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REVIEW ARTICLE

Roux-en-Y Gastric Bypass Versus Sleeve Gastrectomy for Super Super Obese and Super Obese: Systematic Review and Meta-analysis of Weight Results, Comorbidity Resolution

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Abstract

Background Roux-en-Y gastric bypass (RYGB) and sleeve gastrectomy (SG) used for super obesity (SO) and super super obesity (SSO) remain controversial. The meta-analysis was to summarize the evidence.

Methods We searched in MEDLINE and PubMed for studies concerning RYGB and SG for SO or SSO and pooled complication, percentage excess weight loss (%EWL), and resolution of comorbidities.

Results Twelve studies were identified. RYGB achieved higher %EWL at 12 months, but no significant difference at 24 months. Resolution of diabetes mellitus and dyslipidemia reached a statistical significance; however, there was no significant difference in hypertension.

Conclusions RYGB was superior in %EWL for SSO and SO at 12 months. However, regarding at 24 months, RYGB was equal to SG, which is from a meta-analysis and cannot be seen as a definitive conclusion.

Keywords Roux-en-Y gastric bypass · Sleeve gastrectomy · Super super obesity · Super obesity

Introduction

Obesity, as a major health problem, is associated with several comorbidities, including diabetes mellitus (DM), hypertension (HTN), dyslipidemia (DL), cardiovascular diseases, and cancer [1]. Bariatric surgery has gained popularity as the treatment of choice for morbid obesity (40 $kg/m^2 \leq$ body mass index (BMI) < 50 kg/m^2) [2]. In a population of morbidly obese people, the super obese (SO, BMI ≥50 kg/m^2) and super super obese (SSO, BMI ≥60 kg/m^2) [3] individuals present a treatment challenge for bariatric surgeons. Currently, the most commonly performed bariatric procedures are the Roux-en-Y gastric bypass (RYGB) and sleeve gastrectomy (SG) [4, 5]. RYGB provides excellent long-term weight loss and high

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rates of remission of coexisting conditions, which is currently viewed as the gold standard surgical treatment [6]. SG is increasingly used as a stand-alone procedure because of substantial long-term weight loss and remission of diabetes [7–11]. From a recent meta-analysis, RYGB is the more long-term effective procedure in morbid obesity, in comparison with SG and AGB [12]. Several studies focused on the SSO and/or SO have compared outcomes between RYGB and SG, but there is no consensus and there is still no system of published findings on this topic. Therefore, we performed a meta-analysis to summarize available evidence on this issue.

Materials and Methods

Search Strategy

We searched in MEDLINE and PubMed for studies of the effect of bariatric surgery in the super super obese and super obese that were published in any language on December 2018. Key words and/or medical subject heading terms to search were as follow: bariatric surgery or Roux-en-Y gastric bypass (RYGB) or sleeve gastrectomy (SG) and super super obese (SSO) or super obese (SO) or overweight or high body mass index. We also scanned the reference lists of all retrieved articles to identify additional studies. If necessary, we attempted to contact the authors to acquire additional information.

Study Selection

Studies were included if they met the following criteria: (1) include RYGB and SG; (2) have data of perioperative results and early complications, weight loss, or remission of comorbidity, or data necessary to assess them; (3) present the effect of bariatric surgery in the super super obese or super obese.

Data Extraction

All data were extracted independently and cross-checked by three reviewers (WY, YHS, and XTW) according to the prespecified selection criteria. Disagreement was resolved by discussion. The following data from each study were extracted: the last name of the first author, year of publication, study design, sample size, characteristic of patients (age, %female, BMI, comorbidities), time to follow-up and comment (weight loss, comorbidity changes); surgical result (operative time, complications, length of stay).

Definition for Resolution of Comorbidities

We defined the resolution of hypertension as cessation of antihypertensive medication and normal blood pressure values at 12 months. The resolution of type 2 diabetes mellitus was defined as cessation of oral or insulin diabetic medication, normal fasting glucose, and normal HbA1c at 12 months. The resolution of hyperlipidemia was defined as cessation of dyslipidemia medications and normal lipid panel values at 12 months.

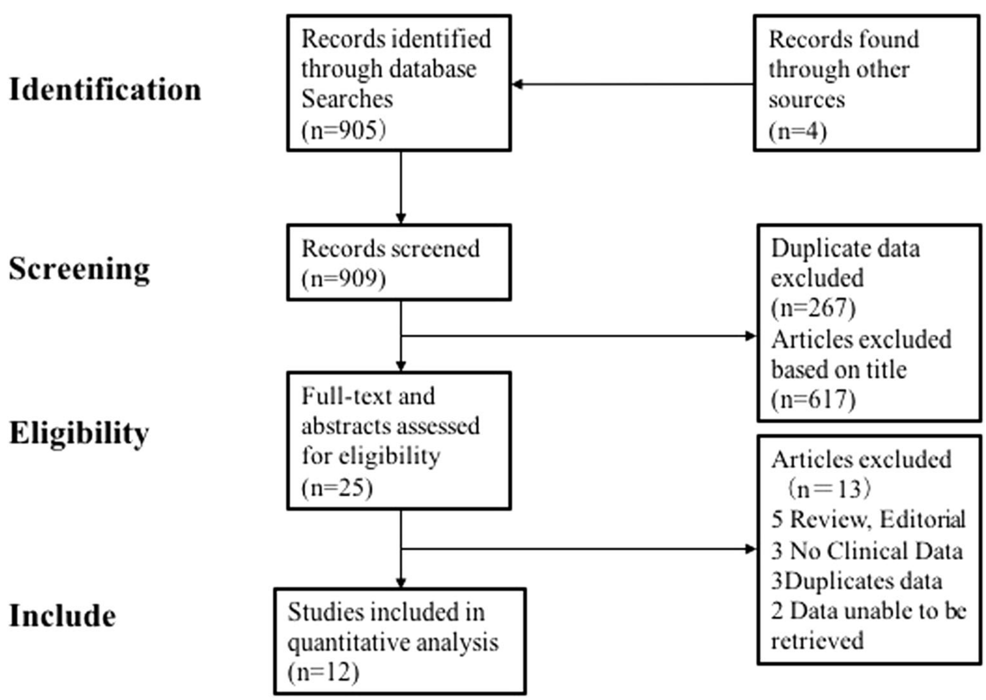

Fig. 1 Screening and selection process of studies

Table 1 Characteristics and demographics of included studies

Author (year)	Type	Patients	Number of patients (RYGB/SG)	Age (M(SG)) RYGB vs SG	%females RYGB vs SG	BMI at baseline (M(SD)) RYGB vs SG	Time to follow-up (months)	Weight outcome	Comorbidities	Outcome
Serrano OK et al. (2015)	Retrospective	SSO	135 (93/42)	33.1 (11.5) vs 38.2 (11.3)	71/52	66.3 (5.4) vs 68.4 (7.9)	1, 3, 6, and 12	%EWL BMI	Arthritis, asthma, diabetes, hypertension, dyslipidemia, OSA, peripheral venous disease, history of thromboembolic disease	Weight loss; Surgical result: operative time, complication, length of stay Diabetes management: HbAlc
Gonzalez R et al. (2015)	Retrospective	SSO	89 (12/77)	44.4 (9.9) vs 38.1 (10.1)	NR	64.2 (2.5) vs 64.9 (4.2)	1, 3, 6, 12, 24, and 36	%EWL %WL	Diabetes, hypertension, dyslipidemia, OSA	Weight loss; Surgical result: operative time, complication, length of stay
Duprée A et al. (2018)	Retrospective	SSO SO	327 220 SO (101/119) 107 SS0 (21/86)	SO 43.6 SSO 40.7	SO 67 SSO 56	SO 54.3 SSO 67.4	NR	NR	Diabetes, hypertension, dyslipidemia, hyperuricemia, heart failure	Surgical result: complications
Celio AC et al. (2017)	Retrospective	SO	50,987 (42,119/8868)	43.7 vs 43.9	72.9/70.9	57.3 vs 57.8	3, 6, and 12	%TWL %EBWL BMIL	Diabetes, hypertension, hyperlipidemia, OSA, gastroesophageal reflux, Ischemic heart disease	Weight loss; Surgical result: complications; Comorbidity changes: diabetes, hypertension, hyperlipidemia, OSA, gastroesophageal reflux
Bettencourt R et al. (2018)	Retrospective	SO	194 (127/67)	42.09 (10.67) vs 44.70 (13.21)	85/64.2	54.32 (4.28) vs 54.73 (4.89)	12 and 24	BMI %EWL %TWL	Diabetes, hypertension, dyslipidemia	Weight loss; Metabolic Characteristics: hypertension, systolic BP, diastolic BP, dyslipidemia, TC, TG, LDL, HDL, diabetes, FPG, HbAlc
Uno K et al. (2017)	Retrospective	SO	48 (20/28)	32.6 (6.6) vs 37.9 (9.2)	60/21.4	55.7 (4.2) vs 57.1 (5.1	12 and 24	BMI Weight %EWL	Diabetes, hypertension, dyslipidemia	Weight loss; Surgical result: operative time, complications, conversion to open surgery; Metabolic profile changes: hypertension, dyslipidemia, diabetes
Thereaux J et al. (2015)	Retrospective	SO	359 (285/74)	40.9 (12.2) vs 45.5 (13.7)	73.7/64.9	56.7 (5.5) vs 57.2 (7.1)	12	BMI %EWL %WL	Diabetes, hypertension, hyperlipidemia, OSA, joint pain, ischemic cardiomyopathy	Weight loss; Surgical result: operative time, complications, conversion to open surgery, length of stay Coexisting conditions changes: hypertension, dyslipidemia, diabetes, OSA, joint pain
Jain D et al. (2018)	Retrospective	SO	1267 (930/337)	44.2 (10.7) vs 43.3 (11.1)	79/81	NR	24	%EWL BMI	NR	Weight loss
Jamin Hong et al. (2018)	Retrospective	SO	607 (501/106)	44.58 (11.94) vs 43.65 (16.08)	67.3/44.3	57/7 (9.27) vs 55.21 (7.90)	6, 12, 18, 24, and 36	%EWL BMI	Diabetes, hypertension, OSA, gastroesophageal reflux, hypercholesterolemia	Weight loss Diabetes remission
Daigle CR et al.	Retrospective	SO	22 (16/6)	67.1 (2.7)	NR	55.9 (3.9)	6–95	%EWL BMI	Diabetes, hypertension, hyperlipidemia, OSA	Weight loss Diabetes remission

Table 1 (continued)

Author (year)	Type	Patients	Number of patients (RYGB/SG)	Age (M(SG)) RYGB vs SG	%females RYGB vs SG	BMI at baseline (M(SD)) RYGB vs SG	Time to follow-up (months)	Weight outcome	Comorbidities	Outcome
(2016)										
Arapis K et al. (2018)	Retrospective	SSO	210 (119/91)	39.7 (9.9) vs 44.9 (11.4)	81.5/58.2	65.1 (4.3) vs 68.2 (97.1)	3, 6, 12, 18, 24, 30, 36, 42, 48, 60, and 72	%EWL BMI %TWL	Diabetes, hypertension, OSA, continuous positive airway pressure, gastroesophageal reflux disease	Weight loss; Surgical result: operative time, complications, length of stay; Coexisting conditions changes: diabetes, hypertension, OSAS, and gastroesophageal reflux disease
Onyewu SC et al. (2017)	Retrospective	SO	87 (70/17)	42.3 (10.5) vs 40.9 (9.3)	90/76	57.1 (6.5) vs 55.7 (6.0)	1, 6, and 12	%EWL BMI	Diabetes, hypertension, hyperlipidemia	Weight loss; Coexisting conditions changes: diabetes, hypertension, hyperlipidemia

RYGP Roux-en-Y gastric bypass, *SG* sleeve gastrectomy, *M* mean, *SD* standard deviation, *BMI* body mass index, *%TWL* percent total weight loss, *%WL* percent weight loss, *%EWL* percent excess weight loss, *%EBWL* percent excess body weight loss, *BMIL* BMI loss, *OSA* obstructive sleep apnea, *SO* super obese, *SSO* super super obese, *BP* blood pressure, *TC* total cholesterol, *HDL* high-density lipoprotein cholesterol, *LDL* low-density lipoprotein cholesterol, *TG* triglycerides, *FPG* fasting plasma glucose, *HbA1c* glycated hemoglobin, *NR* no report

Statistical Analysis

All statistical analyses were performed with the use of data analysis and statistical software STATA version 12.0. The success rate of weight loss ("success" was defined as a %EWL of ≥ 50%), mean differences (MD) of perioperative data (operation time and length of stay (LOS)), and percent of excess weight loss (%EWL) at 12 and 24 months between different bariatric surgery (RYGB and SG) for each aforementioned outcome were pooled using the random-effect model. The incidence of overall complication and resolution of comorbid conditions (diabetes mellitus (DM), hypertension (HTN), and dyslipidemia) was studied. The measure of the effect of interest is the OR with 95%CI (confidence interval). Studies with data on rates of perioperative or 30-day mortality and leaks were included in the analysis of perioperative or 30-day complications. Missing mean and standard deviations at the study end were calculated from other statistics if needed, such as values of mean change from baseline or baseline standard deviations. When some trials report the low and high end, we regard the formula range/6 as the best estimator of the standard deviation [13].

The Q and I^2 statistics were used to test statistical heterogeneity among studies [14]. For the Q statistic, a P value of less than 0.1 was considered to be representative of statistically significant heterogeneity. If a study has a heterogeneous source, it was excluded from the analysis. Data synthesis of these heterogeneous studies was presented in a narrative analysis. Publication bias was assessed by the Egger weighted regression method [15]; P value of less than 0.1 was considered to be representative of statistically significant publication bias.

Results

Search Results and Baseline Characteristics

A total of 909 articles were identified in the search, the titles and abstracts of the articles were screened, and only 25 were deemed potentially eligible. After review of full-text articles and abstracts, 12/25 were eligible for inclusion which were published from 2015 to 2018. The selection process was shown in Fig. 1. The 12 studies (SSO 3, SO 8, SSO and SO 1) that included 54,332 subjects (RYGB 44,414, SG 9918) were identified in this meta-analysis. All of them were retrospective studies, and 4 studies contained the data of 541 SSO with an averaging patient BMI of 66.5. There were 9 studies including 53,791 SO whose averaging BMI were 57.1. The number of patients analyzed ranged from 22 to 50,987, and the time to follow-up of weight ranged from 1 to 95 months.

All studies except one [8] showed the incidence of comorbidities including diabetes, hypertension, dyslipidemia, and the other comorbidities such as ischemic heart disease and obstructive sleep apnea were also contained in some studies. The characteristics of the 12 included trials [16–27] are shown in Table 1.

Follow-up Rate and %EWL at 12 and 24 Months Follow-up

As shown in Table 2, there were different follow-up rates for RYGB patients (31–95%) and SG patients (17–99%) at 12 months. Follow-up rates for RYGB patients were from 14 to 85% at 24 months, and it was from 7 to 93% for SG patients. %EWL at 12 and 24 months follow-up of the included trials are shown in Table 2.

Perioperative Results and Early Complications

Of all the studies included in our analysis, 4 studies contained data on operative time, showing longer operating times for RYGB compared with SG [16, 17, 21, 22, 26]. The overall meta-analysis from the operative time indicated an increase comparing RYGB with SG group (standardized mean difference, SMD 0.298; 95%CI 0.172, 0.768; P = 0.214). In the studies [16, 17, 22, 26] including data on length of stay (LOS), SG yielded longer LOS compared with RYGB, except 2 studies with a longer LOS in the RYGB group [22, 26]. The overall analysis from LOS showed a non-significant effect in two groups (SMD 0.262; 95%CI −0.152, 0.676; $P = 0.215$). Perioperative complications were shown in 9 studies [16–22, 25, 26], and overall complications were observed in 11.5% of RYGB patients and 10.9% of SG patients. The overall analysis from the overall perioperative and 30-day complications showed a non-significant effect in two groups (SMD1.87; 95%CI 0.88, 3.99; $P = 0.104$; SMD1.04; 95%CI 0.97, 1.12; $P = 0.270$, respectively) (Fig. 2). Data on perioperative and 30-day mortality were obtained from 6 studies [16–19, 22, 26], with a total of 29 deaths (0.3%) in the SG group (n = 9415) and 173 deaths (0.4%) in the RYGB group (n = 42,631). The perioperative and 30-day leak rates were presented in 5 studies [16–18, 25, 26], and there were 30 leaks in 9289 SG patients (0.3%) and 176 leaks in 42,481 RYGB patients (0.4%). The analysis from the incidence of perioperative and 30-day anastomotic leak and mortality showed a non-significant effect in two groups (OR 2.38; 95%CI 0.57, 9.95; $P = 0.234$; OR 2.24; 95%CI 0.24, 21.19; $P = 0.482$; OR 1.33; 95%CI 0.05, 33.37; $P = 0.862$; and OR 1.45; 95%CI 0.9, 2.33; $P = 0.125$, respectively) (Fig. 2). There was no meta-analysis of other complications because of few data.

Weight Loss

In some studies, there was a different time point for weight follow-up, and the follow-up of 12 and 24 months was used in the analysis. Ten studies were included in this analysis, of which complete weight outcomes were available at 12 months in 10 studies [16, 17, 19–22, 24–27] and 24 months in 6 studies [17, 20, 21, 23, 24, 26]. Of the studies included in our analysis, RYGB showed a higher %EWL compared with SG at two time points. The meta-analysis from %EWL indicated a significant increase for SSO in RYGB compared with SG groups at 12 and 24 months after bariatric surgery (SMD 0.893; 95%CI 0.458, 1.329; $P = 0.000$ and SMD 1.284; 95%CI 0.987, 1.582; $P = 0.000$, respectively) and a significant increase for SO was observed at 12 months (SMD 0.601;

Table 2 Follow-up rates and %EWL after bariatric procedures

Author (year)	12-month follow-up rate			24-month follow-up rate			%EWL at 12-month follow-up		%EWL at 24-month follow-up	
	Overall	RYGB	SG	Overall	RYGB	SG	RYGB	SG	RYGB	SG
Serrano OK et al. (2015)	35%	40%	24%	NR	NR	NR	49.01 ± 15.56	42.9 ± 17.78	NR	NR
Gonzalez R et al. (2015)	73%	40%	79%	52%	80%	47%	61.4 ± 18.1	43.6 ± 13.8	68.5 ± 16.8	45.8 ± 19.2
Duprée A et al. (2018)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Celio AC et al. (2017)	28%	31%	17%	NR	NR	NR	58 ± 14.5	49 ± 15.7	NR	NR
Bettencour R et al. (2018)	100%	NR	NR	69%	NR	NR	67.58 ± 14.26	58.74 ± 17.78	72.19 ± 14.62	59.9 ± 18.15
Uno K et al. (2017)	96%	95%	96%	79%	75%	82%	73.4 ± 16.1	57.7 ± 21.4	73.7 ± 22	65.1 ± 23.4
Thereaux J et al. (2015)	93%	NR	NR	NR	NR	NR	55 ± 14.6	40.2 ± 15.2	NR	NR
Jain D et al. (2018)	55%	58%	46%	27%	29%	20%	NR	NR	60.2 ± 20.7	61.8 ± 17.3
Jamin Hong et al. (2018)	37%	38%	26%	13%	14%	7%	59.8 ± 19.7	59.7%26.3	66.4 ± 25.9	66.8 ± 22.3
Daigle CR et al. (2016)	77%	75%	83%	NR	NR	NR	55.8 ± 19.3	49.5 ± 10.9	NR	NR
Arapis K et al. (2018)	96%	94%	99%	89%	85%	93%	53.96 ± 5	48.81 ± 5	60.64 ± 5	54.17 ± 5
Onyewu SC et al. (2017)	45%	46%	41%	NR	NR	NR	52 ± 28	35.6 ± 7	NR	NR

RYGB Roux-en-Y gastric bypass, *SG* gastrectomy; *%EWL* percent excess weight loss, *NR* no report

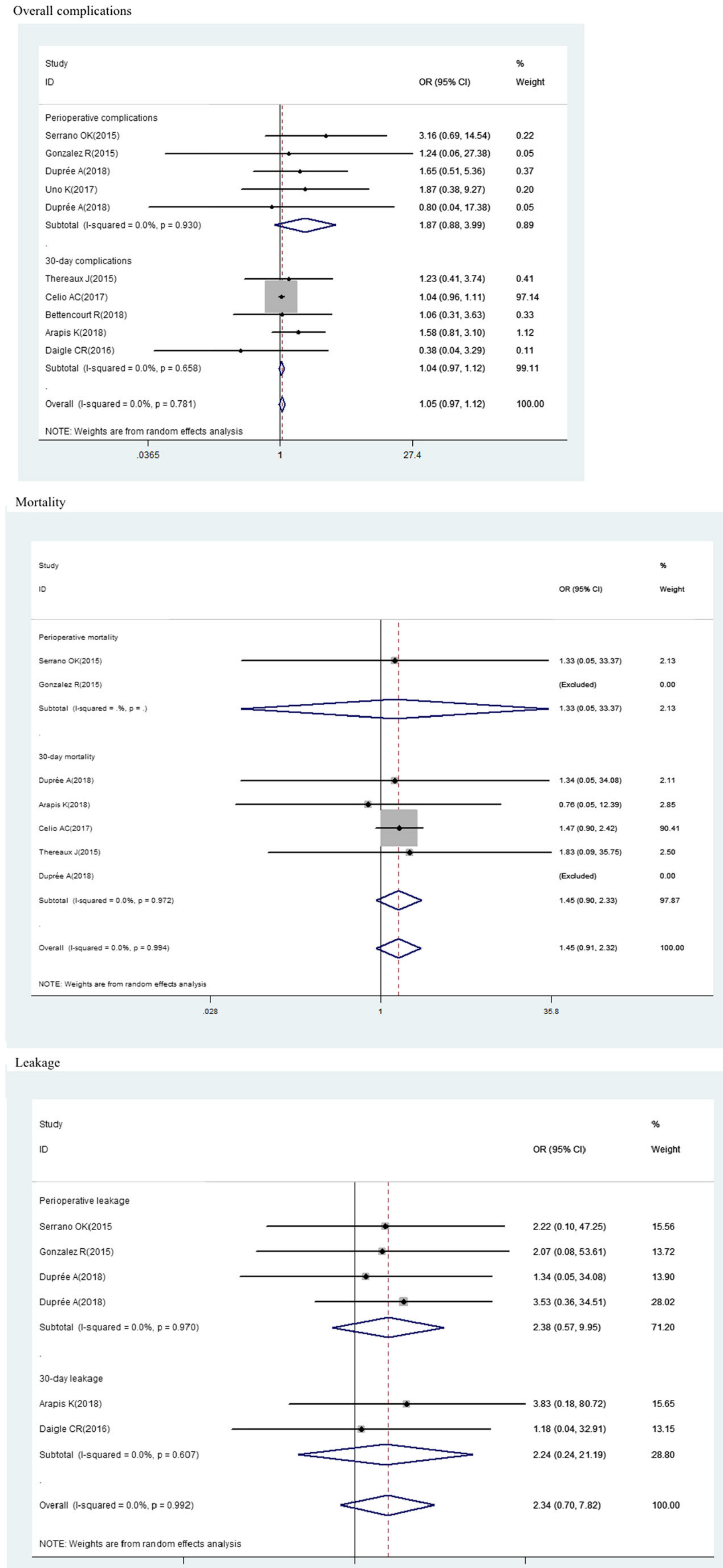

Fig. 2 Forest plot of comparison between RYGB and SG in postoperative overall complications, leakage, and mortality. The left side of the vertical line refers to less rate of overall complications, leakage, and mortality comparing RYGB with SG; however, the right side refers to high rates of overall complications, leakage, and mortality. (In the Forest plot, the square gray boxes reflect the study *n* value, and the diamonds reflect confidence interval. The larger the study *n* value is, the larger the square gray boxes are; the smaller the SMD is, the smaller the diamonds are)

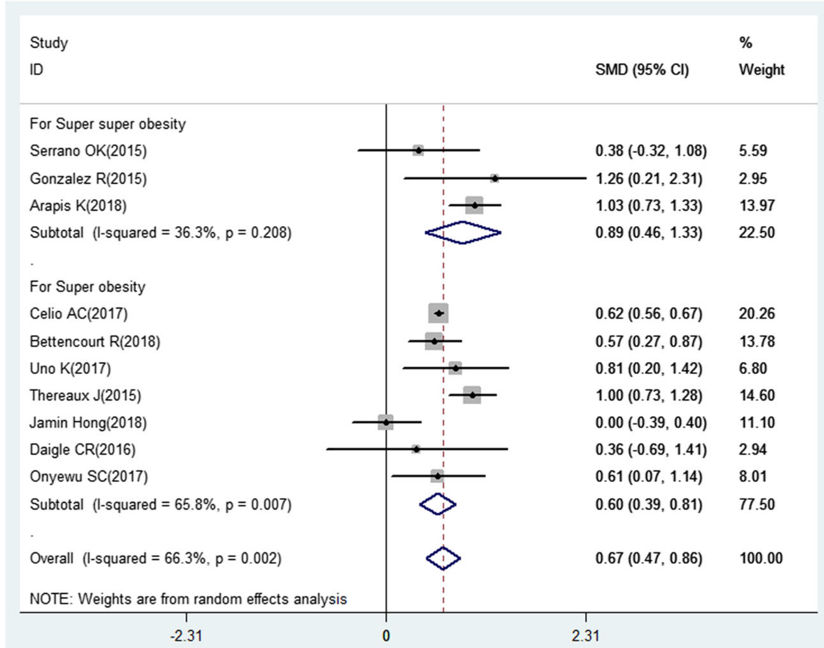

Fig. 3 Forest plot of comparison between RYGB and SG in percentage of excess weight loss (%EWL) at 12 months postoperatively. The left side of the vertical line refers to less %EWL comparing RYGB with SG; however, the right side refers to more %EWL. (In the Forest plot, the square gray boxes reflect the study n value, and the diamonds reflect confidence interval. The larger the study n value is, the larger the square gray boxes are; the smaller the SMD is, the smaller the diamonds are)

95%CI 0.388, 0.814; $P = 0.000$) (Fig. 3); however, a non-significant effect was shown for SO at 24 months(SMD 0.298, 95%CI −0.172, 0.768, $P =$ 0.214; $P = 0.294$) (Fig. 4). The meta-analysis from the success rate of weight loss showed a higher rate in RYGB compared with SG (OR 1.588; 95%CI 1.243, 2.028; $P = 0.000$) (Fig. 5).

Resolution of Comorbidity

A total of 5–6 studies included in this analysis present data on comorbidity resolution at 12 months which included diabetes mellitus (DM), hypertension (HTN), and dyslipidemia (DL). Of these studies, LRYGB group had a higher resolution of all measured comorbidities—DM, HTN, and DL—at 12 months compared with SG group except one study [27] with higher resolution of HTN in the SG group. After RYGB, 52.3% diabetic patients were free from the treatment of diabetes at follow-up compared with 42.7% diabetic SG patients, and there was a significantly higher resolution for patients with HTN (74.3% vs 57.6%) and DL (48.3% vs 37.9%) who underwent RYGB compared with SG. The meta-analysis from DM and DL resolution indicated a higher rate of resolution in

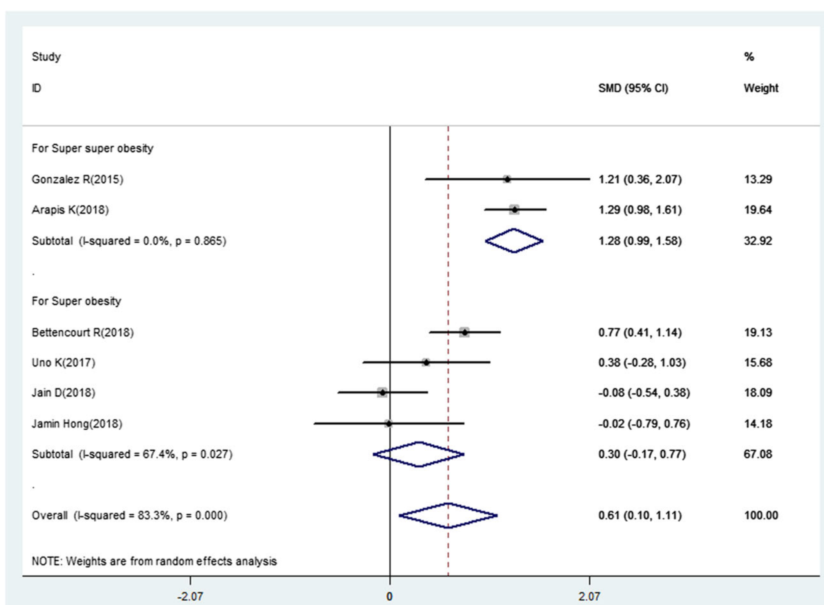

Fig. 4 Forest plot of comparison between RYGB and SG in percentage of excess weight loss (%EWL) at 24 months postoperatively. The left side of the vertical line refers to less %EWL comparing RYGB with SG; however, the right side refers to more %EWL. (In the Forest plot, the square gray boxes reflect the study *n* value, and the diamonds reflect confidence interval. The larger the study *n* value is, the larger the square gray boxes are; the smaller the SMD is, the smaller the diamonds are)

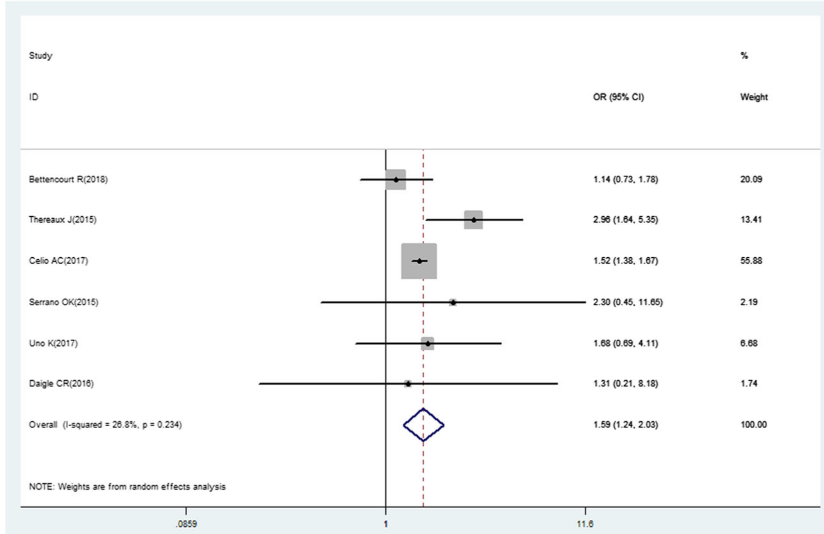

Fig. 5 Forest plot of comparison between RYGB and SG in percentage of excess weight loss ≥ 50%(%EWL ≥ 50%) at 12 months postoperatively. The left side of the vertical line refers to less %EWL ≥ 50% comparing RYGB with SG; however, the right side refers to more %EWL ≥ 50% (In the Forest plot, the square gray boxes reflect the study *n* value, and the diamonds reflect confidence interval. The larger the study *n* value is, the larger the square gray boxes are; the smaller the SMD is, the smaller the diamonds are)

the RYGB compared with SG group (OR 1.244; 95%CI 1.130, 1.370; $P = 0.000$ and OR 1.282; 95%CI 1.161, 1.417; $P = 0.000$, respectively); however, the meta-analysis from HTN showed a non-significant effect (OR 1.448; 95%CI 0.886, 2.368; $P = 0.140$) (Fig. 6). In this study, the meta-analysis of additional comorbidities was not possible because of few data.

There was significant heterogeneity in the pooled analysis in operation time, LOS, %EWL at 12 and 24 months, and resolution of HTN ($I^2 = 98.8\%$, 82.5%, 66.3%, 83.3%, and 55.7%, respectively). The heterogeneity in the subgroup analysis for %EWL by SSO and SO at 12 and 24 months remained significant for SO ($I^2 = 65.8\%$, 67.4%, respectively).

Publication Bias

By the Egger weighted regression method, no publication bias was found in the analysis for perioperative results (operation time $P = 0.599$; LOS $P = 0.401$), %EWL at 12 and 24 months ($P = 0.708$, $P = 0.507$, respectively), resolution of comorbidities (HTN $P = 0.693$, DM $P = 0.854$, and dyslipidemia $P = 0.907$) except for the incidence of overall complications ($P = 0.095$).

Discussion

Bariatric surgery is the most effective long-term therapy for weight loss, and currently, the most common bariatric procedures worldwide are sleeve gastrectomy (SG) and Roux-en-Y gastric bypass (RYGB). A recent meta-analysis suggested that RYGB is the more long-term effective procedure in morbid obesity, in comparison with SG [12]. Although several studies have focused on the comparison of RYGB and SG in super super obesity and super obesity, there is no consensus of the best surgical procedure to treat these patients.

To our knowledge, the present meta-analysis is the first that included trials performed RYGB and SG in SSO or SO individuals. Twelve studies performing both RYGB and SG were included in the present systematic review and meta-analysis. Bypass procedures are more complicated when they are associated with anastomosis of the GI tract; thus, RYGB yielded longer operation time. However, there was no difference shown in LOS. It is necessary to compare the safety between SG and RYGB. Some authors only listed the exact complications but did not define them as a major or minor complication. The leaks and mortality were major ones and could affect prognosis. Thus, we made the meta-analysis from the overall complications and stratified the analyses of the leaks and mortality. There was no difference shown in complications including leakage and mortality compared with SG. In the clinical setting, many bariatric surgeons are faced with long-term weight problems after bariatric surgery. A massive weight loss was seen after both procedures, but RYGB can lead to a more %EWL and higher rate of success in weight loss compared with SG in SSO and SO at a time point of 12 months. For the SSO, RYGB had higher %EWL compared with SG at 24 and 36 months. However, no statistical significance was observed in SO at 24 months. The meta-analysis of the difference of %EWL in SO was not possible because of the lack of data in this study. The follow-up results at 5 years in their trial showed no significant difference in excess BMI loss between the two procedures [28]. Other meta-analyses similarly found the procedures to be statistically similar through 2 years after each time point, yet RYGB generated superior weight loss outcomes [29]. In a multivariate analysis, several studies

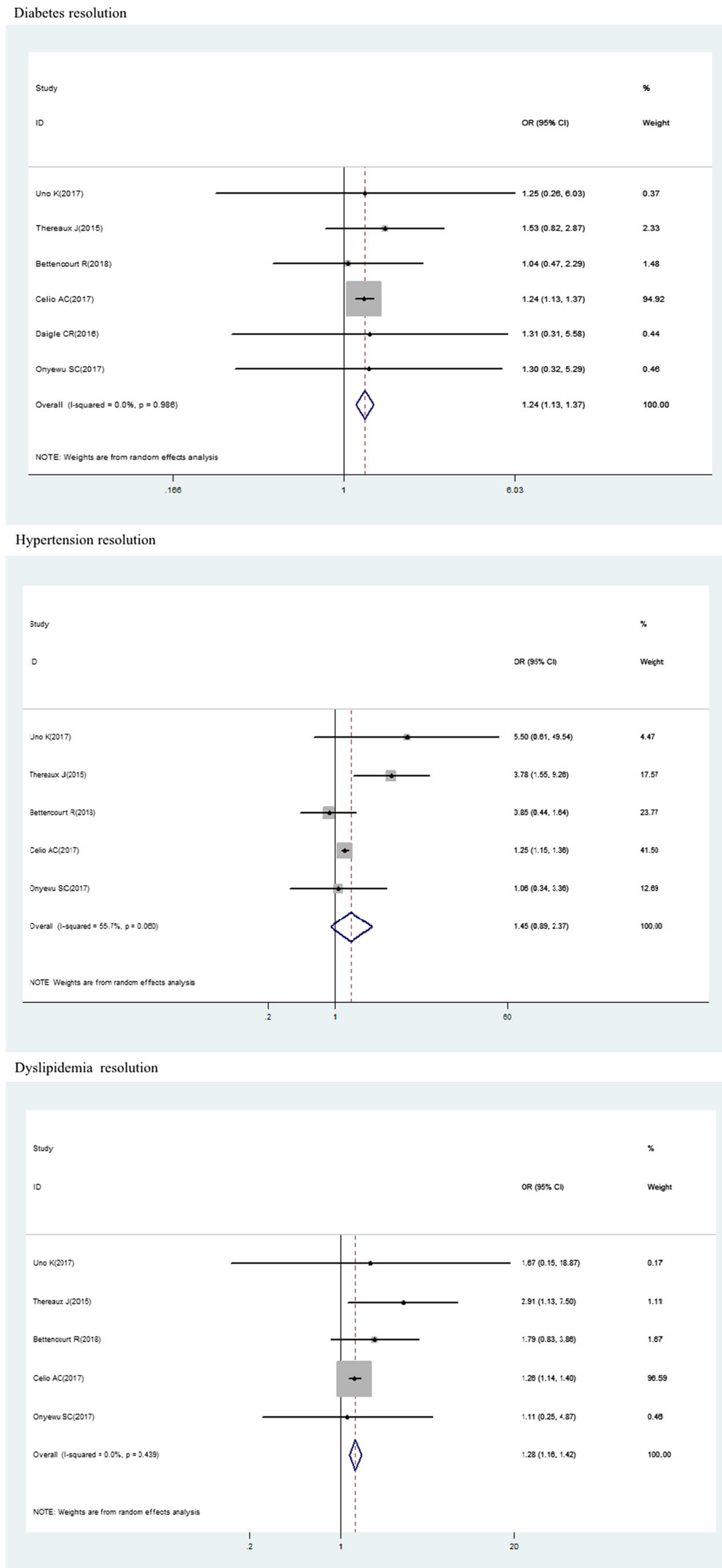

Fig. 6 Forest plot of comparison between RYGB and SG inobesity related comorbidities resolution, including diabetes mellitus, hypertension, and dyslipidemia at 12months postoperatively. The left side of the vertical line refers to less comorbidities resolution comparingRYGB with SG; however, the right side refers to more comorbidities resolution. (In the Forest plot, the squaregray boxes reflect the study *n* value, and the diamonds reflect confidence interval. The larger the study nvalue is, the larger the square gray boxes are; the smaller the SMD is, the smaller the diamonds are)"5. we find that the figure 2,5,6 are not clear,would you please modify them,thanks

identified preoperative BMI as independent negative predictive factors for weight loss after surgery [22, 30–32]. However, most of these studies included subjects with morbid obesity. Different comorbidities of SSO and SO were observed compared with morbid obesity, and they may have different metabolic outcomes, which may be a result of different bariatric outcomes.

Weight loss, the primary goal for most patients, is closely related to resolution rates of comorbidities [33]. The resolution or improvement rate of comorbidities also plays an important role in assessing the efficacy of bariatric surgery. After RYGB, although a trend of a higher resolution of HTN (74.3% vs 57.6%), DM (52.3% vs 42.7%), and dyslipidemia (48.3% vs 37.9%) was seen, the analysis of HTN showed a non-significant effect. RYGB was observed to achieve better control of DM and dyslipidemia in the present meta-analysis. Both types of operations were associated with significant metabolic benefits. Diabetes resolved and glucose levels decreased postoperatively in both study groups as a result of the improvement of insulin resistance due to a marked reduction in calorie intake, weight loss, and reduction in fat mass. Moreover, postoperative increased levels of gut hormones, such as glucagon-like peptide-1 that amplify-cell response to nutrients, are also relevant as previously discussed [34]. After 2 or more years of follow-up, RYGB can yield a much higher resolution of HTN compared with SG in 2 studies [5, 11]. Thus, the resolution of HTN may need much more time.

Several limitations should be discussed for our study. First, this meta-analysis included studies conducted from different countries and some studies were with flawed designs which did not define the ideal body weight or without stratifications, and some with other weaknesses. Secondly, there are a relatively limited number of studies in some meta-analysis, and a few included studies had a small sample size, which may result in heterogeneity of meta-analysis. Thirdly, weight loss effect may correlate with age, race, and %females, but we could not stratify the selected studies based on these factors due to the fact that participants in most articles were from Europe and USA. Fourth, in all meta-analyses for comorbidities, some impact on outcomes was neglected. The dietary intakes may present intra- and inter-individual variations, which may lead to changes in insulin, glucose homeostasis, and lipid profile. Another important issue to consider is that the gut microbiota composition is the main target for metabolic improvements. Fifth, 11 studies have a short-term follow-up (12 months or 24 months), and the time to follow-up of 4 studies was more than 36 months. There was a lack of 5-year outcomes in our study, which is a major limitation. And we did not make an analysis in weight maintenance or weight regain and longer-term risks (anastomotic ulcer, internal hernia, micronutrient deficiencies), since it is limited to 12 or 24 months. A small sample size and high loss to follow-up of the study indicate that the analysis may limit the conclusions that can be drawn; most bariatric studies experience roughly 20 to 35% loss to follow-up [35]. The retrospective nature of the study did not have the potential for active follow-up, which may result in a patient loss to follow-up. Finally, all the studies included were designed retrospectively, which is another major limitation. There is no randomization of accomplished procedure in the different groups, which can result in the possibility of selection bias. The baseline characteristics are different for comorbidities, which are known to be leading factors of operation. The retrospective nature limits the utility of the data and confines to extrapolate information in a passive manner rather than being able to directly control for confounding parameters that may also affect weight loss and weight loss-related variables.

In summary, RYGB yielded longer operation time. However, there was no difference shown in LOS and overall complications. Our meta-analysis regarding 12-month outcomes after surgery indicated that RYGB for the SSO and SO was superior to SG in the efficacy of weight loss and control of DM and dyslipidemia. However, RYGB was equal to SG in weight loss regarding 24-month outcomes. Due to those limitations mentioned above (retrospective nature of the study, short-term follow-up, high loss to follow-up, potential confounding, individual variations, and gut microbiota composition), this result should be considered with some caution. And these results are from a meta-analysis, which is used to show a trend but cannot be seen as a definitive conclusion. Further long-term prospective studies are required to confirm this finding.

Compliance with Ethical Standards

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

Ethical Approval Statement For this type of study formal consent is not required.

Informed Consent Statement Does not apply.

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