Obesity Surgery (2019) 29:3021–3029
https://doi.org/10.1007/s11695-019-04010-3

REVIEW ARTICLE

Endoscopic Gastric Plication for Morbid Obesity: a Systematic Review and Meta-analysis of Published Data over Time

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Published online: 22 June 2019

Abstract

Endoscopic gastric plication or gastroplasty for morbid obesity is gaining worldwide recognition. Data concerning safety and efficacy are rather scarce. Furthermore, clear guidelines are yet to be established. The objective of this meta-analysis is to update the data and investigate the efficacy and safety of the procedure. An online comprehensive search using Cochrane, Google Scholar, PubMed, Web of Science, and Embase on endoscopic gastric plication was completed. The primary outcome was defined as weight loss at 6 months or more after the procedure. Secondary outcomes were defined as the occurrence of adverse events or complications including insufficient weight loss or regain. I^2 statistic was used to define the heterogeneity across studies. Twenty-two cohort studies on 7 different devices met the inclusion criteria, with a total of 2475 patients. The mean baseline BMI was 37.8 ± 4.1 kg/m^2 (median 37.9; range 28.0–60.2). Either a transoral endoluminal stapling or (suction based) (full-thickness) stitching and/or anchor device was used to obtain gastric volume reduction and/or alter gastric outlet. The mean follow-up was 13 months (median 12; range 6–24) for the specified outcomes of each study. Two active, FDA-approved devices were taken into account for meta-analysis: Endoscopic sleeve gastroplasty (ESG) and the primary obesity surgery endolumenal (POSE™). Average pooled %EWL at 6 months ($p = 0.02$) and 12 months ($p = 0.04$) in favor of ESG was 57.9 ± 3.8% (50.5–65.5, $I^2 = 0.0$), 44.4 ± 2.1% (40.2–48.5, $I^2 = 0.0$), and 68.3 ± 3.8% (60.9–75.7, $I^2 = 5.8$), 44.9 ± 2.1% (40.9–49.0, $I^2 = $ N/A) for ESG and POSE respectively. Major adverse events without mortality were described in 25 patients (9 studies, $p = 0.63$). ESG and POSE are both safe and feasible procedures with good short-term weight loss. ESG seems to be superior in terms of weight loss at this point. Few major adverse events are reported and long-term results are awaited.

Keywords Endoscopic · Sleeve · Gastroplasty · Bariatric · Remodeling · Meta-analysis · Review · ESG · Pose

Introduction

Obesity is a worldwide epidemic health problem associated with a substantial increase in morbidity and mortality. The World Health Organization (WHO) reports a tripling of morbid obesity since 1975 [1].

Bariatric surgery has the ability to provide durable weight loss, and effective remission and prevention of comorbidities like type 2 diabetes, hypertension, and dyslipidemia [2–4]. The quest for minimally invasive techniques is boundless and especially in obese patients, the benefits are enormous due to higher inherent surgical morbidity and mortality.

Endoscopic gastroplasty for morbid obesity is a NOTES (natural orifice transluminal endoscopic surgery) minimally invasive, mostly restrictive procedure which is becoming more popular these days. The background idea of the procedure is however not new and multiple devices with different specifications have been introduced, evaluated, adapted, and some of them disappeared without notice. No (randomized) high-quality long-term evidence is available at this moment.

Our aim was to perform a systematic review and meta-analysis to determine the efficacy and moreover, the safety of endoscopic gastric plication for the treatment of obesity.

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Methods

Sources

An online-only comprehensive query on Cochrane, Google Scholar, PubMed, Web of Science, and Embase on endoscopic gastroplasty was conducted. Publications with the keywords: "endoscopic" and "gastroplasty" were evaluated (search strings are depicted in Appendix 1). Additionally, references of reviews were checked for any other relevant articles.

Endoscopic gastric plication was defined as an endoscopic-only remodeling procedure with the objective to at least reduce gastric volume in order to obtain intake restriction and thus facilitate weight loss. Only English clinical trials that presented primary endoscopic gastric plication (or gastroplasty) without concomitant interventions and reported a follow-up of at least 6 months were included (inclusion criteria are depicted in Table 1).

Selection of studies

Screening of articles based on title and abstract was performed by 2 blinded reviewers. The preliminary search identified 86 potential studies that were selected for further evaluation. If a discussion regarding the inclusion of an article was to happen, a third party would have been addressed; however, this was never the case. After screening abstracts and titles, full-text was obtained for 31 articles. Final evaluation led to the inclusion of 22 articles (search strategy is depicted in Fig. 1).

Data Selection

Each article was investigated for demographic data, technical characteristics of the device used, post-interventional weight evolution, and adverse events including technical failure and weight regain. The primary outcome was defined as weight loss at 6 months after the intervention. Secondary outcomes were defined as the occurrence of adverse events or complications including insufficient weight loss or regain during follow-up. Only commercially active, FDA-approved devices were taken into account for meta-analysis.

Table 1 Inclusion and exclusion criteria used in search strategy

Inclusion criteria	Exclusion criteria
Clinical trials	Study design other than clinical trial
Primary intervention	No endoscopic gastroplasty
English	Weight loss not mentioned as an primary outcome measure
Publish date between 1/8/2003 and 1/4/2019	Concomitant surgical procedures
Full text available	Other indication than morbid obesity

Statistics

Weight data was evaluated using excess weight (EW), percentage excess weight loss (%EWL), and body mass index (BMI). Average pooling was applied after analysis of data.

I^2 statistic was used to define the heterogeneity across the publications and when present, a random effect model was used to generate pooled estimates. Analysis of the data was performed using a 95% confidence interval. A p value of < 0.05 was considered significant.

Statistical analysis was performed using Stata 14 (StataCorp. College Station, TX, USA). Forest plots were used to portray weight loss over time.

Results

Twenty-two clinical trials with a baseline total of 2475 patients were included in this review. Mean age at the moment of surgery was 41.2 years old (range 31.5–47.6). Mean baseline BMI was 37.8 ± 4.1 kg/m^2 (range 28.0–60.2; median 37.9). The overall mean follow-up was 13 months (median 12; range 6–24) for the primary outcome (weight loss) with an average lost to follow-up (LTFU) ratio of 18.8%. Complete baseline data is depicted in Table 2.

Seven different techniques and/or endoscopic platforms each reporting their own specific details are presented in the articles. In essence, either a transoral endoluminal stapling or (suction based) (full-thickness) stitching and/or anchor device was used to obtain gastric volume reduction and/or alter gastric outlet.

The mean reported procedural time was 80 min (range 35–131; median 75, $p = 0.83$).

Transoral (vertical) gastroplasty (TOGa®) designed by Satiety Inc. (Palo Alto, CA) consisted of an endoscopic linear stapling device which was lead into the stomach using a transoral guidewire after dilatation of the esophagus with a 60-French (Fr) dilatator. Four clinical trials (128 patients) on the device (2007–2012) with a LTFU ratio of 0–21% after 6–24 months reported adequate weight-loss results: 35 %EWL after 6 months and 43 %EWL after 12 months [5–8]. Other benefits included an improvement in dyslipidemia and type 2 diabetes. Post-procedural COPD exacerbation was reported as the only major adverse event and was managed conservatively. No long-term results are available at this time.

Endoluminal vertical gastroplasty (EVG Bard EndoCinch™ suturing system) designed by Davol (Murray Hill, NJ), a suction-based endoluminal suturing device, was initially designed for the endoscopic treatment of gastro-esophageal reflux disease (GERD), but failed on the long term [9]. Afterwards, gastric plications to create a primary vertical gastroplasty and

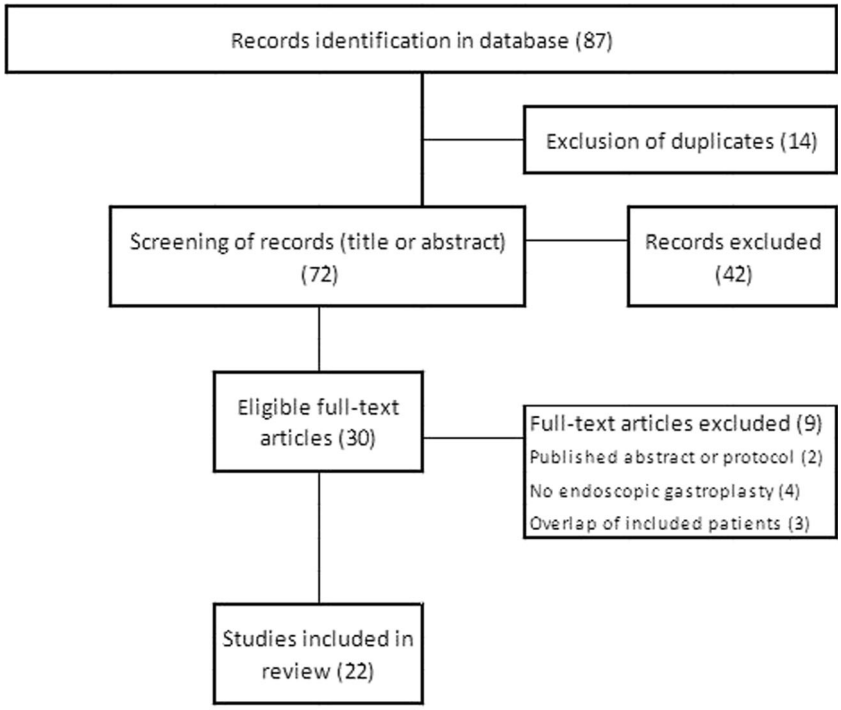

Fig. 1 Outline of search strategy and selection of articles

Outline of search strategy and selection of articles.

also pouch reduction after RYGB [10] were performed. In a 12-month follow-up study (LTFU 8%) on 64 patients, Fogel et al. [11] reported 58.1 ± 19.9 %EWL without major complications.

The transoral gastric volume reduction (TGVR RESTORe Suturing System; Bard/Davol) was introduced as a sequel of EVG. In a small prospective multicenter trial ("TRIM"-trial) on 18 patients with 22% LTFU, Brethauer et al. [12] reported 27.7 ± 21.9 %EWL after 6–12 months follow-up without major adverse events.

The OverStitch Endoscopic Sleeve Gastroplasty (ESG, Apollo Endosurgery) seems to be the first device with the ability to perform profound full-thickness sutures using an anchor catheter and a draw-back needle in a 2 channel endoscope. The stomach is remodeled into a "sleeve"-like tubular structure leaving the fundus intact resulting in altered gastric motility inducing satiety. In this meta-analysis, 8 clinical trials (1721 patients, 2014–2019) were included with 6–24 months follow-up and a LTFU of 32% [13–20]. Average pooled %EWL at 6 months and 12 months was 57.9 ± 3.8% (50.5–65.5, $I^2 = 0.0$) and 68.3 ± 3.8% (60.9–75.7, $I^2 = 5.8$). An average total of 6 (range 4–9) sutures with 8 (range 3–14) "plications" or "bites" were used. Major adverse events were described in 18 patients: pneumothorax ($n = 2$), perigastric collection ($n = 8$), pulmonary embolism ($n = 2$), intraluminal bleeding ($n = 5$), and leakage ($n = 1$).

Primary obesity surgery endoluminal (POSE™; USGI Medical) consists of a 4-channel Incisionless Operating Platform (IOP) device. It is an endoluminal full-thickness suturing device able to anchor stitches in place. Other than only performing a "sleeve-like"-remodeling of the stomach, it induces gastric dysmotility by specifically narrowing the antral inlet and reducing the fundus with plications. In this meta-analysis, 5 studies (465 patients, 2014–2016), including a randomized sham-controlled "ESSENTIAL"–trial with a follow-up of 6–18 months and mean LTFU of 15% were analyzed [21–25]. The average pooled %EWL at 6 and 12 months was 44.4 ± 2.1% (40.2–48.5, $I^2 = 0.0$) and 44.9 ± 2.1% (40.9–49.0, $I^2 =$ N/A). An average of 10 (range 8–13) fundal and 3 (range 1–4) body anchors were used. Major adverse events consisted of intraluminal bleeding ($n = 2$), extra gastric bleeding ($n = 1$), and hepatic abscess ($n = 1$).

The 360°, fully flexible articulating circular endoscopic stapler (ACE; Boston Scientific Corp) uses a vacuum system to acquire a large piece of stomach tissue, subsequently creating a transmural, full-thickness plication by deploying a 10-mM plastic ring with 8 titanium staples. Stomach reduction along the greater curve is completed after creating a maximum of 8 plications in the fundus and 2 additional plications in the antrum of the stomach additionally delaying gastric emptying. In a small (17 patients) prospective, observational, phase 1 study, Verlaan et al. [26] reported a median %EWL of 34.9 (IQR 17.8–46.6) after 12 months without the occurrence of any major adverse events. Eleven out of 17 patients undergoing follow-up endoscopy had persistence of volume reduction.

The endoluminal suturing device (Endomina; Endo Tools Therapeutics SA) has a similar mechanism as the Overstitch grasping the stomach wall in between a drawback needle pusher to create plications. Two studies (62 patients, average LTFU of 10%, one multicentric) by Huberty et al. [27, 28]

Table 2 Baseline characteristics of included studies in the meta-analysis

				Baseline data				Weight loss FU	
Study	Year	Technique	Country	*n*	Sex (female/male)	Age (year)	BMI (kg/m^2)	Months	LTFU (%)
Devière et al.	2007	TOGA®	Mexico/Belgium	21	4/ 17	43.7	43.3 ± 5.0	6	0
Fogel et al.	2008	EVG sutures	Venezuela	64	15/ 49	31.5	39.9 ± 5.1	12	8
Moreno et al.	2008	TOGA®	Belgium	11	4/ 7	44.2	41.6 ± 4.3	6	0
Familiar et al.	2011	TOGA®	Italy/Belgium	67	20/ 47	41	41.5 ± 3.6	12	21
Brethauer et al.	2011	TGVR	USA	18	9/ 9	40	38.6 ± 4.2	12	22
Nanni et al.	2012	TOGA®	Italy	29	3/ 26	39.1	41.7 ± 0.0	24	0
Espinos et al.	2013	POSE	Spain	45	11/ 34	43.4	36.7 ± 3.8	6	40
Lopez-Nava et al.	2014	Endosuture	Spain	20	4/ 16	45.8	38.5 ± 4.8	6	0
Abu Dayyeh et al.	2015	Endosuture	USA	25	4/ 21	47.6	35.5 ± 2.6	20	20
Lopez-Nava et al.	2015	POSE	Spain	147	45/ 102	43.8	38.0 ± 4.8	12	21
Espinos et al.	2015	POSE	Spain	18	4/ 14	39	36.6 ± 2.3	6	0
Verlaan et al.	2015	ACE	The Neth	17	6/ 11	37	40.2 ± 0.0	12	12
Sharaiha et al.	2016	Endosuture	USA	91	29/ 68	43.9	38.6 ± 7.0	24	34
Miller et al.	2016	POSE	Austria/Spain/The Neth	34	9/ 25	38.3	36.2 ± 3.3	12	12
Sullivan et al.	2016	POSE	USA	221	26/ 195	44.2	36.0 ± 2.4	12	3
Kumar et al.	2017	Endosuture	USA/Spain/DR	77	59/ 18	41.3	36.1 ± 0.6	12	43
Lopez-Nava et al.	2017	Endosuture	USA/Spain	248	367/ 181	44.5	37.8 ± 5.6	24	38
Morales et al.	2017	Endosuture	Spain/Belgium	144	23/ 121	41.5	35.1 ± 5.5	18	51
Huberty et al.	2017	Endomina	Belgium	12	8/ 4	36	34.6 ± 2.1	6	9
Sartoretto et al.	2018	Endosuture	USA/Australia	112	35/ 72	45	37.9 ± 6.7	6	54
Huberty et al.	2018	Endomina	Belgium/Czech R./Italy	51	6/ 45	41	35.1 ± 3.0	12	12
Alqahatani et al.	2019	Endosuture	Saudi Arabia	1000	897/ 103	34.4	33.3 ± 9.5	18	14

Transoral vertical gastroplasty (TOGa®; Satiety Inc.), endoscopic vertical gastroplasty (EVG; Bard Endo-Cinch Suturing System), transoral gastric volume reduction (TGVR RESTORe Suturing System; Bard/Davol), endoscopic suturing system (OverStitch; Apollo Endosurgery), primary obesity surgery endolumenal procedure (POSE™ USGI Medical), the articulated circular endoscopic stapler (ACE; Boston Scientific Corp), the endoluminal-suturing device (Endomina; Endo Tools Therapeutics SA). *BMI*, body mass index (kg/m^2); *LTFU*, lost to follow-up (for weight loss data); *USA*, United States of America, *DR*, Dominican Republic; *Czech R*, Czech Republic; *The Neth*, The Netherlands; *FU*, follow-up

reported 32%EWL at 6 months and 29% EWL at 12 months. An average total of 6 plications (range 4–7) were used. No major adverse events were reported.

A learning curve was specifically mentioned in 8 articles with a suggested minimal number of procedures for Endomina (> 5×), POSE™ (> 15×), and Overstitch (> 10×).

Proton pump inhibitors (PPI) 2 weeks before and 4 weeks after intervention were prescribed in 1 study after TOGa® [6] .

The average length of stay (ALOS) was 1.4 days (range 1.0–12.0; median 1.0; $p = 0.68$).

Postoperatively, a liquid diet was prescribed in 17 out of 22 studies during an average of 15 days (range 2–35; median 14, $p = 0.26$). Seven studies explicitly suggested further diet counseling.

Patients underwent routine post-procedural upper gastrointestinal gastrografin swallow (3 studies after TOGa® and 1 after Overstitch, $n = 358$), blood analysis (1 study after POSE™, $n = 147$) and/or abdominal X-ray (3 studies after TOGa® and 1 after Overstitch, $n = 176$) to evaluate the intervention and exclude certain complications.

Abdominal pain, sore throat, and/or nausea with or without vomiting were frequently reported after the procedure regardless of the device used. Other, mild complications (all requiring no intervention) included superficial phlebitis, temporomandibular dysfunction, pharyngitis, esophagitis, (mild) mouth trauma, and self-limiting intraluminal bleeding. None of the major events required surgical intervention and no mortality was reported.

Follow-up endoscopy (on indication, routine or voluntarily) was performed in 129 patients (10 studies) to evaluate the intactness of plications. At ≥ 3 months (mean 6.6; range 3.0–12.0; median 6.0) after the procedure, technical failure was reported in 62 patients: gap between staple lines after TOGa® ($n = 42$), disrupted suture configuration after EVG or TGVR ($n = 16$) or the release of suture lines or plications after Overstitch ($n = 7$). Despite this significant number, none of the studies tried to correlate between technical failure and the incidence of insufficient weight loss or regain.

Overall, 24 patients were explicitly reported to undergo a new bariatric intervention due to weight regain or insufficient

weight loss after an average of 5.9 months (range 2.0–12.0; median 5.0)—3 redo- TOGA®, 2 redo- EVG, 1 RYGB after TOGa®, 5 redo-Overstitch, 1 laparoscopic gastric banding after Endomina, and 12 laparoscopic sleeve gastrectomy (LSG) after TOGa®, Endomina, and ESG. Weight regain was explicitly stated in 9 studies (16 patients).

Endoscopic sleeve gastroplasty (ESG) and the primary obesity surgery endolumenal (POSE™) were taken into account for meta-analysis. Average pooled %EWL at 6 months ($p = 0.02$) and 12 months ($p = 0.04$) in favor of ESG was 57.9 ± 3.8% (50.5–65.5, $I^2 = 0.0$), 44.4 ± 2.1% (40.2–48.5, $I^2 = 0.0$) and 68.3 ± 3.8% (60.9–75.7, $I^2 = 5.8$), 44.9 ± 2.1% (40.9–49.0, $I^2 =$ N/A) for ESG and POSE™ respectively. Forest plots evaluating %EWL accomplished with POSE™ and ESG are depicted in Figs. 2 and 3 respectively.

An overview of %EWL following different aforementioned endoscopic gastroplasty techniques is depicted in Fig. 4.

Discussion

The devices that were included in this review vary in technique; however, the idea remains somewhat the same, mostly remodeling a part or the entire stomach into a tubular sleeve creating restriction. Some studies regarding POSE™ suggest that creating plications near the stomach antrum additionally alter gastric outlet by reducing antrum inlet.

The mechanism of a purely restrictive procedure is to limit the intake of calories by narrowing the access towards the gastro-intestinal conduit thereby achieving satiety. Since the beginning of bariatric surgery, different restrictive procedures have been tested and for different reasons, some have them been abandoned as a (standard) procedure [29].

TOGa® was the first endoscopic linear stapling device. On entering the stomach, it was placed against the lesser curvature under direct vision of a retroflexed endoscope to create a 8-cm-long sleeve of 2-cm in diameter using a vacuum system to apprehend the gastric wall (in 2 times) resulting in a tubular "sleeve"-like conduit. Although good weight-loss results were reported with few (major) adverse events, it was never commercialized. Furthermore, as of 2010, clinical trials on TOGa® did not reach set targets (during FDA approval) and therefore, research and development were halted indefinitely. Most likely, the high number of technical failure ("gaps" between staple lines) resulting in insufficient weight loss or even regain was an important issue.

As a historical remark, the use of non-dividing staples on the gastric wall in order to reduce the gastric volume instead of plain resection (like in LSG) reminds the authors of patients who underwent early (open) RYGB or vertical banded gastroplasty (VBG) with the creation of a non-divided or partially divided gastric pouch resulting in gastro-gastric fistula ("gaps") rates of up to 49% [30]. However, this argument should be used with great caution due to the obvious difference in technique and approach of stapling.

The ACE-stapler has not yet received FDA approval. Working with this first-generation stapler seems time-consuming since it can only fire one plication at a time and needs to be removed to reload. Furthermore, the author mentioned financial problems of the sponsor during the phase 1 trial. At this time, no further human trials regarding ACE have been published.

The transoral gastric volume reduction (TGVR RESTORe Suturing System; Bard/Davol) is a modified version of the EVG (EndoCinch™ suturing system; Bard) being able to perform deeper-thickness suturing and multiple plications without removal and reinsertion of the device (multistitch). Despite this upgrade and some overall positive clinical findings, the plications were not durable on endoscopic follow-up.

The Overstitch-device is able to perform full-thickness sutures; therefore, it might be associated with higher durability

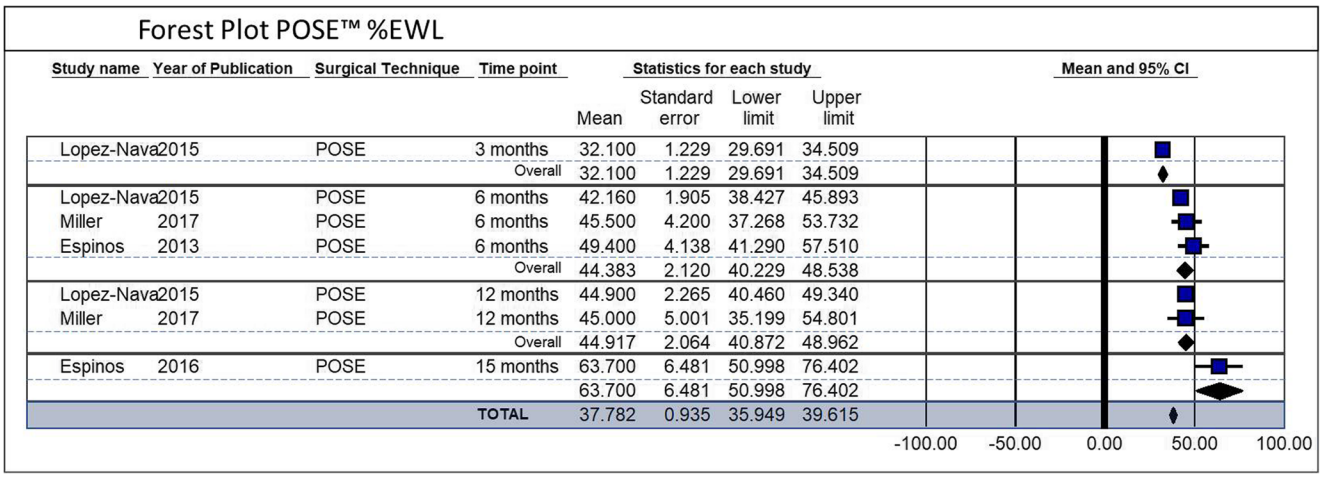

Fig. 2 Forest plot evaluating %EWL accomplished with POSE™

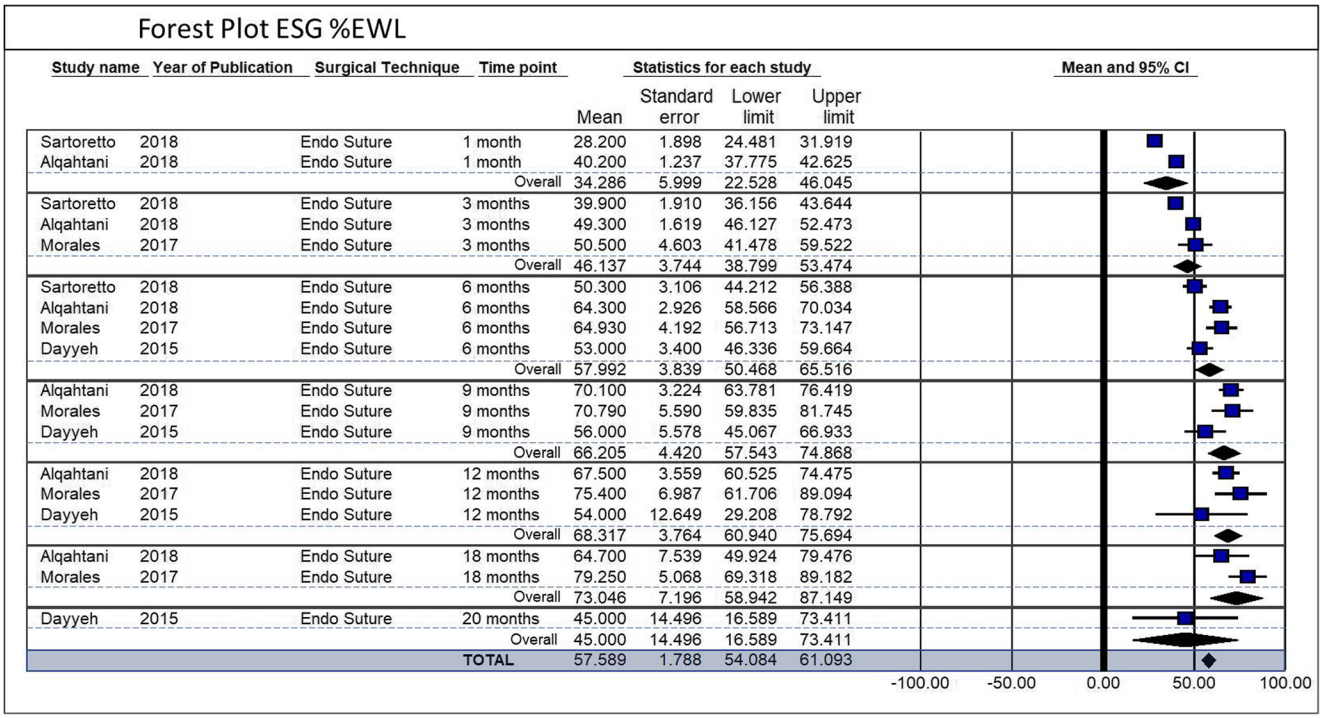

Fig. 3 Forest plot evaluating %EWL accomplished with ESG

[31]. The device has been approved by the FDA for tissue apposition making it feasible for other gastro-intestinal procedures like securing gastric stents, anastomotic reduction and endoscopic suturing of perforations [13]. The need for a 2-channel endoscope might be seen as a limitation; however, a modified device working on a single-channel endoscope is expected soon. In each study, different patterns (running or interrupted fashion) with a variable number of stitches were used resulting in a various amount of "plications." Usually, the procedure was commenced at the stomach antrum, afterwards working towards the gastro-esophageal junction, leaving the fundus intact, which might prolong satiety and delay gastric emptying [20]. No long-term follow-up (> 24 months) is available at this time.

Endomina has a similar working mechanism as the Overstitch. A "sleeve"-like configuration is created by performing double plicatures involving four layers of the gastric wall (2 times serosa-serosa) along the greater curvature also leaving a small fundus intact. The device has not yet received FDA-approval and published data is scarce.

POSE™ first gained FDA approval for anastomotic and pouch reduction after RYGB. Usually, the procedure is started with reduction of the stomach fundus and afterwards the distal gastric body not only resulting in volume reduction, but also remodeling gastric outlet and therefore adding an extra potential satiety inducing feature. This implies starting with a retroflexed scope which could suggest a higher technical burden and a steeper learning curve. POSE™ is the only device that was subjected to a randomized sham-trial (ESSENTIAL).

In a recent meta-analysis by Khan et al. [32], ESG was found to be superior in terms of weight loss when compared with POSE™ at 6- and 12-month follow-up.

In POSE™, plications are created near the fundus, whereas the Overstitch device leaves the fundus intact.

Comparing endoscopic (sleeve) gastroplasty and LSG is not always justifiable [33]. In LSG, the (fundal) ghrelin-producing tissue is removed, altering a cascade of complex multifactorial hormonal changes [34]. Endoscopic interventions are less invasive, seem safe, are theoretically reversible, can be performed in the outpatient setting and some studies have shown cost-effectiveness [35]. It was suggested that ESG seems to slow gastric emptying, whereas LSG seems to speed it [13]. This was also suggested for POSE™ [22]. High-quality long-term evidence concerning the superiority of different restrictive procedures (including LSG) is awaited [36].

The idea of performing gastric plications (at the greater curvature) in order to achieve gastric volume reduction is been performed by laparoscopy for many years. In a review, Kourkoulos et al. [37] reported an %EWL of 60–65 at 24 months (results similar to LSG), a total complication rate of 15% and reoperation rate of 3%. He, however, mentioned the included literature at that point to be "limited and sketchy at times." In a randomized controlled clinical trial (RCT) comparing laparoscopic greater curvature plication (LGCP) with LSG, Grubnik et al. [38] concluded similar weight loss results up to 2 years after surgery. After the second year however, LSG was significantly more effective in terms of weight loss. In a Chinese meta-analysis comparing both techniques (LSG and LGCP) [39],

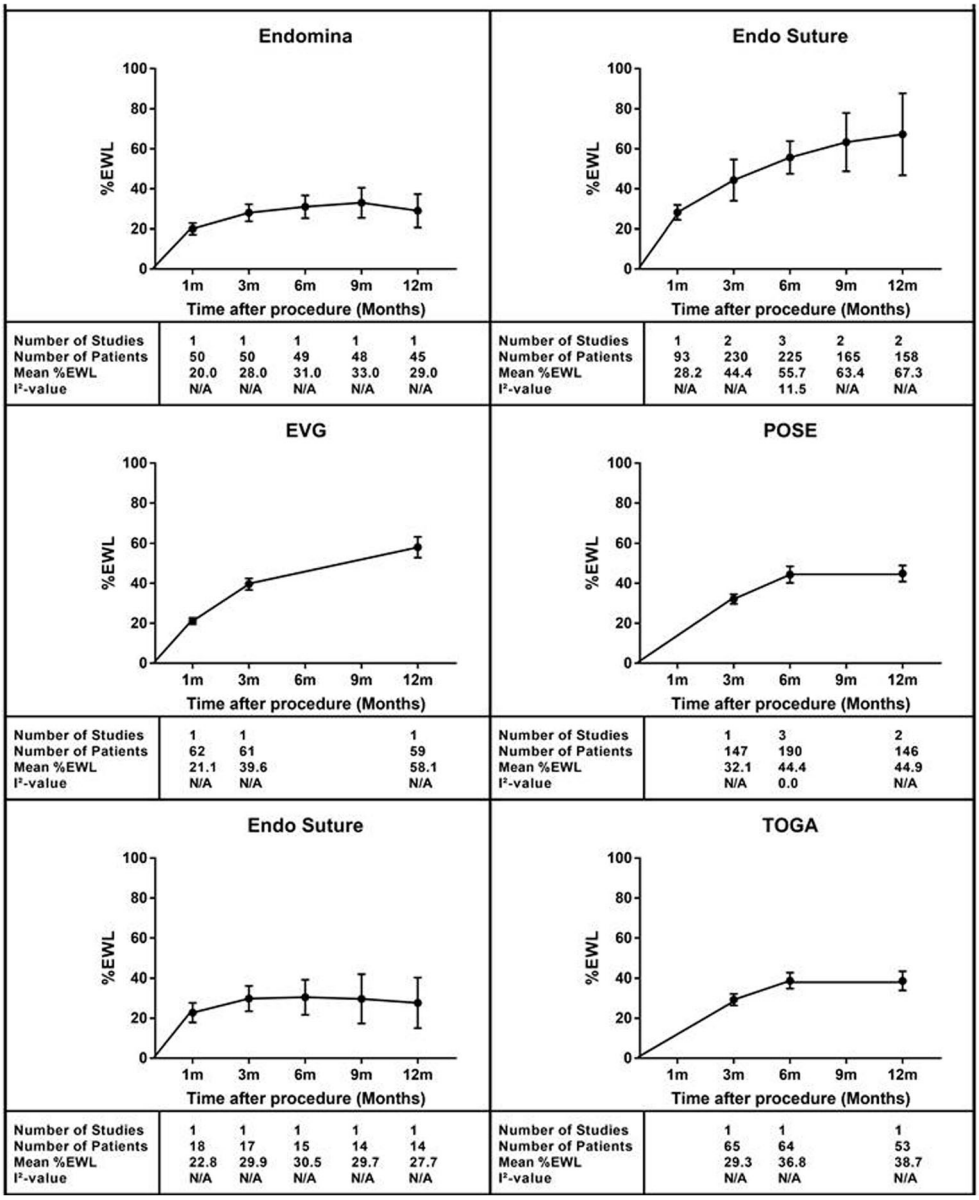

Fig. 4 An overview of %EWL following different endoscopic gastroplasty techniques

similar differences in weight loss were observed 1 year after surgery. Two main reasons explaining the superiority of LSG are suggested, first of all, the preservation of the gastric fundus in LGCP (resulting in lower plasma ghrelin levels) and secondly, the gastric volume enlargement after 6 months due to intrinsic muscle relaxation after LGCP. Probably, the release of plications at some time after surgery also contributes to gastric volume enlargement with less satiety, thus leading to weight regain. In a recent meta-analysis, Barrichello et al. [40] concluded that LSG showed improved weight loss when compared with LGCP, with better satiety, fewer symptoms in the postoperative period, and improved diabetes remission.

No guidelines or statements towards the indication for endoscopic gastroplasty have been agreed on. Although, the IFSO-guidelines [41] state a minimum BMI of 35 kg/m^2 in the presence of specific comorbidities to be a good indication for bariatric surgery. Some of the included studies in this manuscript do present patients with a lower baseline BMI. Endoscopic gastroplasty could be seen as a minimal-invasive option (for people who are not eligible for bariatric surgery and do not seem to respond to more conservative therapies), bridge-to-surgery (reducing peri-operative risk), primary metabolic (e.g., treatment of type 2 diabetes) or revisional treatment [42]. Furthermore, it seems reasonable to believe that in the (near) future, specific indications for endoscopic therapies will be included in patient-tailored guidelines towards the treatment of morbid obesity.

ESG is not only presented as a primary bariatric procedure. Kumta et al. [43] presented a case of volume reduction after prior LSG. This technique was already suggested in 2004 as a

possibility to treat pouch dilation after RYGB [44]. In a meta-analysis published in 2018, Brunaldi et al. [45] concluded that "full-thickness suturing is effective at treating weight regain after RYGB." Other similar devices, like "Stomaphyx" were mainly introduced to perform gastric pouch reduction after RYGB. In a retrospective analysis on 59 patients, Goyal et al. [46] concluded that it could not be recommended as a weight loss strategy in post-gastric bypass patients who regain weight.

The inclusion of different endoscopic techniques each having their own specific features (some of them abandoned due to various reasons), different study designs with sometimes limited follow-up data or baseline included patients and various indications (between-trial heterogeneity) can be seen as a limitation of this study. An important issue regarding this argument is the impossibility of objectifying the amount of volume reduction after each separate procedure which could be a valuable measure to compare. Another limitation is the inability to compare studies only reporting weight loss as percentage total body weight loss (%TBWL), absolute BMI or weight reduction, which could lead to inaccurate conclusions [47]. Furthermore, all inherent limitations of meta-analyses and of the included studies (mostly observational) have to be taken into account.

Conclusion

The development of endoscopic gastric remodeling for morbid obesity has great potential due to its minimally invasive nature. Current limitations include the relatively small number of clinical studies with limited (short-term) follow-up and patients included. ESG seems to be superior in terms of weight loss at this point. As a procedure, it seems feasible with few adverse events reported over time. Patients who seem eligible should be treated in the context of a multidisciplinary team and be provided with adequate follow-up to facilitate long-term weight loss maintenance and benefits on comorbidities. For the set-up of correct guidelines, prospective (randomized trials) are needed with adequate long-term follow-up.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Appendix I Syntaxes used for the search in the different available databases

Embase.com

exp. endoscopic sleeve gastroplasty/co, di, dm, dt, ep, et, pc, si, su, th [Complication, Diagnosis, Disease Management, Drug Therapy, Epidemiology, Etiology, Prevention, Side Effect, Surgery, Therapy]

Cochrane

MeSH descriptor: [Gastroplasty] explode all trees

Web of science

TS = (endoscopic AND gastroplasty)

PubMed publisher

"Endoscopy"[Mesh] AND "Gastroplasty"[Mesh]

Google scholar

allintitle: "endoscopic" and "gastroplasty"

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