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ORIGINAL CONTRIBUTIONS

One Anastomosis Gastric Bypass Versus Roux-en-Y Gastric Bypass for Morbid Obesity: an Updated Meta-Analysis

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Abstract

Introduction We aim to review the available literature on morbidly obese patients treated with one anastomosis gastric bypass (OAGB) or Roux-en-Y gastric bypass (RYGB) in order to compare the clinical outcomes of the two methods.

Methods A literature search was performed in PubMed, Cochrane Library, and Scopus, in accordance with the PRISMA guidelines.

Results Sixteen studies were included in the qualitative analysis, and 11 studies were included in the quantitative analysis (meta-analysis), incorporating 12,445 patients. OAGB was associated with shorter mean operative time. The length of hospital stay was comparable between the two procedures. The incidence of leaks, marginal ulcer, dumping, bowel obstruction, revisions, and mortality was similar between the two approaches. The incidence of malnutrition was increased in patients treated with OAGB, while the incidence of internal hernia and bowel obstruction was greater in the RYGB group. In addition, the OAGB was associated with greater % excess weight loss (%EWL) at 1, 2, and 5 years postoperatively. The rate of diabetes remission was greater in the OAGB group. Nonetheless, the rate of hypertension and dyslipidemia remission was similar between OAGB and RYGB.

Conclusion The present meta-analysis is the best currently available evidence on the topic and demonstrates the superiority of OAGB compared with RYGB, in terms of weight loss and diabetes remission. However, the OAGB was associated with a significantly higher incidence of malnutrition, thus indicating the significant malabsorptive traits of this operation.

Keywords One-anastomosis gastric bypass · Roux-en-Y gastric bypass · RYGB · OAGB · Morbid obesity · Meta-analysis

Introduction

Morbid obesity is a rising epidemic in the western world, and bariatric surgery continues to be the main therapeutic strategy for a significant and sustainable weight loss [1] as well as diabetes remission and improvement of the metabolic profile [2]. Currently, Roux-en-Y gastric bypass (RYGB) is the main operation of choice in many bariatric centers [3] regarding patients with morbid obesity and metabolic disorders or as a salvage procedure after failed bariatric surgery [4]. However, RYGB remains a highly demanding procedure with a relatively steep learning curve [5].

The one anastomosis gastric bypass (OAGB) has been proposed as an alternative procedure to classic RYGB; it is considered a technically easier malabsorptive technique including a single anastomosis and is associated with significant effectiveness [6]. It employs a long gastric tube in conjunction with a gastrojejunal anastomosis [7]. Since the study of Rutledge et al. [7], additional reports [8, 9] have demonstrated excellent

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outcomes in patients who suffer from morbid obesity treated with OAGB. Even though, a previous meta-analysis [10] has already compared the feasibility and safety of these two techniques, it included only limited data regarding significant endpoints, such as % excess weight loss (%EWL). As the number of studies assessing the feasibility of OAGB increases and new randomized controlled trials (RCTs) have been published, it is necessary to reassess whether the results of RYGB and OAGB are at least equivalent. The purpose of this study is to summarize the currently available evidence comparing the surgical outcomes of OAGB and RYGB in the treatment of morbid obesity, thus providing the best currently available level of evidence.

Materials and Methods

Search Strategy and Articles Selection

The present study was conducted in accordance with the protocol agreed by all authors and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [11]. A thorough literature search was performed in Pubmed (Medline), Cochrane Central Register of Controlled Studies (CENTRAL), and Scopus (Elsevier) databases (last search: March 20, 2019) using the following terms in every possible combination: "one-anastomosis," "oagb," "mini gastric bypass," "omega loop," "single-anastomosis," "roux-en-y gastric bypass," "rygb," and "obesity." Inclusion criteria regarding the qualitative analysis (systematic review) were (1) original comparative reports with ≥ 10 patients, (2) written in the English language, (3) published from 1990 to 2019, (4) conducted on human subjects, and (5) reporting outcomes of RYGB and/or OAGB on patients with morbid obesity. The comparative studies were further included in the quantitative analysis (meta-analysis). Two independent reviewers (DEM, VST) extracted the data from the included studies. Any discrepancies between the investigators about the inclusion or exclusion of studies were discussed with the senior author (GT) in order to include articles that best matched the criteria, until consensus was reached. Furthermore, the reference lists of all included articles were assessed for any additional eligible studies. In addition, the kappa coefficient test was applied in order to assess the level of agreement between the reviewers.

Data Extraction

For each eligible study, data was extracted relative to demographics [number of patients, female ratio, mean age, preoperative body mass index (BMI)], along with the intraoperative parameters and postoperative outcomes [mean operative time (MOT), length of hospital stay (LOS), intraoperative and postoperative complications, and %EWL after 1, 2, 5 years]. Two authors (DEM, VST) performed the data extraction independently and compared the validity of their data. Any discrepancies were discussed with the senior author (GT) until consensus was reached.

Statistical Analysis

Regarding the categorical outcomes, the odds ratio (ORs) and 95% confidence interval (CI) were calculated, based on the extracted data, by means of random effects model (Mantel-Haenszel statistical method). OR < 1 denoted outcome was more frequent in the OAGB group. Continuous outcomes were evaluated by means of weighted mean difference (WMD) with its 95% CI, using random effects (inverse variance statistical method) models, appropriately to calculate pooled effect estimates. In cases where WMD < 0, the values in the OAGB group were higher. We selected the random effects model, since we did not expect that all the included studies would share a common effect size. The between-study heterogeneity was assessed through the Cochran Q statistic and by estimating I^2 [11].

In cases that multiple studies analyzed the same population, only the largest study or the one with the longest follow-up was included in the meta-analysis.

Quality and Publication Bias Assessment

The Newcastle-Ottawa Quality Assessment Scale (NOS) [12] was used as an assessment tool to evaluate the non-RCTs. The scale's range varies from 0 to 9 stars, and studies with a score equal to or higher than 5 were considered to have an adequate methodological quality to be included. The RCTs were assessed for their methodological quality with the tools that are used to evaluate the risk of bias according to the Cochrane Handbook for Systematic Reviews of Interventions [13]. Two reviewers (DEM, VST) rated the studies independently and the final decision was reached by consensus.

Our initial purpose was to assess the existence of publication bias using the Egger's formal statistical test [14]. However, the statistical evaluation could not be performed because the number of the studies included in the analysis was not adequate (less than 10), thus compromising substantially the power of the test.

Results

Article Selection and Patient Demographics

The flow diagram of the search of the literature is shown in Fig. 1. Among the 548 articles in Pubmed, CENTRAL and Scopus that were retrieved, 16 studies were included in the

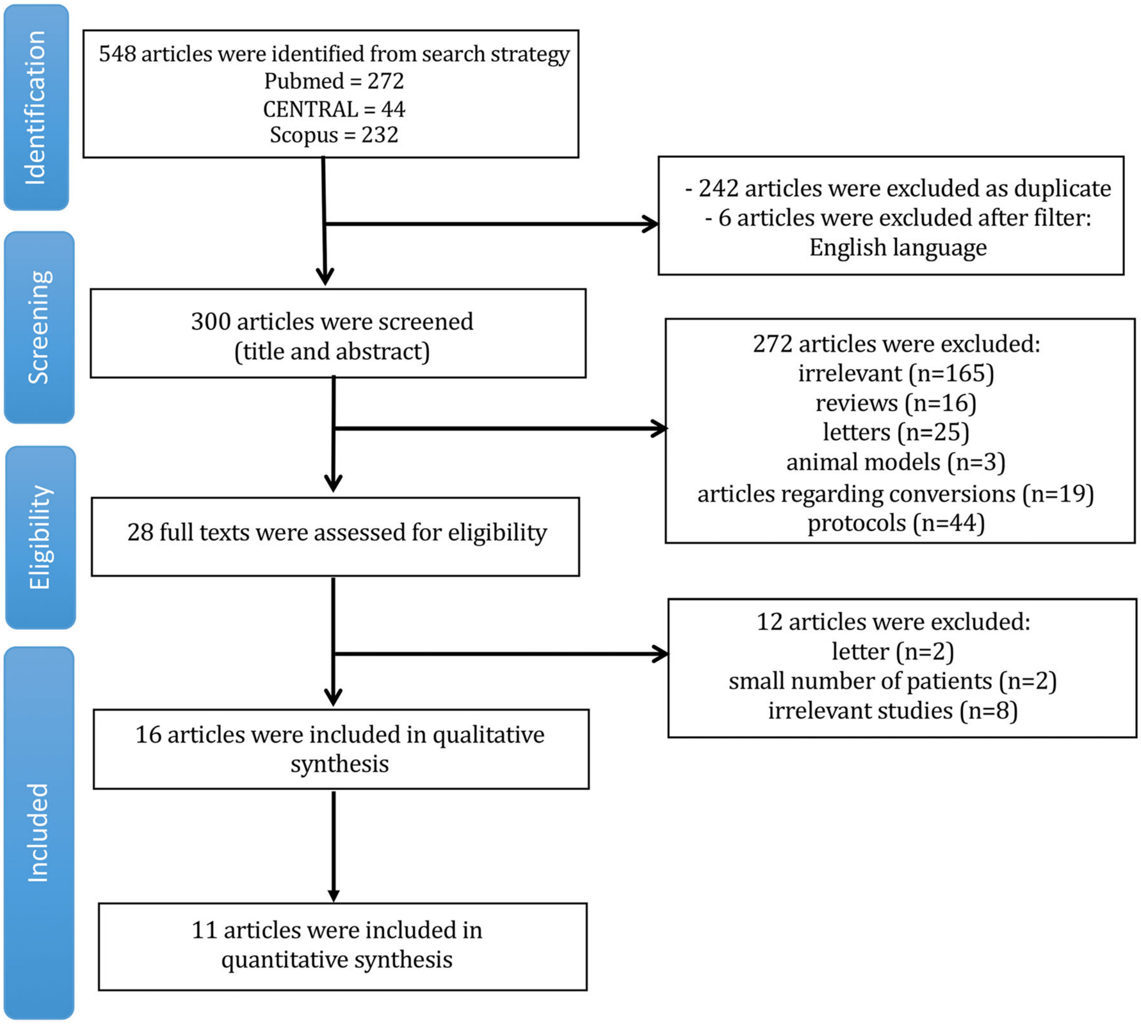

Fig. 1 One anastomosis gastric bypass vs. Roux-en-Y gastric bypass flow diagram

qualitative analysis [7, 15–29] and 11 studies were included in the quantitative synthesis [15–25]. The level of agreement between the two reviewers regarding the inclusion of the studies was "good" (kappa = 0.752; 95% CI 0.575, 0.929). The study design was retrospective in six studies [15, 16, 19, 23, 28, 29], prospective in seven studies [7, 17, 18, 21, 22, 26, 27], and randomized-controlled in three studies [20, 24, 25]. The included studies were conducted in France [17, 24, 25, 27], India [16, 18], Austria [19], Taiwan [15, 20, 21], Venezuela [22], UK [23], Spain [26], Israel [28], USA [7], and Egypt [29] and were published between 2001 and 2019. The OAGB sample size ranged from 20 to 1520 patients. The total sample size was 12,445 patients in the quantitative analysis; 4501 patients were treated with RYGB and 7944 patients were treated with OAGB. In the qualitative analysis, the total sample size was 8094 patients (4501 patients were treated with RYGB and 3593 patients were treated with OAGB). Characteristics of studies comparing the outcomes between patients treated with RYGB and patients treated with OAGB are provided in Table 1, while the non-comparative studies are presented in Table S1. The Newcastle-Ottawa rating scale assessment for all studies is shown in Table 1 and Table S1. Moreover, the quality assessment of RCTs is shown in Table S2. Perioperative and postoperative outcomes are presented in Table 2 and Table S3. Pooled ORs, I^2 and p values of heterogeneity for all outcomes are summarized in Table 3.

Mean Operative Time and Length of Hospital Stay

The mean operative time (MOT) ranged from 88.9 to 205 min for the RYGB and from 35 to 147.7 min for the OAGB (Table 2, Table S3). MOT was significantly increased in RYGB group [WMD 46.54 (95% CI 13.62, 79.45); $p = 0.006$] as shown in Table 3. The length of hospital stay (LOS) ranged from 2 to 6.9 days for the RYGB group, while it ranged from 1.02 to 5.5 days for the OAGB group (Table 2). According to our analysis, the LOS was similar between the two groups [WMD −0 .01 (95% CI − 0.28, 0.25); $p = 0.92$] (Table 3).

Table 1 Characteristics of the studies that were finally included in the meta-analysis. The first author of every study along with the year of publication, the journal, the country of origin, the time period of the study, the study design, the number of participants, the number of female patients, along with the mean age, the mean preoperative body mass index (BMI), and the number of stars according to the Newcastle-Ottawa Quality Assessment Scale

Study ID, year	Journal	Country	Time period	Type of study	Patients, *n*		Female, *n* (%)		Mean age ± SD (range)		Mean BMI, kg/m^2		Follow-up, months	NOS
					RYGB	OAGB	RYGB	OAGB	RYGB	OAGB	RYGB	OAGB		
Almaliki et al. 2017 [15]	Surg Obes Relat Dis	Taiwan	2007–2015	R	157	249	103	156	43.0 ± 9.8	40.1 ± 12.0	34.5 ± 6.6	39.9 ± 8.0	12	6
Baig et al. 2019 [16]	Obes Surg	India	N/A	R	2965	1194	1592 (53.7)	646 (54.1)	43.98 ± 11.65	43.07 ± 11.42	44.93 ± 7.91	45.08 ± 8.82	36	6
Disse et al. 2014 [17]	Obes Surg	France	5/2007–2/2013	P	61	20	43 (70.5)	14 (70)	47 (20–70)	49.5 (21–65)	42.3 (34.3–55.4)	40.1 (41.3–45)	12	7
Jammu et al. 2015 [18]	Obes Surg	India	1/2007–3/2014	P	295	473	210 (71.2)	333 (70.4)	38	46.5	42.5	56.5 (40–73)	53.5	7
Kruschitz et al. 2016 [19]	Obes Surg	Austria	2/2011–2/2013	R	25	25	23 (92)	22 (88)	44.6 ± 10.3	43.8 ± 13.1	45.6 ± 4.1	45.3 ± 5.3	12	7
Lee et al. 2005 [20]	Ann Surg	Taiwan	10/2001–3/2002	RCT	40	40	28 (70)	27 (67.5)	31.1 ± 9.1	30.7 ± 8.4	43.8 ± 4.8	44.8 ± 8.8	24	–
Lee et al. 2012 [21]	Obes Surg	Taiwan	10/2001–9/2010	P	494	1163	362 (73.3)	850 (73.1)	33.5 ± 9.3	32.3 ± 9.1	40.5 ± 5.8	41.1 ± 6.1	60	8
Navarrete et al. 2018 [22]	Obes Surg	Venezuela	9/2008–1/2016	P	100	100	54 (54)	64 (64)	39.43 ± 10.33	40.46 ± 12.4	45.29 ± 8.82	44.8 ± 12.06	12	7
Parmar et al. 2016 [23]	Surg Endosc	UK	10/2012–6/2015	R	47	12	30	9	47 (25–66)	45 (25–64)	64.4 (60–83)	67 (60–84)	RYGB 12 OAGB 6	7
Robert et al, 2019 [24]	The Lancet	France	5/2014–3/2016	RCT	117	117	91 (78)	85 (73)	42.6 ± 10.2	44.4 ± 11.4	43.9 ± 5.1	43.8 ± 6.1	24	–
Ruiz-Tovar et al. 2018 [25]	Surg Endosc	Spain	6/2010–12/2012	RCT	200	200	150 (75)	150 (75)	45 ± 11.3	43.8 ± 11.5	45.3 ± 3.2	45 ± 4.1	60	–

The Newcastle-Ottawa Scale (NOS) for assessing the quality of non-randomized studies. Every study is judged on three perspectives: the selection, the comparability, and the ascertainment of the exposure of the study groups. The highest quality studies are awarded up to 9 stars. The randomized trials were assessed for risk of bias according to the Cochrane Handbook for Systematic Reviews of Interventions (Table S2)

R, retrospective; *P*, prospective; *RCT*, randomized controlled study; *RYGB* = Roux-en-Y gastric bypass; *OAGB*, one anastomosis gastric bypass; *SD*, standard deviation

Table 2 Summary of the assessment of the intraoperative parameters and outcomes of every study that was included in the meta-analysis. The length of hospital stay, the mean operative time, the mortality rate, the remission of type 2 Diabetes (T2D), hypertension (HTN), dyslipidemia, and obstructive sleep apnea syndrome, along with the % excess weight loss (%EWL) after 1 year and at most distant follow-up time point are demonstrated where available

Study ID, year	LOS, days		MOT, min		Mortality, *n* (%)		T2D remission		HTN remission	
	RYGB	OAGB	RYGB	OAGB	RYGB	OAGB	RYGB	OAGB	RYGB	OAGB
Almaliki et al. 2017 [15]	3.9 (1.5)	5.6 (6.0)	163.3 (38.6)	125.1 (35.6)	0 (0)	0 (0)	87 (55.4)	204 (81.9)	–	–
Baig et al. 2019 [16]	–	–	–	–	–	–	–	–	–	–
Disse et al. 2014 [17]	4.8	4.2	152 (70–285)	105 (75–210)	1 (1.6)	0 (0)	6 (26)	5 (62.5)	12 (46)	6 (60)
Jammu et al. 2015 [18]	–	–	160.5 (123–198)	57.5 (42–75)	1 (0.3)	0 (0)	25 (75.8)	59 (95.1)	34 (72.3)	41 (85.4)
Kruschitz et al. 2016 [19]	–	–	–	–	–	–	–	–	–	–
Lee et al. 2005 [20]	6.9 ± 2.8	5.5 ± 1.4	205.0 ± 60.5	147.7 ± 46.7	0 (0)	0 (0)	–	–	–	–
Lee et al. 2012 [21]	3.9 ± 2.1	3.7 ± 4.1	159.2 ± 32.3	115.3 ± 34.6	1 (0.2)	2 (0.2)	–	–	–	–
Navarrete et al. 2018 [22]	2 ± 0.62	1.99 ± 0.85	88.9 ± 3.4	69.0 ± 4.6	0 (0)	0 (0)	16 (88.8)	17 (89.5)	20 (80)	21 (80.7)
Parmar et al. 2016 [23]	2 ± 0.75	2 ± 0.25	129.5 ± 72.5	92.9 ± 31.5	0 (0)	0 (0)	13/22 (59.1)	3/7 (42.9)	11/24 (45.8)	2/8 (25.0)
Robert et al. 2019 [24]	5 (4–6)	5 (4–5)	111 ± 42	85 ± 35	0 (0)	2 (1.7)	6 (38)	12 (60)	–	–
Ruiz-Tovar et al. 2018 [25]	–	–	–	–	0 (0)	0 (0)	51 (86.4)	67 (95.7)	61 (73.5)	72 (83.7)

Study ID, year	DL remission		OSAS remission		%EWL 1 year		%EWL 2 years		%EWL 5 years	
	RYGB	OAGB	RYGB	OAGB	RYGB	OAGB	RYGB	OAGB	RYGB	OAGB
Almaliki et al. 2017 [15]	–	–	–	–	24.1 ± 8.4	30.7 ± 8.7	–	–	23.3 ± 11.1	29.6 ± 10.3
Baig et al. 2019 [16]	–	–	–	–	64.7 ± 17.7	68.2 ± 16.8	69.2 ± 12.2	76.2 ± 12.7	62.1 ± 22.1	72.9 ± 19.3
Disse et al. 2014 [17]	11 (44)	6 (75)	26 (92.8)	8 (100)	–	–	–	–	–	–
Jammu et al. 2015 [18]	37 (74)	42 (93.3)	–	–	–	–	–	–	–	–
Kruschitz et al. 2016 [19]	–	–	–	–	59 ± 19	77 ± 14	–	–	–	–
Lee et al. 2005 [20]	–	–	–	–	58.7 ± 16.4	64.9 ± 9.5	59.2 ± 15.1	64.4 ± 8.8	–	–
Lee et al. 2012 [21]	10 (14.1)	15 (5.4)	–	–	–	–	–	–	60.1 ± 20.4	72.9 ± 19.3
Navarrete et al. 2018 [22]	–	–	–	–	85.9	89.4	–	–	–	–
Parmar et al. 2016 [23]	–	–	–	–	55.6 ± 22.75	59.6 ± 6.4	57.1 ± 22	70.4 ± 8.075	–	–
Robert et al. 2019 [24]	–	–	–	–	–	–	85.8 ± 23.1*	87.9 ± 23.6*	–	–
Ruiz-Tovar et al. 2018 [25]	49 (71.0)	74 (100.0)	–	–	–	–	87.2 ± 6.7*	104.3 ± 7*	77.1 ± 6.1	97.9 ± 7

%EWL % excess weight loss, *RYGB* Roux-en-Y gastric bypass, *OAGB* one anastomosis gastric bypass, *T2D* type 2 diabetes, *HTN* hypertension, *OSAS* obstructive sleep apnea syndrome

*% excess body mass index loss (%EBMIL)

Table 3 Summary of the analysis of the categorical and continuous outcomes

Categorical outcomes	*n*	OR [95% CI]*	Heterogeneity	
			I^2	*p*
T2D remission	7	0.41 [0.25, 0.69]	51%	0.06
HTN remission	5	0.93 [0.55, 1.56]	38%	0.17
Dyslipidemia remission	4	0.55 [0.16, 1.91]	85%	0.35
Leaks	7	1.33 [0.62, 2.84]	0%	0.56
Malnutrition	5	0.12 [0.04, 0.41]	0%	0.75
Marginal ulcer	7	0.74 [0.35, 1.57]	0%	0.45
Intra-abdominal bleed	7	1.61 [0.62, 4.13]	0%	0.52
Internal hernia	6	5.26 [1.76, 15.69]	0%	0.75
Dumping	3	0.77 [0.33, 1.80]	38%	0.20
Bowel Obstruction	6	3.75 [1.42, 9.92]	0%	0.78
Mortality	9	1.02 [0.24, 4.35]	0%	0.56
Continuous outcomes	*n*	WMD [95% CI]	I^2	*p*
MOT	8	46.54 [13.62, 79.45]	100%	< 0.01
LOS	6	− 0.01 [− 0.28, 0.25]	82%	< 0.01
%EWL 1 year	6	− 6.02 [− 8.84, − 3.20]	70%	< 0.01
%EWL 2 years	3	− 7.33 [− 10.08, − 4.58]	32%	0.23
%EWL 5 years	4	− 12.82 [− 20.27, − 5.37]	96%	< 0.01

T2D, type 2 diabetes; *HTN*, hypertension; *MOT*, mean operative time; *LOS*, length of stay; *OR*, odds ratio; *WMD*, weighted mean difference; *CI*, confidence intervals

Complications and Revisional Operations

According to our analysis, the incidence of leaks [OR 1.33 (95% CI 0.62, 2.84); $p = 0.46$], marginal ulcer [OR 0.74 (95% CI 0.35, 1.57); $p = 0.43$], dumping [OR 0.77 (95% CI 0.33, 1.80); $p = 0.54$], along with mortality [OR 1.02 (95% CI 0.24, 4.35); $p = 0.98$] were comparable between the two groups. However, the incidence of malnutrition [OR 0.12 (95% CI 0.04, 0.41); $p = 0.0006$] was increased in the OAGB group. It should be noted that malnutrition was considered as protein malnutrition and that there was a specific definition of malnutrition only in the RCT by Robert et al. [24], defined as albumin concentration of less than 30 g/L or prealbumin concentration of less than 0.2 g/L, or both. In contrast, the incidence of internal hernia [OR 5.26 (95% CI 1.76, 15.69); $p = 0.003$] and bowel obstruction [OR 3.75 (95% CI 1.42, 9.92); $p = 0.008$] was greater in patients treated with RYGB. Hypoglycemia was reported only in one study [23] with a rate of 6.4% for RYGB and 0% for OAGB group. The forest plots regarding complications are shown in Fig. S1.

Revisions were similar between the two groups [OR 1.40 (95% CI 0.57, 3.43); $p = 0.46$]. The main reasons for revision were gastroesophageal reflux regarding the OAGB procedure along with inadequate weight loss regarding the RYGB.

Weight Loss Outcome

In our study, we examined the postoperative %EWL after 1, 2, and 5 years. According to our analysis, %EWL at 1 year postoperatively was greater in the OAGB group [WMD − 6.02 (95% CI − 8.84, − 3.20); $p < 0.0001$] (Fig. 2a). Moreover, the patients treated with OAGB were associated with increased %EWL at 2 years postoperatively compared with those treated with RYGB [WMD − 7.33 (95% CI − 10.08, − 4.58); $p < 0.0001$] (Fig. 2b). In addition, the %EWL at 5 years postoperatively was also increased in the OAGB group [WMD − 12.82 (95% CI − 20.27, − 5.37); $p = 0.0007$] (Fig. 2c).

Resolution of Comorbidities

We performed a four-arm analysis in order to assess the postoperative T2D remission which was increased in the OAGB group [OR 0.41 (95% CI 0.25, 0.69); $p = 0.0006$] (Fig. 3a). Nonetheless, HTN remission was comparable between both groups [OR 0.93 (95% CI 0.55, 1.56); $p = 0.77$] (Fig. 3b). No significant differences between the two groups were reported regarding the resolution of dyslipidemia [OR 0.55 (95% CI 0.16, 1.91]; $p = 0.35$] (Fig. 3c).

Publication Bias

Heterogeneity was high regarding MOT, LOS, %EWL at 1, 5 years postoperatively, and dyslipidemia remission (Table 3). On the other hand, heterogeneity was low regarding %EWL at 2 years postoperatively, complications, and HTN remission (Table 3). The Egger's test could not be performed due to the inadequate number of the included studies. The funnel plots that were produced in order to assess publication bias are shown in Fig. S2. The asymmetries that were found are mainly attributed to the small number of the included studies and the possible bias regarding the selection of the patients, thus proposing that more studies are necessary in order to eliminate publication bias. Finally, there was no significant difference between the two groups regarding the number of patients included in the quantitative analysis.

Discussion

At present, RYGB is the second (38.2%) most popular bariatric operation worldwide according to the IFSO Global Surgery Report 2018 [30]. On the other hand, the OAGB, which is a relatively newer malabsorptive procedure, is the third most common bariatric surgical technique [6, 31]. This study identified 16 unique articles describing RYGB and OAGB as two alternative bariatric procedures, published between 2001 and 2019.

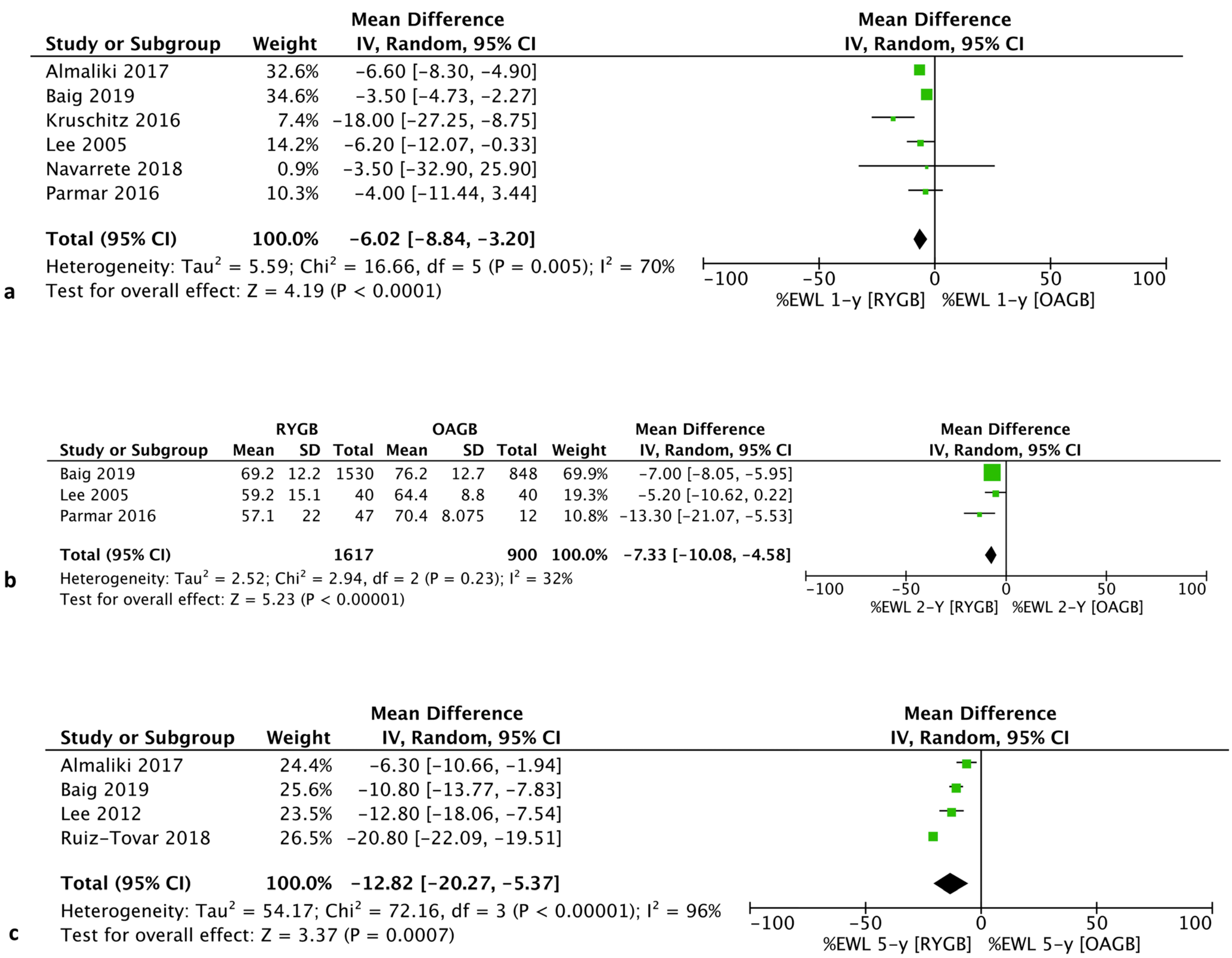

Fig. 2 Forest plot describing the differences in **a** % excess weight loss (%EWL) after 1 year, **b** % excess weight loss (%EWL) after 2 years, and **c** % excess weight loss (%EWL) after 5 years **a** %EWL after 1 year was increased in the OAGB group. **b** %EWL after 2 years was increased in the OAGB group. **c** %EWL after 5 years was increased in the OAGB group

The present study demonstrates that both RYGB and OAGB are well-tolerated, effective, and safe bariatric operations for morbid obesity. The MOT was significantly increased in RYGB approach, as expected, since the procedure includes additional manipulation and measurements regarding the jejuno-jejunal anastomosis compared to the single gastro-jejunal anastomosis of the OAGB. Nonetheless, the LOS was similar between the two groups. An increased LOS was reported mainly in cases of postoperative complications and morbidity. However, the increased heterogeneity that was reported among studies regarding LOS suggests the potential differences in clinical practice, along with differences in the perioperative protocols implemented in each bariatric center regarding the patient recovery.

Both techniques are associated with low and comparable rates of complications and conversions, thus being relatively safe. Leaks and hemorrhage remain the main risks of bariatric procedures, due to the long-stapled lines and gastrointestinal anastomoses. In the present study, the incidence of leaks and hemorrhage was comparable between RYGB and OAGB. Generally, the OAGB is thought to be associated with a lower incidence of leaks due to the longer and wider gastric tube leading to low intraluminal pressure and GERD [32, 33], along with the presence of a single anastomosis. Even though there is an opposite argument on the potential risk of postoperative leaks regarding the OAGB due to the long staple line, previous studies showed, in accordance with our findings, that the leak rate after OAGB does not appear to be related to any particular technical factor, and the main prevention measures are similar to those indicated for sleeve gastrectomy (SG) and RYGB [34]. The First Consensus Meeting on OAGB suggested that "surgeons should avoid going too close to the angle of His to avoid leaks in the area" and highlighted the importance of the intraoperative leak test [33]. Additionally, the incidence of marginal ulcer and dumping was similar between the two groups.

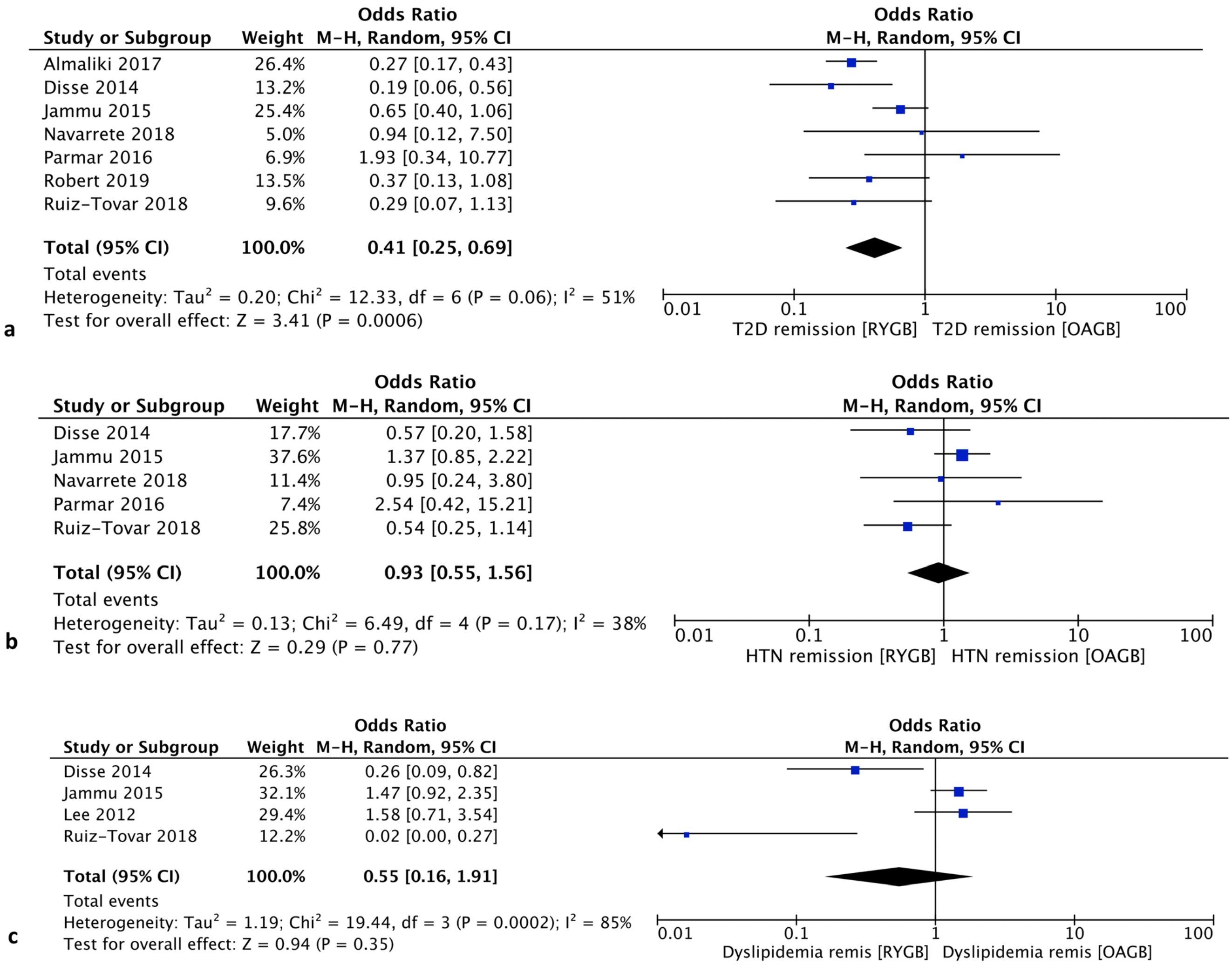

Fig. 3 Forest plot describing the differences in **a** type 2 diabetes (T2D) remission, **b** hypertension remission, and **c** dyslipidemia remission. **a** T2D remission was greater in OAGB group. **b**–**c** No difference was reported regrading resolution of hypertension and dyslipidemia

Our outcomes show that OAGB is associated with a higher incidence of postoperative malnutrition, which is in accordance with the previous meta-analysis [10]. In fact, the malnutrition after OAGB has been mainly observed in those cases where the length of the bypass was > 230 cm [18]. Nonetheless, in the majority of the included studies, the afferent loop was 200 cm. That was also the case in two of the included RCTs [24, 25]. According to this evidence, it is suggested that the standardization of an afferent limb length shorter than 200 cm would minimize the devastating outcomes related to malnutrition. However, future studies are necessary to further assess the efficacy of a biliopancreatic limb of 150 cm which tends to become the norm [33]. Additionally, these findings highlight the significant malabsorptive nature of OAGB. Nevertheless, it is also critical to reach a consensus on the definition of malnutrition, along with the establishment of an appropriate reporting pathway during the postoperative period, in order to avoid a potential reporting bias. In the present meta-analysis, the heterogeneity regarding malnutrition was low, thus indicating a low risk for publication bias. Severe malnutrition can be treated by reversing the OAGB as presented by Jammu et al. [18].

In addition, the incidence of an internal hernia and bowel obstruction was increased in the RYGB group and was in accordance with the previous meta-analysis [4]. In most cases of RYGB that were reported in the studies included, the mesenteric defects, along with the Petersen site were closed [18, 20–23]. According to the Delphi consensus paper on OAGB [35], 82% of the experts agreed that the routine closure of Petersen's space was unnecessary. However, new evidence suggests that the closing of Petersen's defects is necessary, as described by Mahawar [36]. An internal hernia remains the main reason for postoperative bowel obstruction. In fact, according to our findings, the incidence of postoperative bowel obstruction was increased in the RYGB group. Mortality was, also, similar between the two groups. Only a few cases of conversions to other bariatric procedure were reported.

There is a general concern regarding the potential association of OAGB with a greater risk of gastric or oesophageal cancer [37]. However, according to the first consensus paper on OAGB [33] the vast majority of experts (over 90%) felt that OAGB does not increase the risk of gastric or oesophageal cancer. In the present meta-analysis, no case with a gastric or oesophageal carcinoma was reported.

As far as the weight loss is concerned, the %EWL at 1, 2, and 5 years postoperatively was increased in the OAGB group. In fact, RYGB is associated with increased risk of late weight regain because the gastric pouch and outlet may dilate and lead to more food intake [37]. The greater %EWL after OAGB could be possibly attributed to its great malabsorptive characteristics.

Weight loss is directly associated with remission of T2D and dyslipidemia, although other mechanisms involving gut hormone regulation associated with both procedures have also been suggested for the management of the metabolic syndrome [2]. In fact, T2D remission was increased in patients treated with OAGB, in accordance with the previous meta-analysis.

This meta-analysis demonstrates that OAGB is an efficient alternative to RYGB, associated with increased weight loss at 1, 2, and 5 years postoperatively and greater T2D remission rates and proposes the significant malabsorptive traits of OAGB. It also highlights the need for additional studies comparing the RYGB with the OAGB. Ideally, these would be randomized controlled studies, with prospective design and longer follow-up in order to assess the %EWL during greater time-periods. As far as we know, there is already a RCT under schedule (ClinicalTrials.gov Identifier: NCT03673969).

The limitations of this meta-analysis reflect the available literature comparing OAGB and RYGB. Seven studies [7, 17, 18, 21, 22, 26, 27] were prospective and six [15, 16, 19, 23, 28, 29] retrospective, thus posing a certain limitation in this study. Three studies [20, 24, 25] were RCTs. In addition, the heterogeneity was high regarding MOT, LOS, T2D, and %EWL at 1 and 5 years postoperatively and dyslipidemia remission.

On the other hand, the strengths of this study are (1) the clear data-extraction protocol, (2) the well-specified inclusion-exclusion criteria, (3) the search in three different databases, (4) the quality assessment of the included studies, and (5) the up-to-date presentation of the results of data-extraction and analysis.

Conclusion

This systematic review and meta-analysis identified and included 16 studies assessing RYGB and OAGB. These studies suggest that OAGB is associated with shorter MOT, greater T2D remission rate, increased %EWL at 1, 2, and 5 years postoperatively and similar perioperative and postoperative effectiveness, feasibility and safety. However, the present meta-analysis found a significantly higher incidence of postoperative malnutrition in the OAGB group, thus indicating the malabsorptive nature of OAGB. The present meta-analysis is the best currently available evidence and suggests the superiority of OAGB compared with RYGB, in terms of %EWL and T2D remission. Future studies with longer follow-up are necessary to further assess the differences in efficacy between RYGB and OAGB.

Compliance with Ethical Standards

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

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

Informed Consent Does not apply.

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