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ORIGINAL CONTRIBUTIONS

Clinical Outcomes of One Anastomosis Gastric Bypass Versus Sleeve Gastrectomy for Morbid Obesity

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Abstract

Background One anastomosis gastric bypass (OAGB) and sleeve gastrectomy (SG) are popular bariatric surgeries for morbid obesity. Reports on the safety and effectiveness of SG and OAGB are inconsistent. This meta-analysis investigated the clinical outcomes of SG versus those of OAGB for morbid obesity.

Methods Based on PRISMA guidelines, we searched the published articles in English from Scopus, PubMed (Medline), Central (Cochrane), and Embase databases. Articles were retrieved from the start date of each database to February 13, 2019. Statistical analysis of this meta-analysis was conducted in Stata 14.0, and the most appropriate effect model was chosen based on heterogeneity.

Results A total of 20 articles examining 4064 OAGB patients and 3733 SG patients were included in this meta-analysis. Compared with SG, OAGB showed a higher percentage excess weight loss (%EWL) at 6 months (weighted mean difference (WMD) = 11.32; 95% CI 6.00–16.64), 12 months (WMD = 8.22; 95% CI 3.78–12.66), 24 months (WMD = 10.19; 95% CI 0.88–21.25), 36 months (WMD = 7.93; 95% CI 3.37–12.48), 48 months (WMD = 17.22; 95% CI 7.37–27.06), and 60 months (WMD = 16.43; 95% CI 8.96–23.90). In addition, OAGB was associated with a lower rate of postoperative leak, gastroesophageal reflux disease, revisions, mortality, and dyslipidemia remission rates. However, OAGB increased the incidence of ulcers, malnutrition, and bile reflux.

Conclusion OAGB is more effective for %EWL and dyslipidemia remission than SG. In addition, OAGB may lower the risk of postoperative leak, gastroesophageal reflux disease, revision, and mortality. Further comparisons of the clinical outcomes of OAGB versus SG for morbid obesity would benefit from more high-quality controlled studies.

Keywords Bariatric surgeries · Sleeve gastrectomy · Gastric bypass · One anastomosis gastric bypass · Morbid obesity

Introduction

Obesity is a worldwide epidemic that has adverse health impacts including diabetes mellitus, obstructive sleep apnea, stroke, coronary heart disease, hypertension, gastroesophageal reflux disease, and cancer [1, 2]. According to the World Health Organization, there were ~ 700 million obese adults worldwide in 2015, and obesity rates are increasing on a yearly basis [3]. Studies have shown that bariatric surgery is durable and effective for obesity and its medical comorbidities [4]. In addition, it can effectively improve the long-term survival rates of obese patients [4]. SG, as a stand-alone procedure, has become the common bariatric surgery for morbid obesity all around the world because it has a significant weight loss and medical comorbidities' remission rate [5–7]. Moreover, as a part of the biliopancreatic diversion, SG is a simple procedure that maintains intestinal continuity [8, 9]. However, SG suffers from a high incidence of postoperative weight regain, gastroesophageal reflux disease, leak, and bleeding [10–12]. In recent years, OAGB has emerged as a safe and effective alternative in obese patients [13] and its use continues to rise [14]. However, OAGB has been suggested to increase the risk of bile reflux and its repercussions [15, 16]. Over recent decades, the effectiveness and safety of OAGB and SG have

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been compared in various studies, often with inconsistent findings. We conducted this meta-analysis to help surgeons better understand the differences between OAGB and SG, permitting a more informed choice future obesity management.

Methods and Materials

The principles of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2009 Guidelines (PRISMA) [17] were used as the standard.

Search Strategy

Two reviewers searched the following keywords for related articles: "omega loop," "one anastomosis," "single-anastomosis," "mini gastric bypass," and "sleeve gastrectomy" using PubMed, Scopus, Central (Cochrane), and Embase databases. The literature search ranged from the establishment of each database to January 11, 2019. We also examined the references to identify other eligible studies. Two reviewers independently completed the search process. In cases of disagreement, a third reviewer examined the study until a consensus was reached.

Inclusion Criteria

Two reviewers independently reviewed selected articles according to the following criteria: (i) articles comparing the clinical outcomes of SG versus OAGB for morbid obesity; (ii) the language of the articles (English); (iii) final results containing one or more of the following aspects: %EWL, remission, overall complications, specific complications, hospital stay, and operative time; (iv) articles including available data; (v) access to the full text.

Data Extraction and Assessment of Quality

For each eligible article, two reviewers independently extracted the following information: the last name of the author, publication year, country or region, type of article, sample, patient demographics, %EWL, comorbidity remission, overall complications, specific complications, hospital stay, and operative time. Revisional surgery includes reversal surgery, conversion surgery, and repair surgery. Obesity and metabolic disease patients need to undergo reoperation due to poor surgical results or serious complications after the first weight loss procedure. Conversion surgery meant that the patients would receive another different procedure; it meant revision of SG and OAGB to something else. Reversal surgery was conducted to restore the normal anatomical structure of the patients. Repair surgery is performed for adjustment by the surgeon on the patient's original procedure. Based on the NOS guidelines, non-randomized controlled studies which achieved 5–9 points were defined as high-quality articles, and we could define randomized controlled studies with 4–7 points as high-quality articles according to the description of the Jadad scale.

Statistical Analysis

For dichotomous variables, the odds ratio (OR) with a 95% confidence interval (95% CI) was calculated and analyzed. In addition, continuous variables were assessed by calculating the weighted mean difference (WMD) with 95% CI to compare the difference between SG and OAGB groups. For dichotomous variables, OR > 1 denoted that the frequency in the OAGB group was higher. In addition, WMD > 0 suggested that the values in the OAGB groups were higher than those for continuous variables. Moreover, we use range and percentage to express sample size and its percentage when they appear in the "Results" section. In addition, we express other variables in terms of mean and standard deviation. Heterogeneity between the studies was assessed using the Cochran's Q statistic and assessing I^2 test values. The fixed effects model (Mantel-Haenszel method) [18] was used if $I^2 < 50\%$ or the p (heterogeneity) > 0.05. We chose the random effects model (DerSimonian and Laird method) [19] if $I^2 > 50\%$ or the p (heterogeneity) < 0.05. All statistical analyses were performed in Stata 14.0 (StataCorp, College Station, TX, USA).

Results

Literature Search and Patient Demographics

A total of 663 keywords from related articles were retrieved from above databases, and we included 20 articles for final quantitative analysis. The above search process is shown in Fig. 1. A total of 4064 OAGB patients and 3733 SG patients were included this meta-analysis from 20 articles (Table 1). In addition, based on the total score (140 points) of the methodological quality of evaluation and the average score (7 points) of each article, according to the NOS guidelines and the Jadad scale, all studies included had a score of 6 or higher (Table 1). The included articles respectively came from Singapore [20, 21], the UK [22], India [12, 23–27], Spain [28], France [29], Taiwan [30–33], Germany [34], and Italy [35–38]. A total of 9 articles were retrospective design, 7 articles were prospective studies, and 4 articles were randomized controlled studies. The mean BMI at the time of surgery in the SG groups and OAGB groups were 40.84 ± 8.7 and 41.79 ± 8.0 kg/m^2, respectively. The sample size for SG ranged from 12 to 1107 patients, while it ranged from 15 to 1731 patients for OAGB groups and OAGB was performed in 52.1% of all included cases. The female patients in the SG and OAGB groups

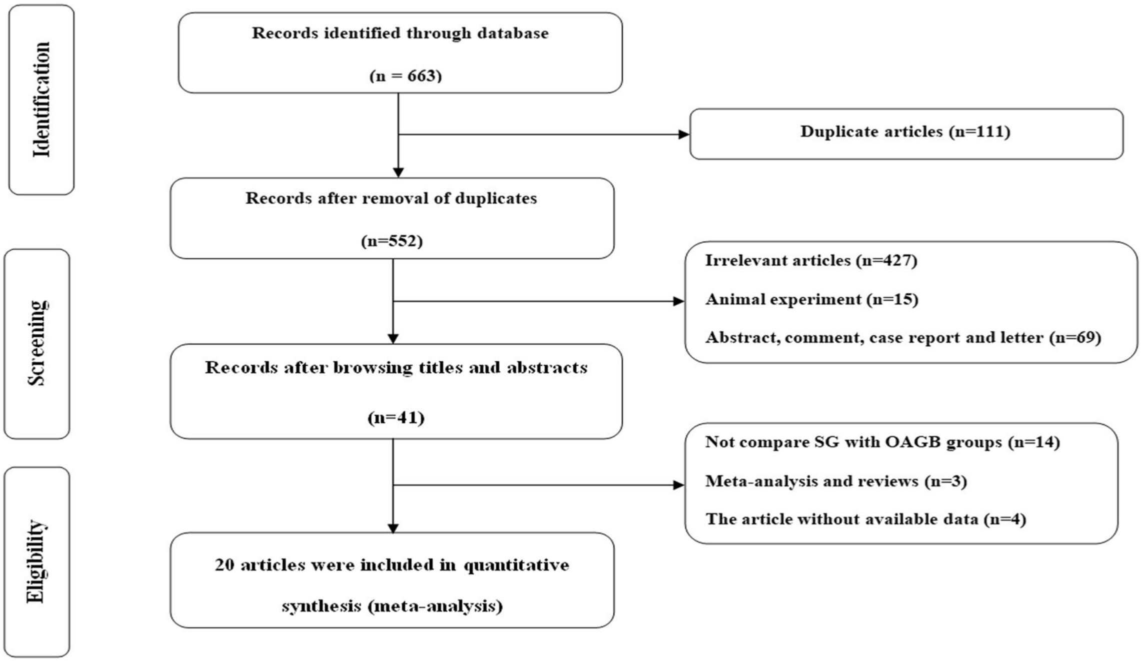

Fig. 1 Flow chart for searching articles. SG, sleeve gastrectomy; OAGB, one anastomosis gastric bypass; WMD, weighted mean difference

respectively accounted for 64.5% and 68.0%. The mean age of SG patients was 38.2 ± 10.9 years, and 36.8 ± 11.3 years for OAGB patients ($p = 0.434$).

%EWL

In our meta-analysis, a total of 11 articles reported available data regarding the %EWL during the course of follow-up (Table 2). The results showed that OAGB led to a better %EWL than SG at 6 months (WMD = 11.32; 95% CI 6.00–16.64) and 12 months (WMD = 8.22; 95% CI 3.78–12.66) (Fig. 2 and Table 3). OAGB showed an improved weight loss at 24 months, but the differences in %EWL between the groups were not significant (WMD = 10.19; 95% CI − 0.88–21.25). In addition, OAGB had a better %EWL at 36 months (WMD = 7.93; 95% CI 3.37–12.48), 48 months (WMD = 17.22; 95% CI 7.37–27.06), and 60 months (WMD = 16.43; 95% CI 8.96–23.90) (Fig. 3 and Table 3).

Remission Rate of Medical Comorbidities

The studies included in this meta-analysis contained available data regarding medical comorbidities from different follow-up periods including diabetes mellitus, hypertension, OSAS, osteoarthritis, and dyslipidemia. The final results showed no significant differences in the remission rates of diabetes mellitus at 12 months (OR = 1.09; 95% CI 0.93–1.26), 24 months (OR = 1.07; 95% CI 0.88–1.30), 36 months (OR = 1.01; 95% CI 0.63–1.63), and 60 months (OR = 0.98; 95% CI 0.81–1.19) (Table 3). In addition, there were no significant differences in the remission rates of hypertension at 12 months (OR = 0.88; 95% CI 0.75–1.03), 24 months (OR = 0.97; 95% CI 0.82–1.15), 36 months (OR = 0.99; 95% CI 0.59–1.65), and 60 months (OR = 0.91; 95% CI 0.77–1.07) (Table 3). Moreover, there was no significant difference in the remission rates of OSAS (OR = 1.15; 95% CI 0.63–2.07) and osteoarthritis (OR = 0.78; 95% CI 0.47–1.30) (Table 3). However, OAGB had higher dyslipidemia remission rates at 12 months (OR = 1.83; 95% CI 1.56–2.15), 24 months (OR = 2.25; 95% CI 1.89–2.66), and 60 months (OR = 2.28; 95% CI 1.38–3.78) (Fig. 4 and Table 3).

Overall Complications and Specific Complications

Ten of the included articles provided data on complications for our final analysis. There were no significant differences regarding overall complications between OAGB and SG groups (OR = 0.85; 95% CI 0.59–1.24; $p = 0.398$) (Table 3). For specific complications, OAGB could reduce the incidence of postoperative leak (OR = 0.33; 95% CI 0.17–0.65; $p = 0.001$) and gastroesophageal reflux disease (OR = 0.14; 95% CI 0.07–0.28; $p = 0.000$) compared with SG groups (Fig. S1a and Table 3). In addition, the risk of ulcers (OR = 6.51; 95% CI 2.38–17.80; $p = 0.000$), malnutrition (OR = 31.19; 95% CI 5.85–166.40; $p = 0.000$), and bile reflux (OR = 5.71; 95% CI 1.03–31.77; $p = 0.047$) was higher in the OAGB groups (Fig. S1b and Table 3). No statistical differences were observed regarding bleeding (OR = 1.01; 95% CI 0.54–1.92; $p = 0.964$), anemia (OR = 3.23; 95% CI 0.62–16.69; $p = 0.162$), and vomiting (OR = 0.61; 95% CI 0.24–1.59; $p = 0.315$) (Table 3).

Table 1 Characteristics of the studies included in the meta-analysis (SG/OAGB)

Author, year	Country	Type	Sample	Female, *n* (%)	Mean age, mean (SD)	BMI (kg/m^2), mean (SD)	Operative time, mean (SD)	Hospital stay, mean (SD)	NOS or Jadad
Toh [20], 2018	Singapore	R	393 43	243 (61.8) 30 (69.8)	40 (11) 47 (9)	43 (7.9) 40.3 (9.1)	-	-	8
Singla [23], 2018	India	P	50 25	37 (74) 21 (84)	40.95 (9.77) 39.56 (10.09)	54.18 (4.06) 53.76 (3.28)	-	-	7
Shivakumar [24], 2018	India	RCT	100 101	65 (65) 62 (61.3)	39.89 (11.75) 42.89 (14.02)	44.57 (7.16) 44.32 (7.88)	44.81 (10.62) 64.81 (10.62)	3.95 (0.73) 3.2 (0.64)	6
Tovar [28], 2018	Spain	RCT	200 200	150 (75) 150 (75)	43.9 (10.9) 43.8 (11.5)	46.5 (3.4) 45 (4.1)	-	-	6
Alkhalifah [21], 2018	Singapore	R	1107 1731	829 (74.9) 1212 (70.0)	35.2 (10.1) 33.8 (10.4)	36.4 (7.6) 40.4 (7.7)	115.2 (35.7) 124.6 (38.8)	3.1 (3.1) 5.0 (4.1)	7
Abdel-Rahim [25], 2018	India	P	20 20	17 (85.0) 13 (65.0)	42.95 (7.63) 42.9 (6.17)	47.77 (6.18) 50.88 (3.99)	-	-	7
Jammu [12], 2015	India	P	339 473	154 (45.4) 333 (70.4)	23 46.5	35 56.5	60.0 (7.5) 57.5 (8.25)	-	7
Kansou [29], 2016	France	R	136 136	125 (91.9) 127 (93.4)	41.2 (12.3) 41.2 (11.3)	43.4 (6.5) 42.8 (5.0)	-	-	8
Kular [26], 2014	India	R	118 104	-	-	42 (5.2) 44 (3.1)	76.6 (28.3) 52 (20.2)	3.4 (2.4) 2.5 (1.3)	8
Lee [33], 2014	Taiwan	RCT	30 30	22 (68.8) 22 (73.3)	46.4 (8.1) 44.6 (8.6)	31 (2.8) 30.2 (2.2)	-	-	8
Madhok [22], 2016	UK	R	56 19	31 (55.4) 9 (47.4)	51 (10.5) 45 (9.75)	65 (9) 67 (6)	75 (50.5) 92 (31.5)	2 2	6
Milone [35], 2015	Italy	P	86 74	46 (53.5) 46 (62.2)	33.7 (5.61) 34.9 (6.01)	46.0 (4.77) 47.3 (3.88)	-	-	8
Musella [36], 2015	Italy	R	110 96	30 (27.3) 38 (39.6)	49.2 (9.1) 48.5 (8.7)	48.1 (7.8) 48.3 (9.2)	-	-	6
Plamper [34], 2016	Germany	R	118 169	72 (61.0) 121 (71.6)	43.4 (11.2) 43.2 (11.1)	54.6 (10.3) 54.1 (6.6)	112.1 (33.5) 81.7 (25.3)	7.2 (5.5) 4.5 (2.6)	6
Seetharamaiah [27], 2016	India	RCT	100 101	65 (65.0) 62 (61.4)	39.89 (11.75) 42.89 (14.02)	44.57 (7.16) 44.32 (7.88)	44.81 (10.62) 64.81 (10.62)	3.95 (0.73) 3.2 (0.64)	8
Tolone [38], 2015	Italy	P	25 15	- 10 (66.6)	- 38 (8.2)	46.1 (5) 46.4 (5.5)	-	-	6
Lee [30], 2015	Taiwan	R	519 519	387 (75) 403 (78)	36.0 (9.1) 35.9 (9.1)	37.5 (6.1) 37.4 (5.9)	113.5 (31.1) 117.2 (33.3)	3 (1.7) 3.4 (2.4)	8
Yang [32], 2014	Taiwan	P	32 89	13 (41) 68 (76)	33.9 (9.4) 32.1 (10.3)	42.4 (8.9) 41.7 (5.6)	-	-	6
Lee [31], 2013	Taiwan	R	12 33	-	31.8 (9.2)	39.6 (0.7) 41.7 (7.3)	-	-	6
Musella [37], 2014	Italy	P	175 80	122 (70) 38 (48)	38.25 34.8	47.9 50.8	-	-	8

[12, 25–39]: the studies included in this meta-analysis; *SG* sleeve gastrectomy, *OAGB* one anastomosis gastric bypass odds ratios, *P* prospective trial, *R* retrospective trial, *RCT* randomized controlled trial, *SD* standard deviation, *NOS* Newcastle–Ottawa Scale for observational studies, *Jadad* assessment of quality for randomized controlled studies; the age, operative time, hospital stay, and BMI were express as mean (SD); "-" data was not available

Revisions

A total of 8 articles reported available data regarding revision surgery. Upon analysis, OAGB was found to lower the risk of revision surgery (OR = 0.59; 95% CI 0.43–0.81).

Hospital Stay and Operative Time

Six articles reported available data on hospital stays. No significant differences between OAGB and SG groups (WMD = − 0.40; 95% CI − 1.35–0.55) were observed. There were 8 studies with available data on the operative time. No significant differences were found regarding the operative times (WMD = 1.26; 95% CI − 8.47–11.00) of the SG and OAGB groups (Table 3).

Perioperative Mortality

A total of 10 articles provided data on the mortality rates. The results indicated that the incidence of mortality in the OAGB groups was lower than that in the SG groups (OR = 0.38; 95% CI 0.15–0.99) (Fig. S1a and Table 3).

Table 2 Characteristics of the studies included in meta-analysis (%EWL) (SG/OAGB)

Author, year	%EWL					
	6 months	12 months	24 months	36 months	48 months	60 months
Toh [20], 2018	49.7 (17.7) 58.0 (22.5)	61.2 (20) 68.1 (28.5)	56.1 (29.3) 62.7 (33.5)	47.8 (22.8) 66.2 (35.8)	40.8 (22.5) 64.0 (14.5)	47.3 (27.4) 65.2(27.4)
Singla [23], 2018	-	56.20 (18.9) 74.57 (13.2)	-	-	-	-
Shivakumar [24], 2018	-	63.97 (13.4) 66.19 (10.9)	62.79 (21.1) 64.77 (17.3)	61.15 (25.2) 66.48 (15.7)	-	-
Tovar [28], 2018	-	-	-	-	-	76.3 (6) 97.9 (7)
Alkhalifah [21], 2018	-	85.2 79.0	92.2 81.1	-	-	83.7 80.4
Abdel-Rahim [25], 2018	33.73 (4.3) 48.80 (5.4)	45.33 (5.1) 64.65(6.4)	-	-	-	-
Jammu [12], 2015	-	53.6 92.2	-	-	-	-
Kansou [29], 2016	-	71.4 (19.0) 79.3(17.8)	-	-	-	-
Kular [26], 2014	-	69 (22.5) 63 (21.2)	66.2 (23.4) 71.6 (24.3)	61 (26.4) 70 (22.6)	56 (25.0) 69 (20.4)	51.2 (23.0) 68 (24.0)
Madhok [22], 2016	36 (19.7) 44 (8.5)	45 (21.5) 58 (7.7)	38 (22.2) 66 (7.7)	-	-	-
Musella [36], 2015	-	52.4 (18.3) 64.7 (22.9)	-	-	-	-
Plamper [34], 2016	-	57.3 (19) 66.2 (13.9)	-	-	-	-
Seetharamaiah [27], 2016	-	63.97 (13.2) 66.87 (10.8)	-	-	-	-
Tolone [38], 2015	-	56 63 (9.6)	-	-	-	-
Lee [30], 2015	-	-	-	-	-	68.7 (30.3) 78.2 (19.7)
Yang [32], 2014	-	67.2 (18.4) 72 (20)	-	-	-	-
Lee [31], 2013	-	31.4 37.1	-	-	-	-
Musella [37], 2014	-	61.4 72.1	-	68.3 79.5	-	-

[12, 25–39]: the studies included in this meta-analysis; *SG* sleeve gastrectomy, *OAGB* one anastomosis gastric bypass odds ratios, *%EWL* percentage excess weight loss; %EWL was express as mean (standard deviation); "-" data was not available

Discussion

Since SG was introduced as a first stage of the biliopancreatic diversion in 1999, it has gained worldwide recognition because of its significant reduction in weight, and improved remission rates of obesity-related comorbidities [39–41]. Compared with RYGB, OAGB has attracted more recent attention because it had one less anastomosis [13, 42]. Moreover, OAGB seemed to have the advantage of being less technically demanding and less incidence of potential morbidity. Weight loss and metabolic outcomes initially published were as good as those reported for the RYGB or better [43]. However, its complications such as ulcer, bile reflux, and malnutrition make its use controversial [44]. Shivakumar concluded that there was no significant difference between OAGB and SG groups in terms of weight loss [24]. This conclusion was different from the other five articles which concluded that OAGB has better weight loss effect. Singla concluded that there was a similar resolution of comorbidities in the OAGB and SG groups, and Toh concluded that the remission rate of diabetes mellitus was equally high between SG and OAGB surgical groups despite ethnic differences [20, 23]. Their results were different from the other four articles which concluded that OAGB had a better remission of medical comorbidities than SG. In this meta-analysis, we further explored the clinical outcomes of OAGB and SG to help surgeons select the most effective surgical approach.

Although three similar meta-analyses have been recently published, the numbers of included articles were small and the conclusions were inconsistent [45–47]. Quan et al. conducted a meta-analysis containing 6 studies to compare

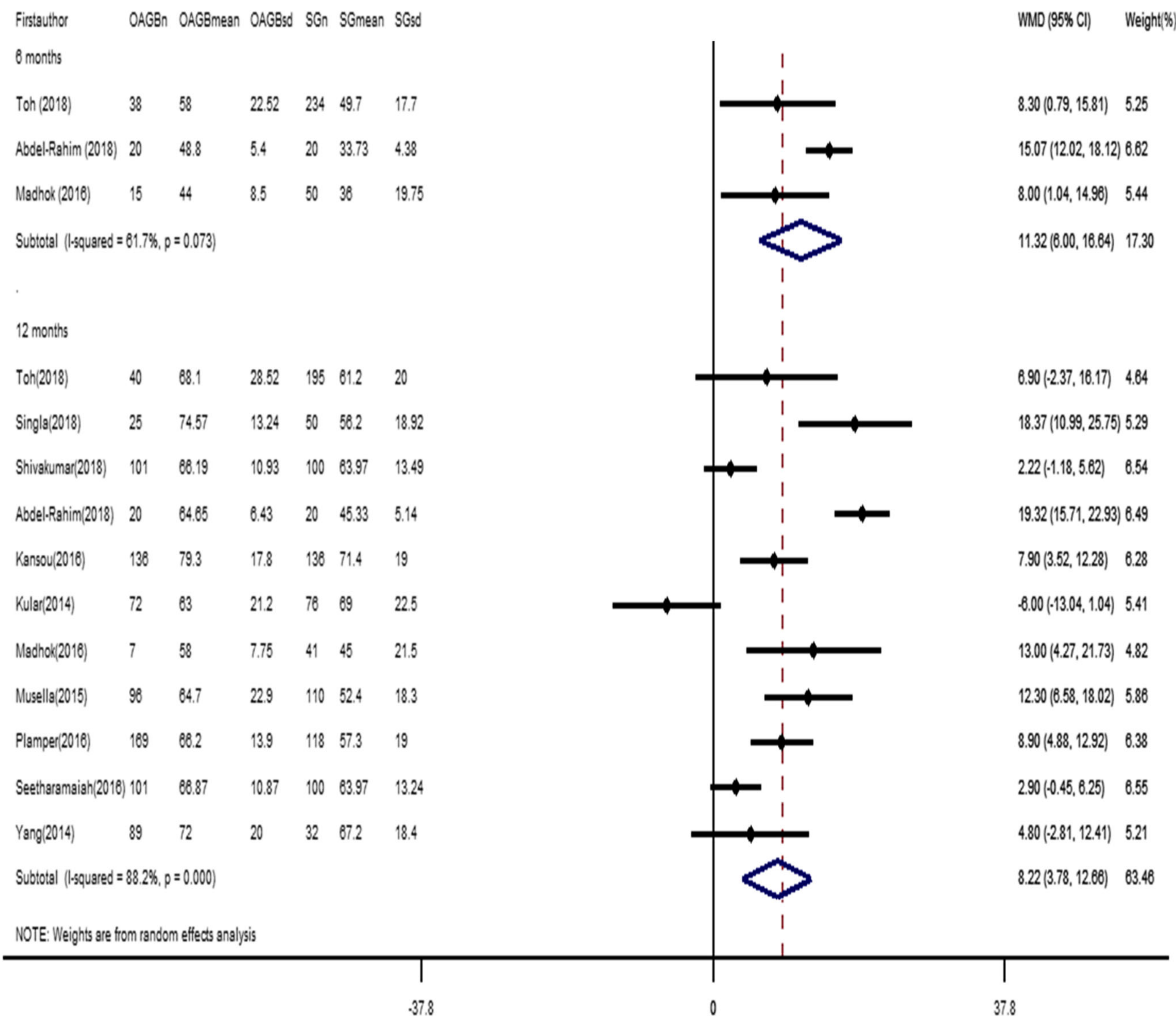

Fig. 2 The forest plot showed the WMD (95% CI) of %EWL at 6 and 12 months between OAGB and SG groups for morbid obesity. SG, sleeve gastrectomy; OAGB, one anastomosis gastric bypass; WMD, weighted mean difference; CI, confidence interval; %EWL, percentage excess weight loss

OAGB and other bariatric surgeries such as SG. They concluded that OAGB appeared to be effective in weight loss and diabetes mellitus remission and non-inferior to other bariatric surgeries. They collected and analyzed %EWL at 12 months, and the results showed that OAGB and SG had similar reduction in weight loss. Moreover, they concluded that OAGB had better remission rate of diabetes mellitus than SG without making subgroup analysis by follow-up time. The meta-analysis conducted by Wang et al. concluded that OAGB is a more effective bariatric procedure than SG. The result indicated OAGB had a higher remission rate of diabetes mellitus than SG. Similarly, the analysis of remission rate of diabetes mellitus did not take follow-up time into account. Magouliotis et al. conducted a meta-analysis and 17 studies met the inclusion criteria incorporating 6761 patients. They suggested the OAGB group had increased weight loss, remission of comorbidities, and lower mortality. The incidence of leaks and intra-abdominal bleeding was similar between the two approaches. However, the data extraction about %EWL from the article conducted by Kansou and the number of female from Jammu and Sharma's article appears not to be accurate. Therefore, the inaccurate data extraction also questions the accuracy of the meta-analysis. Our meta-analysis indicated that OAGB and SG are feasible, effective, and well-tolerated surgical approaches. The results showed that OAGB and SG groups had comparable operative times and hospital stays.

Regarding postoperative complications, OAGB and SG had similar risks. In terms of specific complications, differences were found between the two groups. Ulcer, bile reflux, and malnutrition occurred more frequently in patients receiving OAGB. The main difference was the results about bile reflux compared with previous similar meta-analysis conducted by Magouliotis et al.;

Table 3 Summary odds ratios for the association between OAGB and SG for morbid obesity by study characteristics

	No. of studies		p	Heterogeneity tests	
				p	I^2 (%)
Categorical outcomes		OR (95% CI)			
Complications					
Overall complications	10	0.85 (0.59, 1.24)	0.398	0.027	52.0
Specific complications					
Leaks	8	0.33 (0.17, 0.65)	0.001	0.297	16.9
Bleeding	8	1.01 (0.54, 1.92)	0.964	0.832	0.0
Ulcer	9	6.51 (2.38, 17.80)	0.000	0.994	0.0
Anemia	3	3.23 (0.62, 16.69)	0.162	0.042	68.5
Vomiting	4	0.61 (0.24, 1.59)	0.315	0.913	0.0
Malnutrition	3	31.19 (5.85, 166.40)	0.000	0.195	38.8
Bile reflux	3	5.71 (1.03, 31.77)	0.047	0.921	0.0
GERD	5	0.14 (0.07, 0.28)	0.000	0.201	33.1
Revisions	8	0.59 (0.43, 0.81)	0.001	0.311	15.1
Mortality	10	0.38 (0.15, 0.99)	0.049	0.836	0.0
Remission rate					
DM					
1 year	12	1.09 (0.93, 1.26)	0.287	0.994	0.0
2 years	4	1.07 (0.88, 1.30)	0.512	0.991	0.0
3 years	2	1.01 (0.63, 1.63)	0.952	0.994	0.0
5 years	3	0.98 (0.81, 1.19)	0.834	0.561	0.0
HTN					
1 year	8	0.88 (0.75, 1.03)	0.109	0.826	0.0
2 years	4	0.97 (0.82, 1.15)	0.738	0.904	0.0
3 years	2	0.99 (0.59, 1.65)	0.972	0.879	0.0
5 years	3	0.91 (0.77, 1.07)	0.238	0.192	39.4
DL					
1 year	2	1.83 (1.56, 2.15)	0.000	0.312	2.1
2 years	2	2.25 (1.89, 2.66)	0.000	0.594	0.0
5 years	3	2.28 (1.38, 3.78)	0.001	0.016	75.9
OSAS					
1 year	2	1.15 (0.63, 2.07)	0.649	0.762	0.0
Osteoarthritis					
1 year	2	0.78 (0.47, 1.30)	0.348	0.685	0.0
Continuous outcomes		WMD (95% CI)			
Hospital stay	6	− 0.40 (− 1.35, 0.55)		0.000	98.6
Operative time	8	1.26 (− 8.47, 11.00)		0.000	98.7
%EWL					
6 months	3	11.32 (6.00, 16.64)	0.000	0.073	61.7
12 months	11	8.22 (3.78, 12.66)	0.000	0.000	88.2
24 months	4	10.19 (− 0.88, 21.25)	0.071	0.000	85.7
36 months	3	7.93 (3.37, 12.48)	0.001	0.233	31.3
48 months	2	17.22 (7.37, 27.06)	0.001	0.133	55.8
60 months	4	16.43 (8.96, 23.90)	0.001	0.001	82.5

SG sleeve gastrectomy, *OAGB* one anastomosis gastric bypass odds ratios, *OR* odds ratios, *WMD* weighted mean difference, *CI* confidence intervals, *No.* number, *GERD* gastroesophageal reflux disease, *DM* diabetes mellitus, *HTN* hypertension, *DL* dyslipidemia, *OSAS* sleep apnea–hypopnea syndrome, *%EWL* percentage excess weight loss

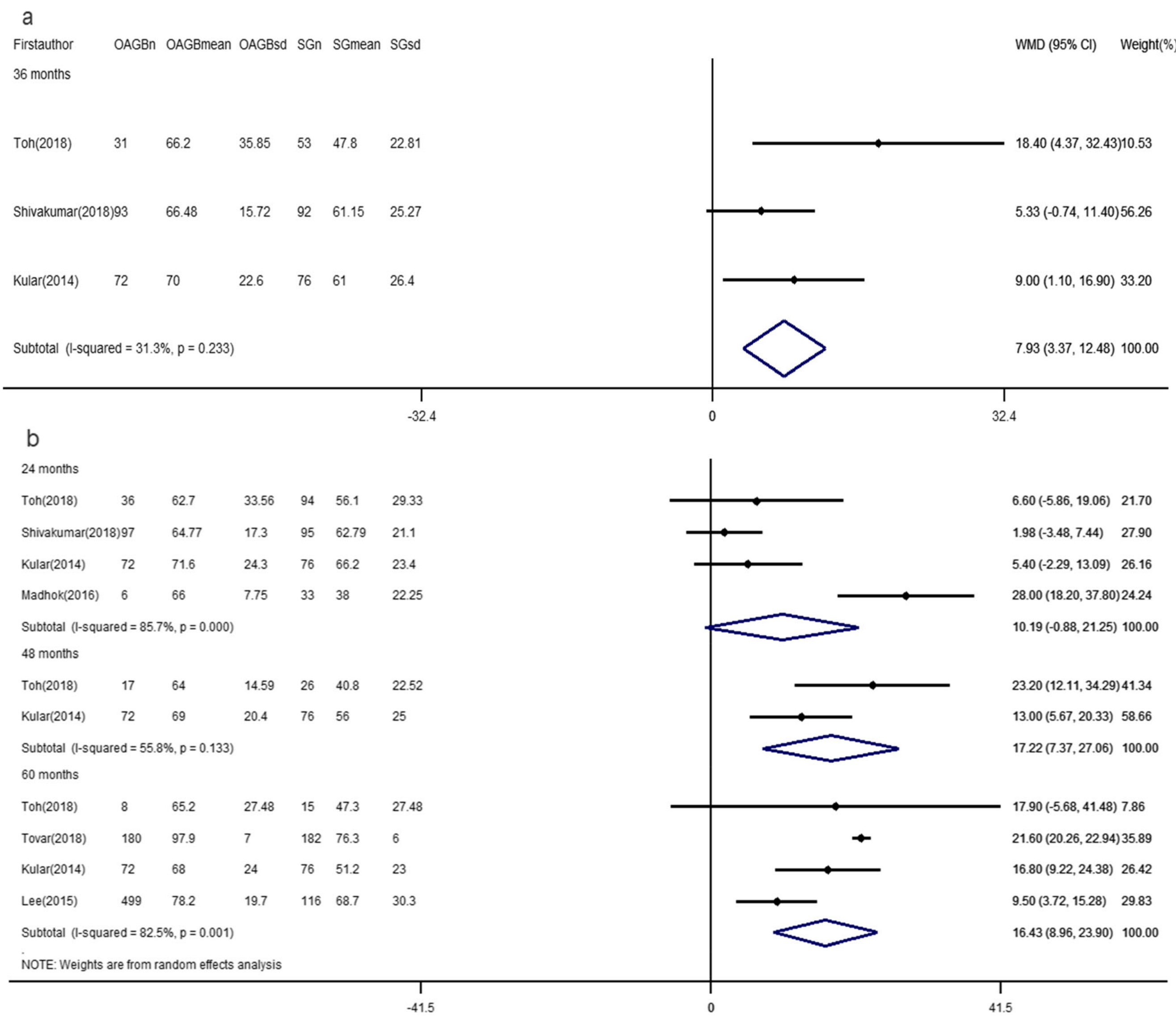

Fig. 3 The forest plot showed the WMD (95% CI) of %EWL at 24, 36, and 60 months between OAGB and SG groups for morbid obesity. SG, sleeve gastrectomy; OAGB, one anastomosis gastric bypass; WMD, weighted mean difference; CI, confidence interval; %EWL, percentage excess weight loss

they concluded that the incidence of bile reflux disease was greater in patients that underwent SG. Compared with SG, OAGB has the characteristics caused of gastrointestinal anastomosis, which may account for the higher incidence of postoperative marginal ulcers. There were 3 articles with available data regarding bile reflux; the results showed that the probability of bile reflux in the patients receiving OAGB was 5.71 times higher than patients receiving SG. The fact that some patients receiving OAGB needed to convert to RYGB due to bile reflux indirectly supported this conclusion [48]. Postoperative malnutrition was a common late complication with an incidence of 2% in patients receiving OAGB most likely due to a too long biliopancreatic limb. Postoperative leak and gastroesophageal reflux disease were more common in patients receiving SG [49, 50]. In addition, no significant differences in bleeding, anemia, and vomiting between the two procedures were observed. The study conducted by Magouliotis et al. concluded a different opinion that OAGB and SG had similar incidence of leaks, but the final result lacked persuasion because of the relatively small number of articles included and a higher heterogeneity than our result about leak. Mortality and revision rates in two of the articles suggested that the risk of revision in patients receiving SG was higher [45, 46]. In addition, the study conducted by Magouliotis et al. indicated that the incidence of mortality was higher in patients receiving SG. In agreement with previous studies, we found that OAGB led to a lower risk of mortality and revision. Postoperative complications such as leak and GRED in patients receiving SG may account for finding [10, 51].

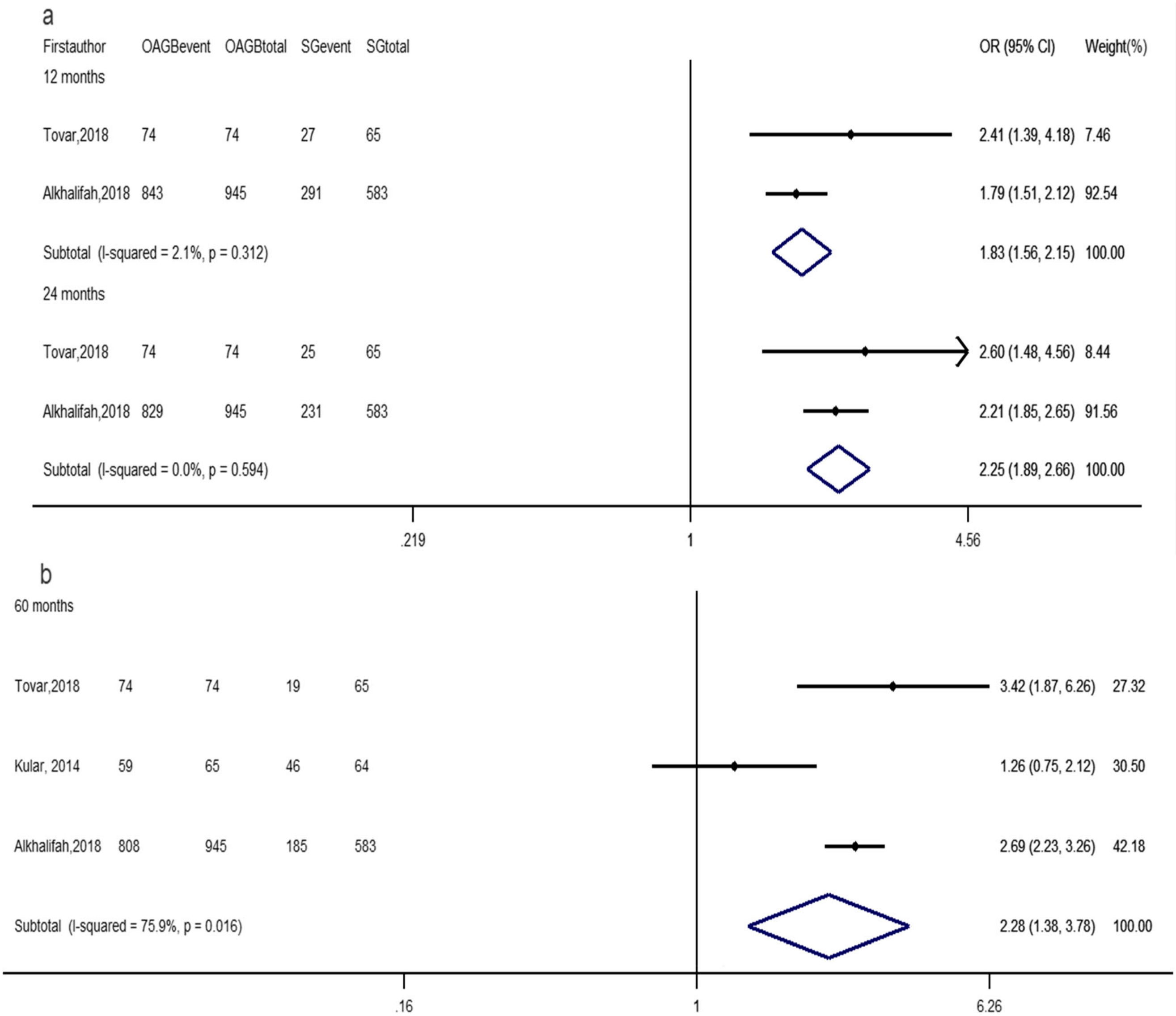

Fig. 4 The forest plot showed the OR (95% CI) of remission rate of dyslipidemia at 12, 24, and 60 months between OAGB and SG groups for morbid obesity. SG, sleeve gastrectomy; OAGB, one anastomosis gastric bypass; OR, odds ratios; CI, confidence interval

With regard to the remission rates of medical comorbidities, we observed no differences in the remission rates of diabetes mellitus and hypertension at 12 months, 24 months, 36 months, and 60 months postoperatively [52]. In addition, no differences in osteoarthritis remission were observed. Moreover, patients receiving OAGB had better dyslipidemia remission rates in agreement with previous studies [45]. Previous meta-analyses suggested that OAGB increases the remission rates of patients to a greater degree than SG, but the results did not consider the follow-up time, making them unreliable. Moreover, since the data regarding the remission rate of medical comorbidities from the included articles were follow-up time-dependent, the most obvious difference between our results and the previous meta-analysis was that we make subgroup analysis according to the follow-up time to find out more actual comparison with different follow-up stages.

Previous similar meta-analyses only analyzed the data about %EWL for 1, 2, and 5 years. The results showed that patients receiving OAGB had better %EWL than SG at 6 months and 12 months. However, although OAGB had a tendency to improve weight loss, there was no statistical difference in the %EWL at 24 months. This conclusion was supported by Magouliotis et al. in which the %EWL at 24 months in the OAGB groups and SG groups were comparable [45]. In addition, we analyzed weight loss data for longer follow-up periods and concluded that the OAGB had a better effect on the %EWL at 36 months, 48 months, and 60 months. Felsenreich et al. demonstrated that patients receiving SG had a higher risk of weight regain at 10 years postoperatively [53]. Their conclusions also indirectly support our results at long-term follow-up time, differences in the %EWL between the groups possibly due to more weight regain after SG.

The major limitation of this meta-analysis was the study design. The high number of 9 non-randomized controlled studies limited this meta-analysis. In addition, the retrospective studies retrieved from different time periods with low/high experience in bariatric surgery may have an impact on findings. Then, different centers had different previous experiences with the two procedures also have an impact on the clinical outcomes. Moreover, it is hoped that future research articles will have a unified and clear definition of postoperative complications. Thus, our findings in regard to some of the adverse effects reported should be interpreted with care. Moreover, there was no unified and clear definition of malnutrition in the included articles, which was defined as albumin concentration of less than 30 g/L or prealbumin concentration of less than 0.20 g/L, or both. There were however many advantages of this meta-analysis including as follows: (i) large sample size for final analysis; (ii) accurate data extraction and the main endpoints have longer follow-up data.

Conclusions

This meta-analysis indicated that both OAGB and SG are feasible and effective surgical procedures for morbid obesity. OAGB had a better %EWL within 60 months of follow-up, higher dyslipidemia remission rates, and a lower risk of postoperative leak, gastroesophageal reflux disease, revisions, and mortality. However, patients who underwent OAGB were more prone to complications including ulcers, bile reflux, and malnutrition. More high-quality randomized controlled studies are required for a further comparison of the clinical outcomes of OAGB versus SG for morbid obesity.

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Compliance with Ethical Standards

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

Ethical Approval Statement This article does not contain any studies with human participants or animals performed by any of the authors.

Informed Consent Statement Does not apply.

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