 8) and Begg's rank test ($p=.401$) further confirmed the absence of significant publication bias.

Meta-regression analysis of the studies' characteristics did not show any associations affecting the calculated RD of total complications (Table 4), indicating that the heterogeneity of total complications came from other factors.

Discussion

In this study, endoscopy-assisted expander placement and open tissue expander placement in plastic and reconstructive surgery were compared. The results showed that the endoscopic technique was associated with lower complication rates and shorter surgery time, hospital stay, and time to full expansion.

In the early 1990s, plastic surgeons began using video-laparoscopy to aid the placement of expanders [27,28]. One way to establish the cavity was by continuous expansion and bulging using controlled injection of carbon dioxide [28]. Another method did not require the use of a carbon dioxide insufflation device. A special retractor with vertical and lateral movement was applied to keep the optical cavity open by separating the skin from the underlying fascia [10,29]. An endoscope (5-mm or 10-mm diameter, and 0° , 30° or 45°) was inserted into the cavity and, under endoscopic vision, the plane of the area for placement of the expander was carefully dissected sharply or bluntly [30]. Takeuchi et al. and Kovach et al. reported good results in using a balloon

Table 1. Characteristics of the included studies.

First author, year, country	Mean age (years)	Number of females, n (%)	Indication	Study design	Study language	Total number of patients (expanders)	Number of patients (expanders) receiving endoscopic technique	Number of patients (expanders) receiving open technique	Follow-up mean time and rate
Toronto, 2007, USA	23.1 (Open) 34.9 (Endo)	Not specified	Giant congenital nevi, trauma, burns, chronic wounds, and hemias	RCS	English	69 (202)	18 (75)	51 (127)	Expansion duration (one patient was lost to follow-up)
Sharobaro, 2008, Russia	25.1 (Endo)	18 (66.7) (Endo)	Post-burn deformations	RCS	English	356 (826)	27 (46)	329 (780)	Expansion duration 100%
Levi, 2010, USA	28 (Open) 41 (Endo)	15 (100)	Burn breast	RCS	English	13 (33)	6 (16)	7 (17)	52 months 86.7% (13/15)
Mi, 2013, China	35.2	68 (53.1)	Not specified	RCS	Chinese	128 (not specified)	46 (not specified)	82 (not specified)	Expansion duration 100%
As'adi, 2016, Iran	27.2	35 (55.6)	Facial burn scar	RCT	English	63 (81)	32 (43)	31 (38)	16 months 100%
Yu, 2016, China	Not calculated (range, 6–26)	29 (41.2)	Microtia and scar	RCS	Chinese	70 (not specified)	35 (not specified)	35 (not specified)	Expansion duration (matched cohort)
Huang, 2017, China	32.5 (Open) 30.5 (Endo)	28 (46.7)	Scar, nevus, hemangioma, breast cancer	RCT	Chinese	60 (not specified)	30 (not specified)	30 (not specified)	Expansion duration 100%

Endo: endoscopic; RCT: randomized controlled trial; RCS: retrospective cohort study.

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
As'adi 2016	+	+	+	?	+	+	+
Huang 2017	?	?	?	?	+	—	+

Figure 2. Risk of bias assessment for randomized controlled trials.**Table 2.** Newcastle–Ottawa Quality Assessment of the cohort studies.

First author, year	Selection	Comparability	Outcome	Total	Quality
Toronto, 2007	4 stars	1 stars	3 stars	8 stars	High
Sharobaro, 2008	4 stars	1 stars	3 stars	8 stars	High
Levi, 2010	4 stars	1 stars	2 stars	7 stars	High
Mi, 2013	3 stars	1 stars	3 stars	7 stars	High
Yu, 2016	4 stars	2 stars	3 stars	9 stars	High

dissector and endoscopy to facilitate extensive dissection through small incisions, especially in the trunk and limbs [31,32]. After meticulous hemostasis, the expanders are placed in the specified area, and injected after a few days.

Endoscopic expander placement has been previously shown to lower the risk of complications [8,11–16]. In this meta-analysis, a 28% lower pooled risk of complications was demonstrated after endoscopy-assisted expander placement than after traditional open expander placement. Subgroup analysis showed a lower risk of hematoma, infection and dehiscence, which was probably due to the precise hemostasis achieved under endoscopic visualization [11]. Additionally, the small remote incision used in the endoscopic technique reduces the possibility of cavity contamination by outside bacteria. Our previous study found that a hematoma offered an ideal medium for bacterial proliferation and greatly increased the possibility of expander infection [33]. Remote incision, far from the stress of the expansion, also minimizes the chances of wound dehiscence [12].

Whether the risks of extrusion and deflation can be reduced by the endoscopic technique remain controversial [11–13]. Although the use of an endoscope reduces the length of the surgical incision, the pockets for expander placement are not narrowed. In addition, it must be noted that the incidence of

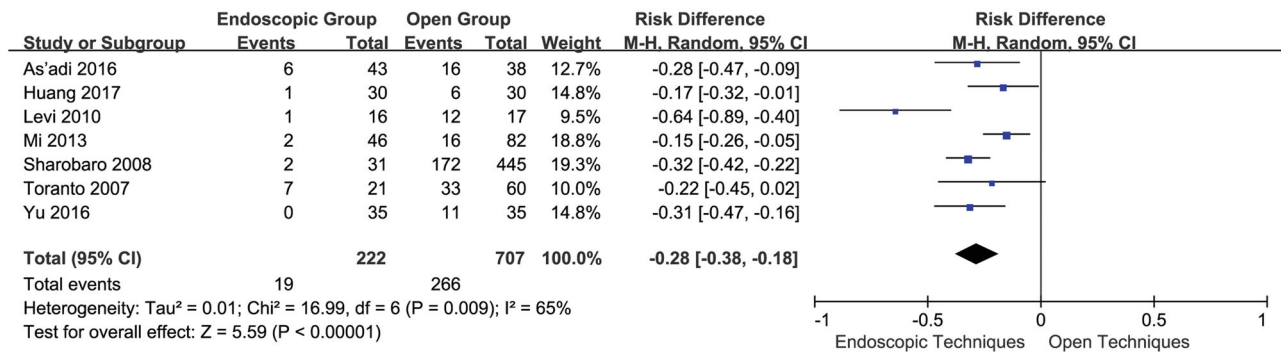


Figure 3. Forest plot for overall complication.

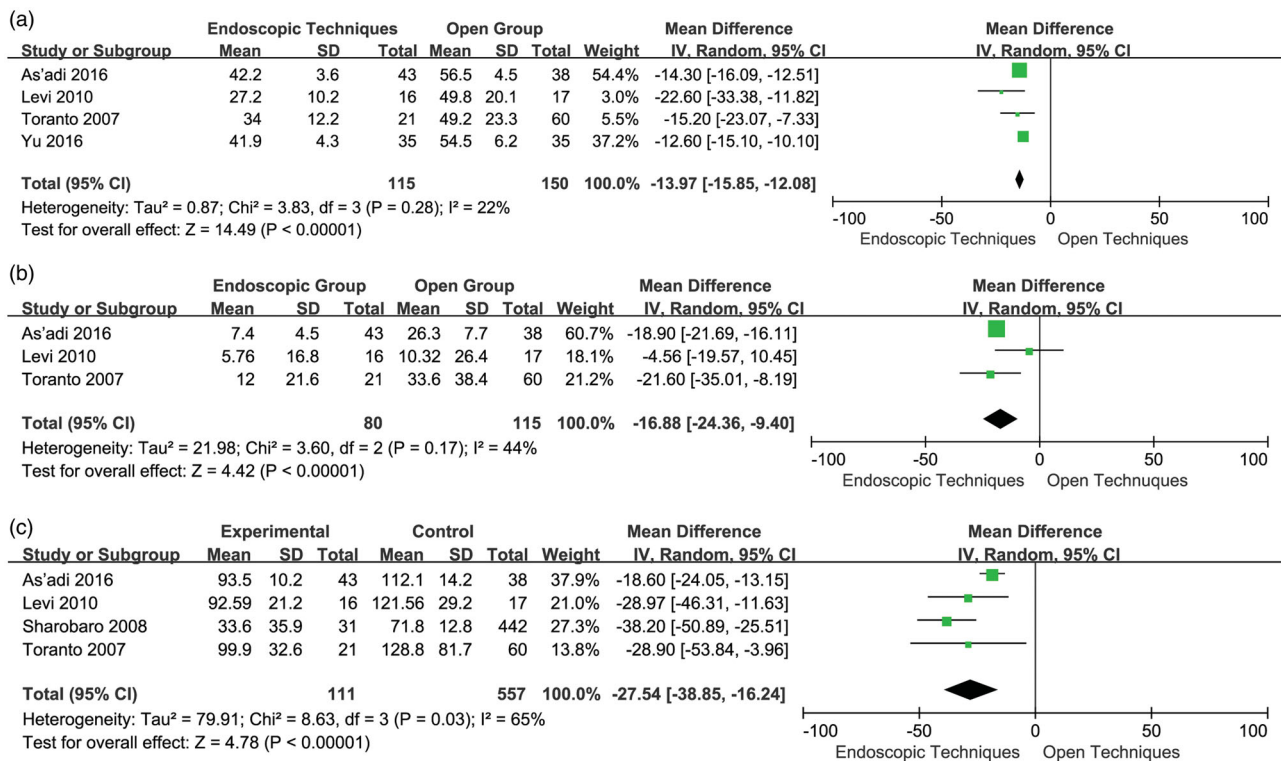


Figure 4. Forest plot for other outcomes. (a) Surgery time; (b) hospital stay; (c) time to full expansion.

deflation is closely related to the quality of the expander, with poor quality expanders being prone to damage and leakage of injection ports [11].

The clinical situations of expander placement were different in different parts of the body and different indications. Thus, a subgroup analysis was conducted based on anatomical location. Three studies showed that the use of an endoscope in the head/neck can significantly reduce the complication rate of expander placement [11,13,14]. Due to the abundant blood supply in the head/neck, many small bleeding points emerge during dissection. Under the magnified view of the endoscope, these bleeding points are easily seen and coagulated. Unfortunately, due to the small number of studies, our study has not yet clarified whether patients who underwent expander placement in the trunk or limbs could benefit from the use of endoscopes. Furthermore, due to the limited information in the previous literature, further subgroup analysis by indications could not be conducted. Attempts were also made to obtain any missing details, but the data were no longer available, or the authors could not be reached.

In this study, surgery time, hospital stay and time to full expansion were significantly shorter in patients who underwent endoscopy-assisted expander placement. Some early studies reported that endoscopy-assisted expander placement requires a longer operative time [28,29], but this was disproved by later research that showed that the endoscopic technique could significantly shorten placement time, especially when more than one expander had to be placed [11–13,15]. These contradictory conclusions may be due to differences in the proficiency of the surgeons in endoscopic procedures. The small and remote incision, and the earlier initiation of expansion, all contribute to shortening the hospital stay and time to full expansion. Importantly, without complications that interfere with the process of expansion, fluid injection can be safely performed at an early stage.

The major advantages of endoscopy-assisted expander placement over open expander placement can be summarized as follows: (1) the endoscope allows the surgeon to dissect a wide area through a small, remote incision [29]; (2) the risk of wound dehiscence is reduced [34,35]; (3) expansion can be initiated earlier and the duration of expansion can be shortened [34–36]; (4)

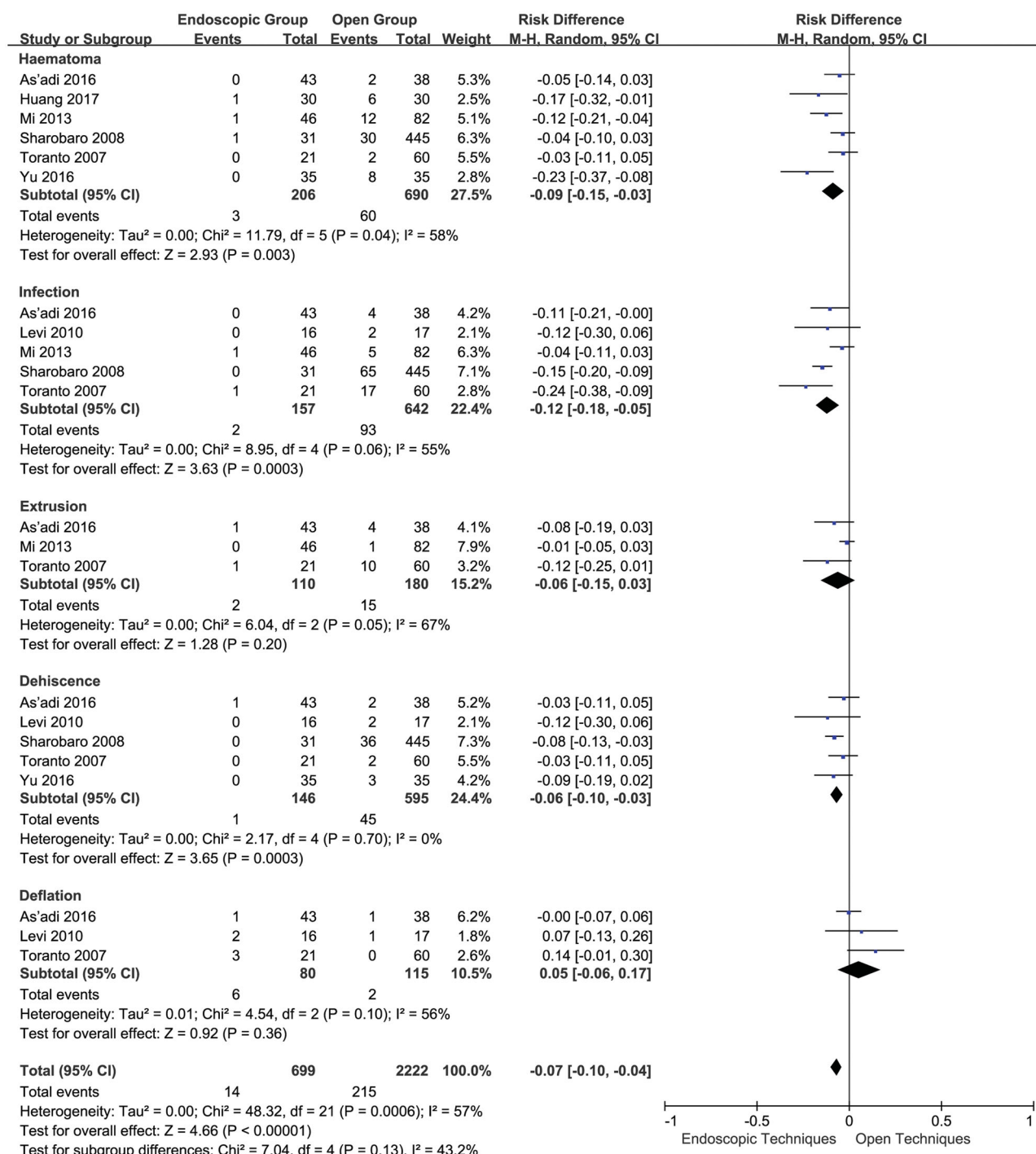


Figure 5. Forest plot for different complications (subgroup analysis).

appearance of subcutaneous hemorrhage can be closely monitored because of the clear, magnified view [29]; and (5) under direct vision, the dissection planes and blood vessels can be better recognized [37]. Meanwhile, the disadvantages are (1) the application of an endoscopy calls for a video system, a light source, and extra surgical instruments, which increases costs [28] and (2) the surgeon needs to be specially trained in the procedure [28,29].

The indications for endoscopic tissue expander placement and for traditional open expander placement are similar [27]. However, previous reports suggest that the endoscopy-assisted technique may be particularly suited for pediatric patients (because of less surgical trauma) [38–41], for treatment in the

facial or cervical region (because of the better hemostasis) [13,34], for the treatment of cases that require wide dissection (because of the better visualization) [10,42,43], and for expander placement in the head/neck [11,13,14].

This study has some limitations. First, in our cohort, the main indications for expander placement were scar and breast reconstruction, which may be an important source of heterogeneity in the pooled results. Second, although eight literature databases were searched, the number of articles that met the eligibility criteria was relatively small, and only two were RCTs. However, the total number of patients was large and most studies were of good quality, with no evidence of publication bias.

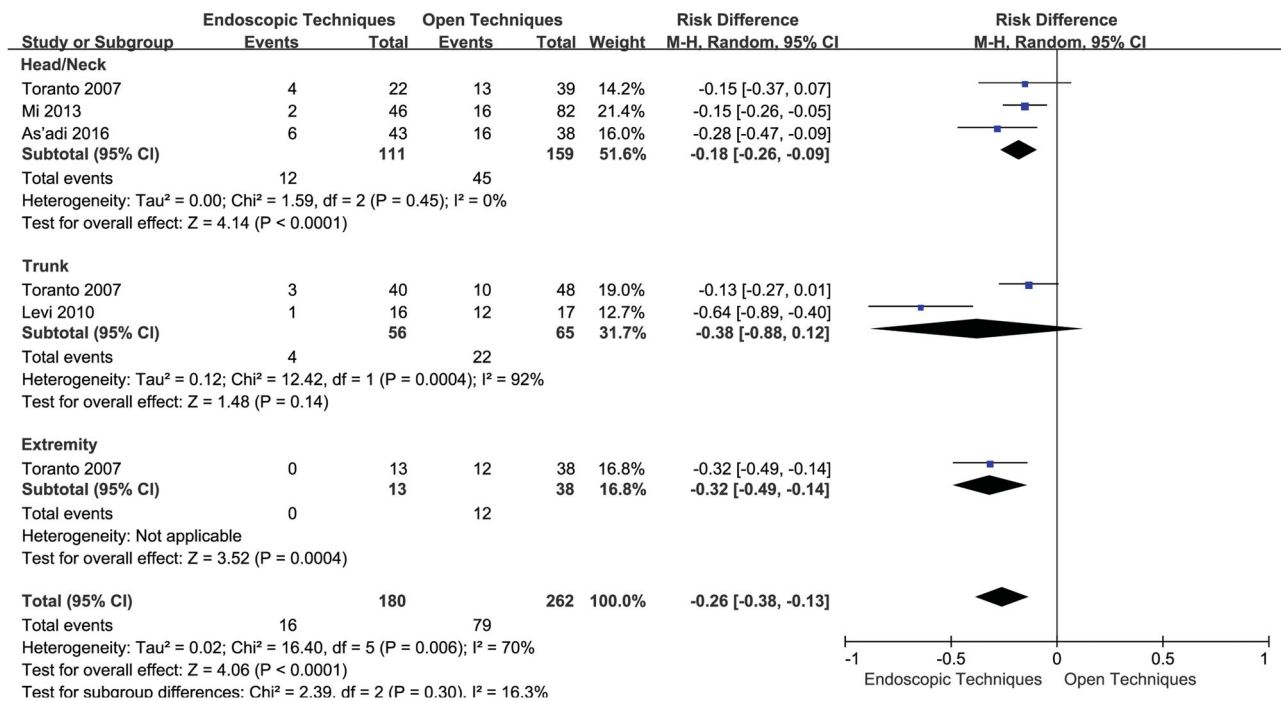


Figure 6. Forest plot for different anatomic locations (subgroup analysis).

Table 3. Sensitivity analysis.

Study omitted	Risk difference	95% CI	I^2
Toronto, 2007	-0.29	-0.40, -0.18	70%
Sharobar, 2008	-0.28	-0.40, -0.15	67%
Levi, 2010	-0.24	-0.31, -0.17	32%
Mi, 2013	-0.31	-0.41, -0.21	54%
As'adi, 2016	-0.28	-0.40, -0.17	70%
Yu, 2016	-0.28	-0.39, -0.16	70%
Huang, 2017	-0.30	-0.41, -0.19	67%

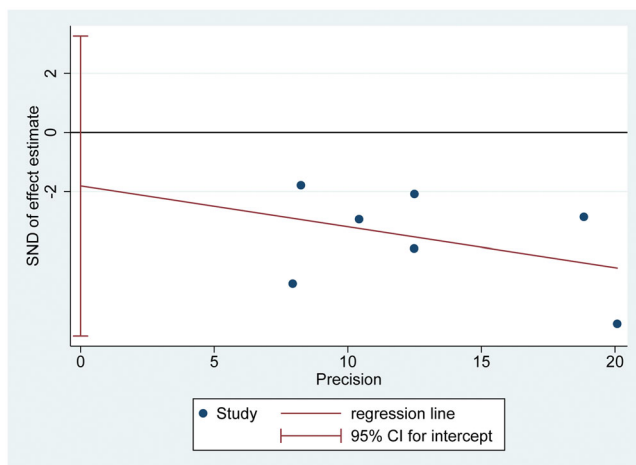


Figure 7. Funnel graph for assessing publication bias. SE: standard error; RD: risk difference.

Table 4. Results of meta-regression.

Variable	Coefficient	SE	p	95% CI
Research type	-0.06	0.21	.792	-0.72, 0.60
Article language	0.11	0.25	.677	-0.68, 0.91
Population of subjects	-0.04	0.30	.905	-0.98, 0.90

SE: standard error.

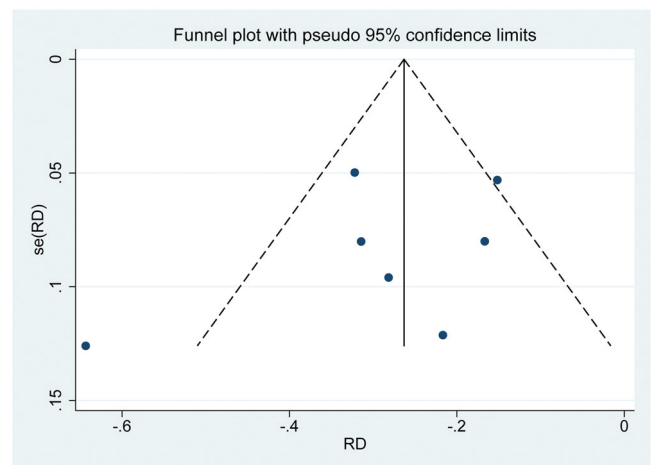


Figure 8. Egger funnel graph. SND: standard normal deviate; CI: confidence interval.

Conclusions

Endoscopic placement of expanders may lower the risk of complications, especially in the head/neck, such as hematoma, infection and dehiscence, and could also shorten surgery time, hospital stay and time to full expansion. Further studies, preferably randomized clinical trials, are needed to confirm the benefits of endoscopic-assisted tissue expander placement.

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Disclosure statement

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