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REVIEW ARTICLE

# Mid-long-term Revisional Surgery After Sleeve Gastrectomy: a Systematic Review and Meta-analysis

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**Abstract**
This study aimed to make a meta-analysis regarding mid-long-term outcomes (≥ 3-year follow-up) after sleeve gastrectomy (SG), focusing on incidence, reasons, and results of revisional surgery. PubMed, EMBASE, and CENTRAL were searched and 32 studies were included. The overall revision rate was 10.4%, but for patients with ≥ 10-year follow-up, the rate was 22.6%. European studies had a higher revision rate (14.4%) than other studies. The most common reason for revision was failure in weight loss, and the most frequent revisional procedure was gastric bypass. Revisional surgery was favorable for weight reduction and comorbidity resolution. In conclusion, revision rate is not rare after SG, especially when looking at long-term follow-up. Bariatric surgeons and patients need to fully understand and deal with the need for revision after SG.

**Keywords** Revisional surgery · Sleeve gastrectomy · Mid-long-term · Systematic review · Meta-analysis

## Introduction

In light of the ever-increasing prevalence of obesity in the world, an increase of bariatric surgery in clinical practice has been seen [1]. Bariatric surgery brings about durable weight reduction as well as significant improvement of obesity-related comorbidities [2]. Sleeve gastrectomy (SG) was originally regarded as a first-step bariatric procedure for severely obese patients. However, with the advantage of relative safety and effective results in the short term, SG became a stand-alone bariatric procedure subsequently [3]. According to the recent data, SG has become the most common bariatric surgery around the world, reaching 45.9%, followed by Roux-en-Y gastric bypass (RYGB) (39.6%) [1].

In spite of postoperative short-term satisfying outcomes, revisional surgery is still unavoidable for some SG patients due to weight loss failure and/or complication during the mid-long-term follow-up period after this procedure [4]. Current literature data regarding the incidence of revisional surgery vary greatly between studies. Some data showed that the rate of revision after SG could be up to 30% [5], while others reported a relatively low percentage of the need for revisional surgery [6, 7]. Therefore, the incidence of revision after SG remains to be answered.

Up to now, there have been some systematic review evaluating the treatment effect of SG, but little attention was paid on its revision [8, 9]. Although a previous meta-analysis had pooled the overall revision rate after SG based on studies with > 7-year follow-up, it had only included few studies, and not conducted subgroup analysis based on follow-up period and region, which may affect the revision rate [10]. In addition, the revisional reasons, revisional procedures, and surgical outcomes have not been previously analyzed using a systematic review and meta-analysis yet. The aim of the current study was to apply a systematic review and meta-analysis of mid-long-term outcomes (≥ 3-year follow-up) after SG, focusing on the incidence, reasons, and treatment results of revisional surgery.

## Methods

We conducted a meta-analysis according to the preferred reporting items for systematic reviews and meta-analyses (PRISMA), combined with the recommendations from the

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Cochrane Collaboration and Meta-analysis of Observational Studies in Epidemiology (MOOSE) [11, 12]. Given that this is an analysis of published articles, with no real concern to individual patients, ethical approval and informed consent were not required.

### Literature Search

PubMed, EMBASE, and the Cochrane Central Register of Controlled Trails (CENTRAL) were searched from inception to January 2019. Medical subject headings along with free terms were adopted together for literature search, including (sleeve gastrectomy OR SG OR LSG) AND (long-term OR long term OR mid-term OR midterm OR 3 years OR 4 years OR 5 years OR 6 years OR 7 years OR 8 years OR 9 years OR 10 years) AND (revision OR revisional OR converted OR conversion OR reoperation OR failed). Additionally, we also screened the references of identified articles and reviews for other potential articles.

### Inclusion and Exclusion Criteria

Randomized controlled trials (RCT) and observational clinical studies were included if they met the following criteria: (1) providing mid-long-term follow-up (≥ 3 years) outcomes after SG, (2) reporting the incidence of revisional surgery after SG or other information sufficient to calculate the incidence. Non-English studies, reviews, conference abstract, case reports, comments, letters, animal studies, and studies with the number of SG patients less than 20 or reporting zero value of incidence were excluded. In addition, the patients undergoing SG as part of planned two-stage bariatric surgeries were also excluded. For studies enrolled overlapping populations, we only included the study with the most comprehensive information and excluded the other.

Two investigators independently performed the stages of study selection, data extraction, and quality assessment. Regarding disagreements, it would be discussed with a third investigator in order to get the consensus.

### Data Extraction and Quality Assessment

After deleting the duplicated articles, titles and abstracts of the remaining articles were screened to examine whether they matched the inclusion criteria or not. Full-text was further reviewed when needed.

Two reviewers independently extracted the following data from each of the included studies using a pre-specified data extraction form: the first author' name, location, publication year, patients' characteristics, follow-up duration, and outcomes of interest. The primary outcome of interest was the incidence of revisional surgery after SG. The secondary outcomes included the reasons for revision and the follow-up results after revision. With regard to missing data, the study authors would be contacted for complete information by emails if possible.

Quality assessment of the included trials was conducted based on a quality rating system containing the following 5-point scales: (1) the clarity of definition of revisional surgery; (2) the representativeness of the patients' sample; (3) the credibility of diagnostic criteria of revisional surgery; (4) the credibility of diagnostic evaluation; (5) the completeness of outcomes. The score rated from 1 to 5 with one meaning the best quality and five meaning the worst quality [13, 14].

### Statistical Analysis

Stata (version 11.0) was used for calculating the pooled incidence of revisional surgery. The Cochran Q-statistic and $I^2$ statistic were used to measure between-study heterogeneity. Significant heterogeneity was expected when $p$ value < 0.1 and $I^2 > 50\%$, indicating that a random effects model would be used to pool estimates. A fixed effects model would be chosen when between-study heterogeneity was not significant. We also carried out subgroup and sensitivity analyses to explore possible sources of heterogeneity in enrolled studies if feasible and necessary. Pre-specified subgroup analyses included region (Europea, Eastern Asia, Middle East, America), publication year (the Year 2015 or earlier, the Year 2016 or later), and follow-up duration (3–5 years, 5–10 years, ≥ 10 years). Regarding sensitivity analyses, the methods of changing the pooling model (random effects model or fixed effects model) and omitting one study each time were performed. The funnel plot, along with the Begg and Egger tests, was conducted for assessing possible publication bias.

## Results

### Search Process, Study Characteristics, and Quality Assessment

Our initial literature search yielded 1690 potentially relevant articles. After removal of duplicate articles, there were 1355 titles and abstracts left for screening. Afterwards, 123 studies were reviewed in full-text. And finally, 32 publications (3 RCTs, 29 observational studies) were included in qualitative synthesis and meta-analysis, with a total of 6665 patients [7, 15–45]. The process of study selection is displayed in Fig. 1.

Table 1 showed the study characteristics. These studies adopted data from different regions (e.g., Europea, Eastern Asia, Middle East, America). Patients had different reasons for revisional surgery (e.g., failure in weight loss, gastroesophageal reflux disease (GERD)). The duration of follow-up ranged from 3 years to more than 10 years.

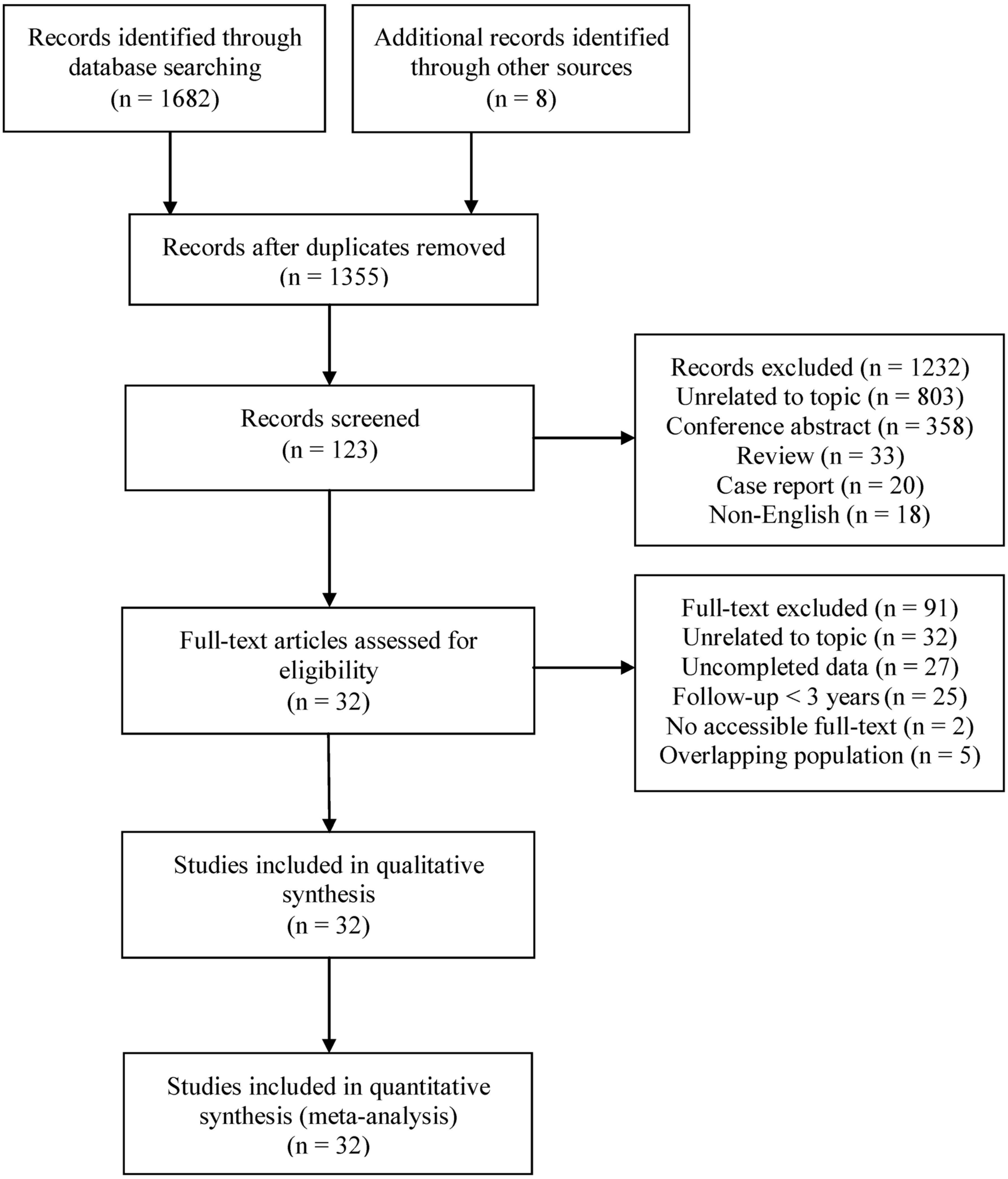


**Fig. 1** PRISMA flow diagram of study selection

## Meta-analysis of Incidence of Revisional Surgery

All of the included trials involving 6665 patients reported the incidence of revisional surgery after SG. Our data revealed that the incidence rate of revision ranged from 2.5 to 33.0%. Because of significant heterogeneity among these studies ($p < 0.001$, $I^2 = 86.8\%$), a random effects model was used to pool results. The results showed that the pooled incidence of revisional surgery was 10.4% (95% confidence interval (95%CI), 8.5–12.4%) (Fig. 2).

In the sensitivity analysis, the stability of pooled incidence of revisional surgery got confirmation by changing the random effects model to a fixed effects model ($p = 6.4\%$, 95%CI 5.8–7.0%). Additionally, through excluding research one by one, it was found that no individual study would remarkably affect the pooled incidence, with a range from 9.7% (95%CI 7.9–11.6%) to 10.8% (95%CI 8.8–12.8%). The Begg ($p = 0.001$) or Egger ($p < 0.001$) test showed that there was significant publication bias in the literature. For this reason, we performed a trim and fill analysis and found that after adding ten studies, the pooled

**Table 1** Characteristic of included studies

| Authors | Year | Location | Preoperative BMI (kg/m$^2$) | Preoperative Age (years) | *n* | *N* | Follow-up (yeas) | Quality assessment |
|---|---|---|---|---|---|---|---|---|
| Ruiz-Tovar | 2019 | Spain | 46.5 ± 3.4 | 43.9 ± 10.9 | 6 | 182 | 5 | 2b |
| Altieri | 2018 | USA | NA | NA | 174 | 1781 | 4 | 2b |
| Peterli | 2018 | Switzerland | 43.6 ± 5.2 | 43.0 ± 11.1 | 15 | 101 | 5 | 2b |
| Chang | 2018 | Taiwan | NA | NA | 14 | 65 | 10 | 2b |
| Castagneto | 2018 | Italy | 46.6 ± 7.3 | 43.4 ± 11.0 | 7 | 121 | 10+ | 3b |
| Kowalewski | 2018 | Poland | 35.9–72.0 | 17–64 | 16 | 100 | 8.0 | 2b |
| Felsenreich | 2018 | Austria | 49.0 ± 9.1 | NA | 32 | 97 | 10+ | 2b |
| Flølo | 2017 | Norway | 46 ± 6.3 | 40.3 ± 10.5 | 7 | 168 | 5 | 2b |
| Noel | 2017 | France | 31.1–77.9 | NA | 23 | 139 | 8 | 2b |
| Mandeville | 2017 | Belgium | 30.3–67.5 | 15–69 | 26 | 88 | 8.48 | 2b |
| Schauer | 2017 | USA | 36.2 ± 3.9 | 47.9 ± 8.0 | 2 | 50 | 5 | 2b |
| Gadiot | 2017 | Netherlands | 44.8 ± 6.7 | 42 ± 10.7 | 44 | 277 | 5–8 | 4b |
| Lessing | 2017 | Israel | 43.3 ± 6.3 | 30–64 | 2 | 51 | 5 | 2b |
| Yilmaz | 2017 | Turkey | NA | 34.1 ± 13.1 | 32 | 500 | 3.01 | 2b |
| Garofalo | 2016 | Canada | 45.1 ± 5.6 | 65–74 | 5 | 30 | 3 | 2b |
| Arman | 2016 | Belgium | 38.8 ± 7.5 | 38.7 ± 9.7 | 20 | 63 | 11.7 | 2b |
| Seki | 2016 | Japan | 43.3 ± 10 | 40.7 ± 11.2 | 6 | 179 | 5 | 2b |
| Angrisani | 2016 | Italy | NA | NA | 9 | 99 | 5 | 2b |
| Dakour | 2016 | Lebanon | 42.8 ± 7.1 | 36.5 ± 13.3 | 4 | 76 | 7 | 2b |
| Casella | 2016 | Italy | 45.9 ± 7.3 | NA | 4 | 152 | 6.25 | 2b |
| Dogan | 2015 | Netherlands | 45.8 ± 6.0 | 39.7 ± 10.0 | 23 | 245 | 3.1 | 2b |
| Lee | 2015 | Taiwan | 37.5 ± 6.1 | 36.0 ± 9.1 | 16 | 154 | 5 | 2b |
| Abd | 2014 | Egypt | 46 ± 9 | 33 ± 7 | 56 | 1395 | 6.34 | 2b |
| Prevot | 2014 | France | 47.7 ± 7 | 40 ± 11 | 11 | 95 | 5 | 2b |
| Boza | 2014 | Chile | 34.9 | 16–65 | 4 | 161 | 4.5 | 2b |
| Sieber | 2014 | Switzerland | 46 ± 7.1 | 43 ± 11.4 | 8 | 68 | 5.9 | 2b |
| Rawlins | 2013 | USA | 39–106 | NA | 4 | 55 | 5 | 2b |
| Catheline | 2013 | France | 49.9 ± 9.1 | 41.8 ± 11.3 | 8 | 53 | 5 | 2b |
| Abbatini | 2013 | Greece | 52.1 ± 8.5 | 49.3 ± 8 | 7 | 33 | 3 | 2b |
| Sarela | 2012 | United Kingdom | 35.8–63.7 | 23–65 | 4 | 20 | 8–9 | 2b |
| Bohdjalian | 2010 | Austria | 48.2 ± 1.3 | 46.2 ± 2.5 | 4 | 26 | 5 | 2b |
| Himpens | 2010 | Belgium | 39.5 ± 5.5 | 28–71 | 13 | 41 | 6+ | 2b |

*NA* not available, *n* number of patients undergoing revisional surgery

data is still statistically significant. Therefore, the pooled estimate for incidence rate of revision is robust.

## Subgroup Analyses of the Incidence of Revision

For the purpose of exploring the potential source of heterogeneity, we performed subgroup analyses by different regions, reasons for revisional surgery, and follow-up duration (Table 2). Grouping the studies by regions led to homogeneous result for four studies conducted in Middle East ($p$ = 0.262, $I^2$ = 25.0%), but not for studies conducted in the other three regions. However, the pooled results showed that European studies ($p$ = 14.4%, 95%CI 10.9–17.8%) have a higher rate of revision than Eastern Asian studies ($p$ = 10.5%, 95%CI 2.1–18.9%), American studies ($p$ = 5.9%, 95%CI 1.1–10.7%), and Middle Eastern studies ($p$ = 4.5%, 95%CI 3.6–5.4%). In addition, grouping the studies by publication years and follow-up duration did not resolve the issue of heterogeneity, but a phenomenon was found that the revisional rate would increase along with longer follow-up times, with 7.4% (95%CI 5.5–9.4%) for the studies with 3–5-year follow-up, 13.3% (95%CI 8.7–18.0%) for the studies with 5–10-year follow-up, and up to 22.6% (95%CI 7.2–38.0%) for the studies with ≥ 10-year follow-up.

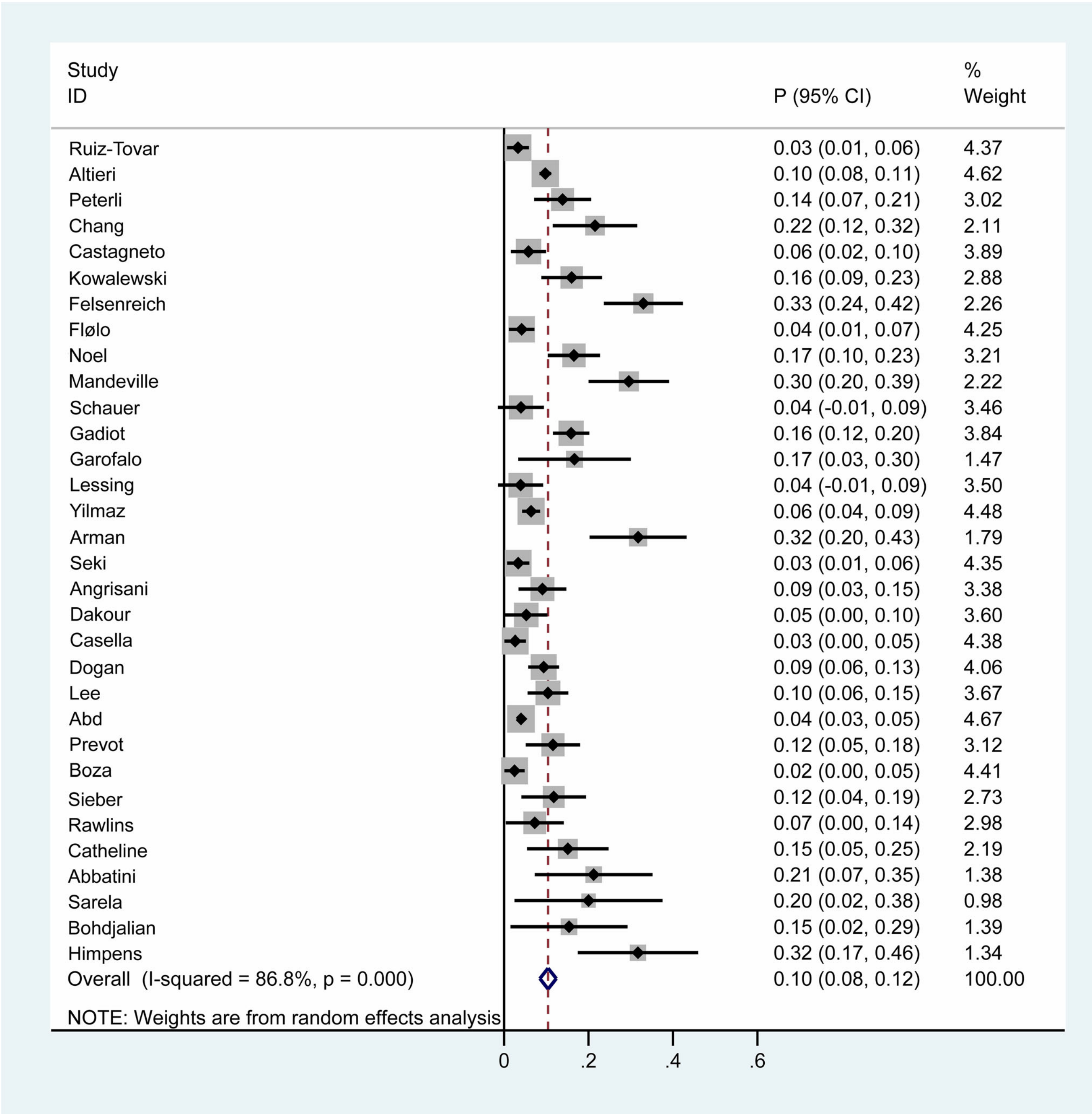


**Fig. 2** Forest plots demonstrating the incidence of revision

## Reasons and Surgical Procedures for Revisional Surgery

All but four of the included studies provided information about the reasons for revisional surgery after SG; detailed data is shown in Table 3. From the table, one could see that there were various causes for revision, such as failure in weight loss (including insufficient weight loss (IWL) and weight regain (WR)), GERD, intractable diabetes, gastric stricture, and dysphagia. However, these included studies had some difference regarding the definitions of IWL, WR, and GERD. Generally speaking, IWL was defined as the percentage of excess weight loss (%EWL) < 50% and/or the percentage of excess body mass index loss (%EBMIL) < 50%; WR was considered with > 25% EBMIL and/or EWL regain after an initial sufficient weight loss following SG [20, 23, 35]. GERD was defined by symptom complaints, upper endoscopy, and/or validated scores [20, 21, 24]. Overall, the most common reason for revision was failure in weight loss. For the

**Table 2** Subgroup analyses for the prevalence of revisional surgery

| Subgroup | Stratification | No. of studies | $p$ value for heterogeneity | $I^2$ | Pooled prevalence (%) | $p$ value for pooled results |
|---|---|---|---|---|---|---|
| Region | Europea | 21 | < 0.001 | 86.8% | 14.4 [10.9, 17.8] | < 0.001 |
| | Eastern Asia | 3 | < 0.001 | 87.7% | 10.5 [2.1, 18.9] | 0.014 |
| | America | 4 | < 0.001 | 89.5% | 5.9 [1.1, 10.7] | 0.015 |
| | Middle East | 4 | 0.262 | 25.0% | 4.5 [3.6, 5.4] | < 0.001 |
| Publish year | Year 2016 or later | 20 | < 0.001 | 88.3% | 10.7 [8.1, 13.3] | < 0.001 |
| | Year 2015 or earlier | 12 | < 0.001 | 79.4% | 10.0 [6.9, 13.3] | < 0.001 |
| Follow-up duration | ≥ 3 years and ≤ 5 years | 18 | < 0.001 | 75.9% | 7.4 [5.5, 9.4] | < 0.001 |
| | > 5 years and < 10 years | 10 | < 0.001 | 90.8% | 13.3 [8.7, 18.0] | < 0.001 |
| | ≥ 10 years | 4 | < 0.001 | 92.9% | 22.6 [7.2, 38.0] | 0.004 |

studies with > 5-year follow-up, the revisional rate due to failure in weight loss was up to 11.8% (95%CI 8.0–15.6%, $p < 0.001$) (Fig. 3). The pooled rate of revision due to GERD was 3.1% (95%CI 1.5–4.7%). With respect to the surgical procedures for revision, different researchers had different choices, such as RYGB, repeated sleeve gastrectomy (R-SG), biliopancreatic diversion (BPD), duodenal switch (DS), and biliopancreatic diversion and duodenal switch (BPD-DS). The most commonly used procedure was RYGB; less common operations included duodenal-jejunal bypass (DJB) and one-anastomosis gastric bypass (OAGB).

### Follow-up Outcomes of Revisional Surgery

Some studies described the follow-up outcomes after revisional surgery [21, 24, 29]. A favorable effect of revisional surgery on weight reduction and comorbidity resolution had been shown in these studies, which was supported by the remission or improvement of diabetes, hypertension, dyslipidemia, and GERD postoperatively. Through comparing data between primary and revisional surgery patients (Table 4), we found that there was higher weight reduction in revisional patients in comparison to primary procedure patients. Therefore, for those patients encountering weight loss failure after SG, it is reasonable to conclude that revisional surgery might be beneficial for them.

## Discussion

In the literature, an amount of interest has been devoted to the impact of SG on weight reduction, hypertension, type 2 diabetes mellitus, and dyslipidemia [9]. However, revision after SG did not get enough attention yet. It is well known that patients undergoing AGB procedure would have a high rate of revision after surgery. The question arises whether or not will we convert SG at a similar rate as AGB procedure? This is an important question that needs to be determined. The current study aimed to look at the incidence, reasons, and follow-up outcomes of revisional surgery after SG by systematically outlining the current literature, and found that the revisional rate was up to 10.4% (95%CI, 8.5–12.4%) after SG, based on the studies with ≥ 3-year follow-up.

Although the history of SG procedure is shorter than other bariatric procedures, like RYGB, AGB, and BPD-DS, SG is the most popular bariatric procedure worldwide, being used in a great number of countries [3]. We found that the incidence of revision is higher in European studies than Eastern Asian and American studies. Exact reasons for these differences are still unknown; some possible explanations may be racial difference, different health policy, patients' different attitudes to revisional surgery, and technical differences in index procedure (such as a larger sleeve or failure in gastric fundus resection). Another noteworthy phenomenon is that with the follow-up time extends, the incidence of revision increases too, from 7.4% with 3–5 year follow-up to 22.6% with ≥ 10-year follow-up. If we include the patients who also encounter weight loss failure or GERD, but not receive revisional surgery, the revisional rate would be higher. So a high rate of revision makes some people wonder whether or not SG should be restricted for use in the future, just like AGB [46]. We also need to know that revisional surgery is always more technically challenging.

Now that we know the high rate of revision after SG, we should then analysis its reasons. Only with a well understanding of these reasons can we make a better choice of surgical patients and decrease the revision rate. Based on our pooled data, the main cause for revision is failure in weight loss, followed by GERD. Failure in weight loss after SG is not due to a single cause but due to a combination of factors, including the dilatation of the gastric fundus and/or antrum, too big gastric bougie, and patients' non-compliance with postoperative dietary changes and behavior modification

**Table 3** Reasons and surgical procedures for revisional surgery

| Authors | Reasons for revisional surgery (*n*, %) | | | Surgical procedures for revisional surgery (*n*, %) | | | | |
|---|---|---|---|---|---|---|---|---|
| | Failure in weight loss | GERD | Others | RYGB | R-SG | BPD-DS | DS | Others |
| Ruiz-Tovar | 3 (1.6%) | 3 (1.6%) | – | 6 (3.2%) | – | – | – | – |
| Altieri | – | – | NA (174, 9.8%) | – | – | – | – | NA (174, 9.8%) |
| Peterli | 5 (5.0%) | 9 (8.9%) | – | 11 (10.9%) | – | 3 (3.0%) | – | – |
| Chang | – | – | GERD or WR (14, 21.5%) | 11 (16.9%) | – | – | – | Hiatal repair (3, 4.6%) |
| Castagneto | 4 (3.3%) | 2 (1.7%) | NA (1, 0.8%) | 2 (1.7%) | – | 4 (3.3%) | – | OAGB (1, 0.8%) |
| Kowalewski | 15 (15%) | 1 (1%) | – | 14 (14%) | – | – | – | OAGB (1, 1%), Band (1, 1%) |
| Felsenreich | 22 (22.7%) | 11 (11.3%) | – | 31 (32.0%) | – | – | 1 (1.0%) | Santoro's procedure (1, 1.0%) |
| Flølo | 6 (3.6%) | 1 (0.6%) | – | 1 (0.6%) | 2 (1.2%) | 4 (2.4%) | – | – |
| Noel | 14 (10.1%) | 9 (6.4%) | – | 6 (4.3%) | 12 (8.6%) | – | 4 (2.9%) | SADI (1, 0.7%) |
| Mandeville | 19 (21.6%) | 5 (5.7%) | IWL and GERD (2, 2.3%) | 26 (29.6%) | – | – | – | – |
| Schauer | – | – | Gastric leak (2, 4%) | 1 (2%) | – | – | – | Jejunostomy (1, 2%) |
| Gadiot | 38 (13.7%) | 6 (2.2%) | – | 44 (15.9%) | – | – | – | – |
| Garofalo | 3 (10%) | – | Gastric stricture (2, 6.6%) | 4 (13.3%) | – | – | 1 (3.3%) | – |
| Lessing | 2 (3.9%) | – | – | 2 (3.9%) | – | – | – | – |
| Yilmaz | 26 (5.2%) | 6 (1.2%) | – | 9 (1.8%) | 23 (4.6%) | – | – | – |
| Arman | 16 (25.4%) | 4 (6.4%) | – | 6 (9.5%) | 3 (4.8%) | – | 10 (15.9%) | Hiatoplasty (1, 1.6%) |
| Seki | 5 (2.8%) | 1 (0.6%) | – | – | 2 (1.1%) | – | 3 (1.7%) | Seromyotomy (1, 0.6%) |
| Angrisani | 7 (7.1%) | 2 (2.0%) | – | 5 (5.1%) | – | – | 4 (4.0%) | – |
| Dakour | 3 (3.9%) | – | – | – | 2 (2.6%) | – | – | OAGB (1, 1.3%) |
| Casella | 4 (2.6%) | – | – | – | – | 4 (2.6%) | – | – |
| Dogan | 21 (8.6%) | – | Dysphagia (2, 0.8%) | 23 (9.4%) | – | – | – | – |
| Lee | 6 (3.9%) | 8 (5.2%) | Gastric stricture (1, 0.6%), Intractable diabetes (1, 0.6%) | – | – | – | – | NA (16, 10.3%) |
| Abd | 37 (2.7%) | 19 (1.4%) | – | 24 (1.8%) | 19 (1.4%) | – | – | Band (13, 0.9%) |
| Prevot | – | – | NA (11, 11.6%) | – | 3 (3.2%) | – | 8 (8.4%) | – |
| Boza | 3 (1.9%) | – | Gastric stricture (1, 0.6%) | 3 (1.9%) | – | – | – | DJB (1, 0.6%) |
| Sieber | 8 (11.7%) | – | – | 2 (2.9%) | – | 6 (8.8%) | – | – |
| Rawlins | – | – | NA (4, 7.3%) | – | – | – | 4 (7.3%) | – |
| Catheline | 8 (15.1%) | – | – | 5 (9.4%) | 3 (5.7%) | – | – | – |
| Abbatini | 7 (21.2%) | – | – | – | – | – | – | BPD (7, 21.2%) |
| Sarela | – | – | NA (4, 20%) | 3 (15%) | – | – | 1 (5%) | – |
| Bohdjalian | 3 (11.5%) | 1 (3.9%) | – | 4 (15.4%) | – | – | – | – |
| Himpens | 13 (31.7%) | – | – | – | 2 (4.9%) | – | 11 (26.8%) | – |

*IWL* insufficient weight loss, *WR* weight regain, *GERD* gastro-esophageal reflux disease, *RYGB* Roux-en-Y gastric bypass, *R-SG* repeated sleeve gastrectomy, *BPD-DS* biliopancreatic diversion and duodenal switch, *DS* duodenal switch, *OAGB* one-anastomosis gastric bypass, *DJB* duodenal-jejunal bypass, *BPD* biliopancreatic diversion, *NA* not available

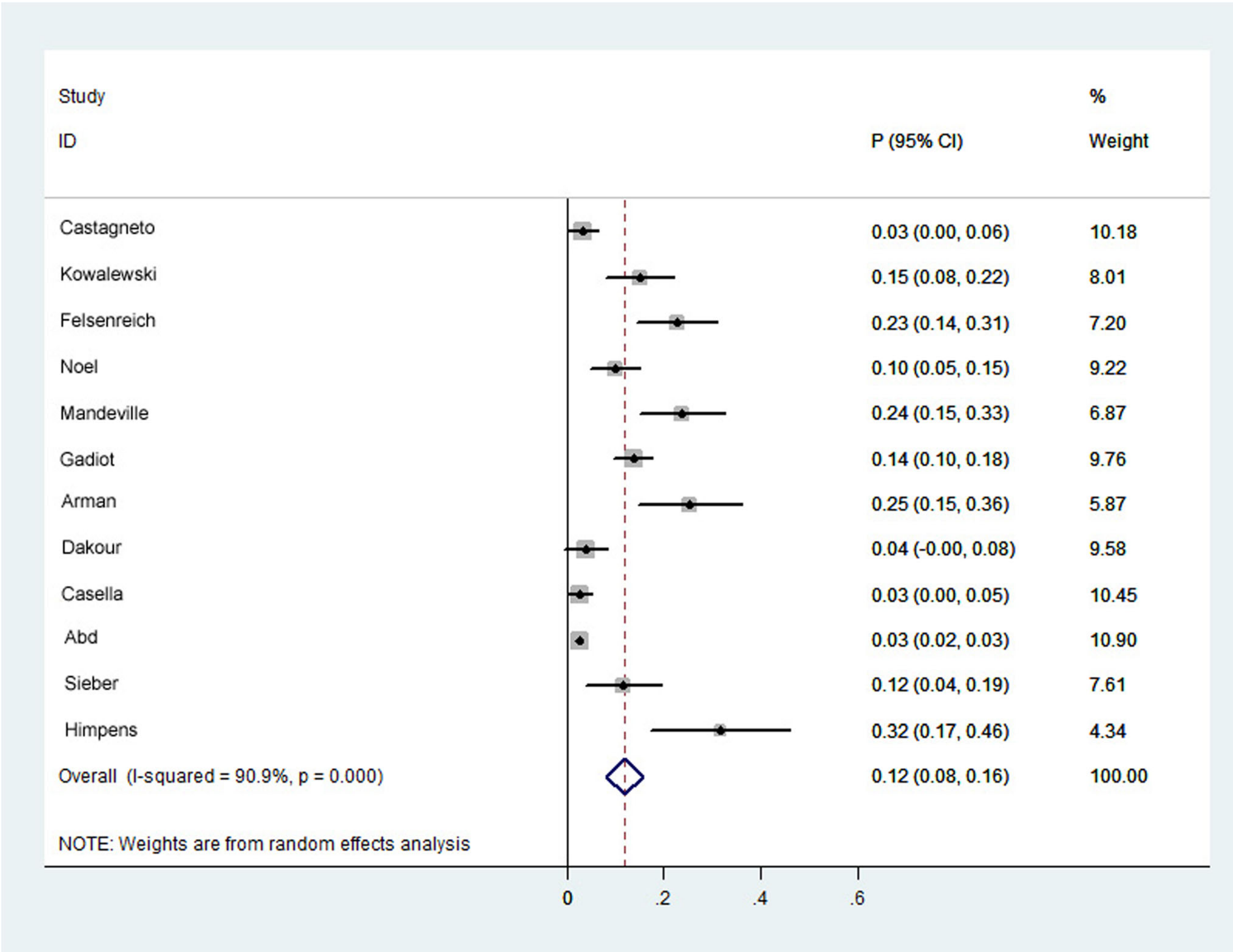


**Fig. 3** Forest plots demonstrating the revision rate due to failure in weight loss among studies with > 5-year follow-up

[47, 48]. Hence, strict technical demand and postoperative multidisciplinary guidance are very necessary for SG patients. As for the relation between GERD and SG procedure, there has not been consistent conclusion in the literature yet [49]. Some authors reported reduced rate of GERD after SG, while others indicated opposite results [50, 51]. In any case, GERD is an intractable complication for SG patients; if the GERD symptom is already very serious before surgery, SG may not be a good surgery for them.

By reason that quite a few patients need revision in the long-term follow-up, it is essential to explore which revisional surgery is the best choice for these patients. Among our included studies, some provided information about surgical outcomes after conversion. RYGB, R-SG, BPD-DS, and DS all had been chosen for revision. For IWL due to gastric dilatation without comorbidities recurrence, R-SG was suggested with good results; while for patients without significant gastric dilatation, converting to BPD-DS can be an option [23]. Regarding WR, RYGB could be chosen but it was reported that the weight reduction was lower in SG patients converted to RYGB than primary RYGB patients [52]. SADI has also been proposed for treating weight regain with or without comorbidities recurrence, but it is still a relatively new procedure and needs further research [23]. And for failed SG owing to GERD, common revisional surgery is RYGB, which would not increase stomach pressure. Felsenreich et al. found that all the patients with reflux symptoms after SG went into remission after revisional RYGB [21]. What is noteworthy is that comparative studies between two revisional bariatric surgeries are quite few; these points are future research directions because the need to convert a certain percentage of SG patients in the mid-long-term follow-up is an important clinical issue.

This study provides a quantifiable measure of revision issue after SG. However, it has some limitations. One is that patient characteristics and follow-up duration vary differently from one to another study and may cause reporting biases. For this issue, we used random effects model to pool results, in order to get the most conservative estimates. Moreover, we performed subgroup analysis, sensitivity analysis, and trim and fill analysis; the results indicated that the pooled incidence

**Table 4** Comparison results between primary and revisional surgery patients

| Included studies | Surgery group | Follow-up time after SG | Change of weight index | | Improvement of comorbidity | | |
|---|---|---|---|---|---|---|---|
| | | | Before SG | End-point | Before SG (*n*) | End-point (*n*, %) | |
| | | | | | | Remission | Improvement |
| Kowalewski | SG group | 8.0 years | – | %EWL 51.1 ± 22.3% | Hypertension (49), diabetes (19) | Hypertension (14, 28%), diabetes (7, 37%) | Hypertension (15, 31%), diabetes (4, 21%) |
| | Revision group | 8.0 years | – | %EWL 57.8 ± 18.2% | Hypertension (6), diabetes (3) | Hypertension (1, 17%), diabetes (1, 33.3%) | Hypertension (2, 33%), diabetes (1, 33.3%) |
| Felsenreich | SG group | 10+ years | BMI 48.7 ± 9.1 | BMI 35.5 ± 6.7 | – | – | – |
| | Revision group (1) | 10+ years | BMI 51.4 ± 10.2 | BMI 35.2 ± 8.2 | – | – | – |
| | Revision group (2) | 10+ years | BMI 47.3 ± 6.9 | BMI 33.8 ± 6.8 | – | – | – |
| Prevot | SG group | 5 years | – | %EWL 43 ± 25% | – | – | – |
| | Revision group | 5 years | – | %EWL 68 ± 21% | – | – | – |
| Himpens | SG group | 6 years | BMI 39.9 ± 5.9 | BMI 31.1 ± 6.2 | – | – | – |
| | Revision group | 6 years | BMI 38.4 ± 4.0 | BMI 26.7 ± 6.2 | – | – | – |

*SG* sleeve gastrectomy, *BMI* body mass index, *%EWL* percentage of excess weight loss were robust. Another limitation is that data about revisional outcomes is limited, making us unable to run meta-analysis of surgical outcomes after revision. All in all, more research taking patient characteristics into account are warranted, so as to determine which revision surgery is the best for failed SG.

## Conclusion

This systematic review and meta-analysis demonstrated that revision rate is not rare after SG, especially when looking at long-term follow-up. The most common reason for revision is failure in weight loss, and the most frequent revisional procedure is RYGB. There is a need for bariatric surgeons and patients to fully understand and deal with the need for revision after SG.

### Compliance with Ethical Standards

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

**A Statement of Formal Consent** For this type of study, formal consent is not required.

**A Statement of Human and Animal Rights** Given that there are no interventions implemented on patients, ethical approval is not required.

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